Review

Predictive analysis of dyslipidemia in non-obese and lean individuals using body composition analyzer

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Abstract. *Objective:* The aim is to examine the predictive value of body composition analysis and anthropometry for dyslipidemia and NAFLD in non-obese and lean individuals. *Method:* A descriptive study was conducted to select non-obese and lean individuals who received nutritional counseling at our hospital's nutrition department from January 2023 to December 2023 and were assessed by professional clinical nutritionists for anthropometric measurements. Non-alcoholic fatty liver disease (NAFLD) is a chronic liver condition characterized by the excessive accumulation of fat in the liver. We applied the bioelectrical impedance method to analyze human body composition involves collecting medical history data and laboratory test results. By combining data conversion, we can obtain weight, body mass index (BMI), body fat percentage (PBF), visceral fat index (VAI), skeletal muscle mass index (SMI), skeletal muscle mass (SMM), fasting plasma glucose (FPG), liver function-related indicators, and nutritional blood indicators. Comprehensively analyze the impact of human body composition analysis and anthropometric indicators on the risk of blood lipids and non-alcoholic fatty liver disease (NAFLD) in non-obese and lean individuals. *Results:* The final analysis included 190 individuals. The detection rate of abnormal FPG metabolism was 21.1%, the overall detection rate of abnormal blood lipid metabolism was 58.9%, and the detection rate of abnormal sugar and lipid metabolism was 85.3%. FPG is positively correlated with WHR and the risk of NAFLD. TC is positively correlated with PBF, the risk of NAFLD, and WHR. TG is positively correlated with the risk of NAFLD and negatively correlated with SMM and SMI. LDL-C is positively correlated with PBF, WHR, and the risk of NAFLD. HDL-C is negatively correlated with the risk of NAFLD and WHR and correlated with SMM ($P < 0.05$). PBF is an independent risk factor for increased FPG and TC, and it has a significant impact on HDL ($P < 0.05$). *Conclusion:* Non-obese and lean individuals also have a risk of hyperlipidemia and non-alcoholic fatty liver disease (NAFLD). PBF measured by human body composition analysis and WHR, SMM, and SMI obtained from human body measurements are closely related to each other. They have reference value for alerting to blood lipid abnormalities and monitoring blood lipid levels.

Key words: dyslipidemia, non-alcoholic fatty liver, human body composition

Introduction

The incidence of health issues caused by high blood lipids has been increasing annually due to economic growth and improvements in living standards. Cardiovascular and cerebrovascular disorders are now significant contributors to mortality in humans. One known risk factor for atherosclerosis is

dyslipidemia (1). However, recent population surveys conducted in various parts of the nation have revealed that the rates of knowledge, treatment, and control of blood lipid abnormalities fall well short of the recommended levels (2-3). Additionlly, the majority of obese patients focus more on their own blood lipid health, while non-obese and lean individuals frequently ignore it. The need for scientifically sound and practical approaches to support the prevention and control of blood lipid abnormalities is critical, given the dire circumstances surrounding their prevention and management. Non-alcoholic is a chronic liver illness caused by an excessive accumulation of liver fat. Despite the strong association between obesity and non-alcoholic fatty liver disease (NAFLD), several epidemiologic studies have indicated that a significant proportion of patients with NAFLD have relatively normal body mass indices (BMIs). It is customary to describe this condition as "lean" or "non-obese" NAFLD (4-6). The increasing occurrence of non-alcoholic fatty liver disease (NAFLD), the most prevalent type of long-term liver damage, has raised concerns across the globe. Approximately 10–20% of people with non-alcoholic fatty liver disease (NAFLD) who are not overweight or obese (BMI < 25 kg/m^2, or BMI < 23 kg/m^2 in Asians) have "lean NAFLD." They also have higher rates of fibrosis, cardiovascular morbidity, and all-cause mortality in advanced stages (7-10). There is still much to learn about the pathophysiological pathways underlying lean NAFLD. Research has indicated that there is a stronger correlation between lean NAFLD and variables such as genetic predisposition, environment, and epigenetic regulation. Research has shown that the metabolic risk of lean nonalcoholic fatty liver disease (NAFLD) is not entirely reflected by BMI, and the majority of lean NAFLD patients have other indicators of body composition (11). Some indicators of human body composition analysis have been found to be somewhat correlated with blood lipids and non-alcoholic fatty liver disease (NAFLD) in previous research. However, the study is not comprehensive, and the measured indicators are limited. The technique of bioelectrical impedance is typically used in the analysis of human body composition to determine the amount of fat and non-fat components of the body. Assessing various metrics, such as body fat percentage, is essential for accurately representing the condition of the human body. The assessment and analysis of human body composition are easy, non-invasive, and less expensive than traditional blood testing. More clinically important signs can be obtained through data conversion. Therefore, it is worthwhile to investigate whether markers from human body composition analysis and body measurements can be used to estimate the blood lipid status of non-obese and lean individuals. More people being swiftly and least invasively examined for symptoms of metabolic disease has the potential to significantly reduce major morbidity and mortality in the general population (12). This exploratory study aims to investigate the potential relationships between body composition, anthropometrics, and blood lipid levels in non-obese and lean individuals using affordable, scalable, and minimally invasive technologies. The ultimate goal is to enhance the ability to predict serious health conditions. In this article, we debated whether it is worthwhile to conduct an in-depth study to determine the blood lipid status of non-obese and lean individuals using markers derived from human body composition analysis and anthropometric measurements. We hope that our findings can provide a basis for early intervention, treatment, and screening for individuals at high risk of coronary heart disease or dyslipidemia.

Methods

Study design and patients

In this study, we selected a population that received nutritional counseling at our hospital's nutrition department from January 2023 to December 2023 and were assessed by professional clinical nutritionists for anthropometric measurements.

Inclusion criteria: lean NAFLD: BMI (Weight/Height^2 kg/m^2) < 23 kg/m2; Age ≥ 18.

Exclusion criteria: Alcoholism; HIV; lipodystrophy; lysosomal acid lipase deficiency; familial hypobetalipoproteinemia; medication-induced hepatic steatosis (methotrexate, amiodarone, tamoxifen, and steroids); mental illness; cognitive communication disorders; placement of a metal stent or pacemaker inside

the body; difficulty in movement; inability to stand independently for less than 5 minutes; acute infectious diseases; use of lipid-lowering medications such as estrogen and glucocorticoids; malignant tumors; abnormal thyroid function; severe abnormalities in heart, lung, liver, and kidney function.

This study screened a total of 1410 individuals aged 18-90. This research was approved by the institutional ethics board of the First Affiliated Hospital of Nanjing Medical University.

Medical history collection and anthropometry

This study was conducted by a designated clinical nutritionist who was trained to inquire about the subjects' menstrual history, past medical history, and medication treatment history. Height: The height of the subject is measured as the distance between the horizontal pressure plate and the foot plane, with the subject taking off their shoes and without a hat, their body straight, and their eyes level. The unit of measurement is cm, accurate to one decimal place.

Analysis of human body composition

This study was conducted by a certified clinical nutritionist who was trained to inquire about the subjects' menstrual history, past medical history, and medication treatment history. Height: The height of the subject is measured as the distance between the horizontal pressure plate and the foot plane. The subject should take off their shoes and remove any hats, stand with their body straight, and keep their eyes level. The unit of measurement is centimeters, accurate to one decimal place.

Laboratory indicator testing

Utilizing the Tsinghua Tongfang human body composition analyzer. In the morning, individuals stand on an empty stomach and empty their bowels to measure, ensuring close contact between the electrodes on their limbs. The testing content includes weight, body mass index (BMI), defatted weight, body fat, body fat percentage (PBF), visceral fat index (VAI), skeletal muscle mass index (SMI), skeletal muscle mass (SMM), limb muscle mass, fatty liver risk coefficient, etc. Operated by professional clinical nutritionists trained in the field.

Quality control

Utilize a standard human body composition analyzer and a height meter for measurements. Medical personnel involved in the research should undergo rigorous screening and training in the initial phases. Designate a specific individual to oversee on-site supervision to guarantee precise and thorough data collection.

Data conversion and blood lipid determination standards

The conversion of anthropometric indicators results in a waist-to-hip ratio, calculated as waist circumference (cm)/ hip circumference (cm); Referring to the "Guidelines for the Prevention and Treatment of Abnormal Blood Lipids in Chinese Adults (2016)," the criteria for blood lipid abnormalities are as follows: serum TC ≥ 5.20 mmol/L; LDL-C ≥ 3.37 mmol/L; TG ≥ 1.70 mmol/L; HDL-C < 1.04 mmol/L. Meeting one or more of the above criteria can lead to a diagnosis of dyslipidemia. Normal body fat percentage varies by gender. For women, the healthy range is typically 20% to 25%, while for men it is 12% to 20%. The normal waist-to-hip ratio for males ranges from 0.85 to 0.9, while for females it ranges from 0.67 to 0.8.

Statistical analysis

Use SPSS 22.0 for data entry, organization, and analysis. Quantitative data is first subjected to normal distribution testing. Normal distribution of quantitative data is typically represented by mean ± standard deviation ($x \pm s$). Comparison between two groups is done using the $\chi 2$ test. Skewed distribution of quantitative data is represented by median and interquartile range [M(Q)], while qualitative data is usually represented by composition ratio or rate. Quantitative data with a normal distribution and uniform variance were compared between two groups using a one-way analysis of variance. The Kruskal-Wallis rank sum test is used for intergroup comparison of quantitative data

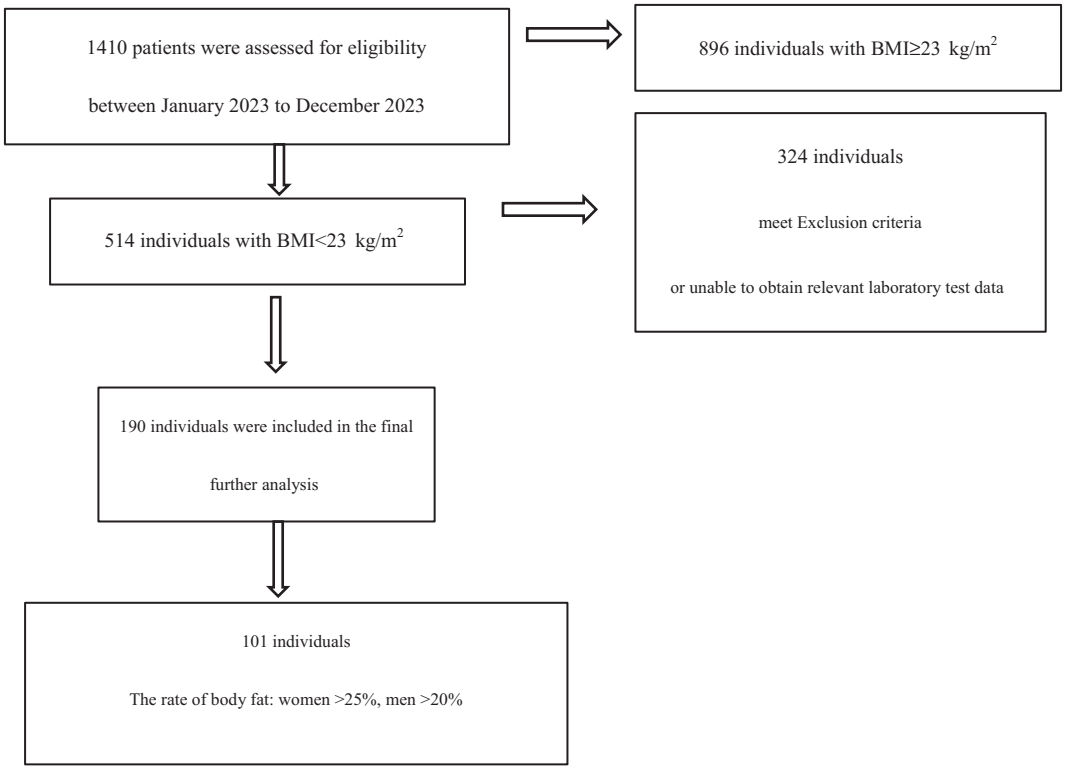

Figure 1. Flow chart of the information regarding subjects' enrollment.

with skewed distribution or uneven variance. Pearson or Spearman correlation analysis was utilized to examine correlations. $P \leq 0.05$ represents a statistically significant difference.

Results

Subjects

A total of 1410 patients were assessed for eligibility between January 2023 and December 2023 in the Nutritional Department of the First Affiliated Hospital of Nanjing Medical University. Among them, 514 (36.5%) individuals with a BMI < 23 kg/m² were selected, including 205 males and 309 females. According to gender differences, 176 (34.2%) individuals were selected with a body fat percentage higher than the normal value. 200 participants did not meet the inclusion criteria and had no contraindications. Among them, 124 individuals were unable to obtain relevant laboratory test data due to personal reasons. All body composition data and laboratory test data from 190 individuals were included in the final analysis (Figure 1).

Baseline characteristics

Among the 190 individuals analyzed in the final analysis, the average BMI was 20.90 ± 1.32 kg/m^2. Specifically, 102 males had an average BMI of 20.95 ± 1.30 kg/m^2, while the average BMI of 88 women was 20.86 ± 1.35 kg/m^2. In terms of gender differences, 101 (53.2%) individuals were identified with a body fat percentage higher than the normal value. The increase rates of TG, TC, LDL-C, and the decrease rates of HDL-C were 21.1%, 27.9%, 22.6%, and 25.3%, respectively. The detection rate of abnormal FPG metabolism was 21.1%. The overall detection rate of abnormal blood lipid metabolism is 58.9%. The detection rate of abnormal sugar and lipid metabolism is 85.3%. There is a statistically significant difference in the rate of impaired FPG regulation among different

age groups (P < 0.05). Additionally, there are statistically significant differences in the detection rates of abnormal blood lipid metabolism and abnormal FPG and lipid metabolism among different genders and age groups (P < 0.05) (Table 1).

Analysis results of human body composition in non-obese and lean individuals

The Body Mass Index (BMI), Waist-to-Hip Ratio (WHR), and Visceral Adiposity Index (VAI) of the group with impaired fasting plasma glucose (FPG) regulation were higher than those of the normal group. The Skeletal Muscle Index (SMI), Skeletal Lean Mass (SLM), Percentage of Body Fat (PBF), VAI, WHR, and risk of Non-Alcoholic Fatty Liver Disease (NAFLD) in the group with abnormal lipid metabolism and the group with abnormal FPG and lipid metabolism were higher than those in their respective normal groups. The Skeletal Muscle Mass (SMM) and SMI of the groups with impaired FPG regulation, abnormal lipid metabolism, and abnormal FPG and lipid metabolism were lower than those of their respective normal groups (Table 2).

Analysis results of clinical outcomes about liver function in non-obese and lean individuals

The liver function of the impaired FPG regulation group, the abnormal blood lipid metabolism group, and the abnormal FPG and lipid metabolism group were all higher than their respective normal groups, and some differences were statistically significant (P < 0.05) (Table 3).

The correlation between human body composition indicators and FPG, blood lipids, and risk of NAFLD in non-obese and lean individuals

Analyze the correlation between human body composition indicators and fasting plasma glucose (FPG) and blood lipids. The study found that FPG is positively correlated with waist-to-hip ratio (WHR) and the risk of non-alcoholic fatty liver disease (NAFLD); total cholesterol (TC) is positively correlated with PBF, risk of NAFLD, and WHR; triglycerides (TG) are positively correlated with the risk of NAFLD and negatively correlated with SMM and SMI; LDL-C is positively correlated with PBF, WHR, and the risk of NAFLD; HDL-C is negatively correlated with the risk of NAFLD and WHR, and positively correlated with SMM, showing statistically significant differences (P<0.05) (Table 4).

Linear regression analysis of independent influencing factors of TC, TG, HDL, LDL, FPG, and risk of NAFLD in non-obese and lean individuals

To eliminate the mutual influence between various indicators, the indicators with statistical differences mentioned above are taken as independent variables. BMI, WHR, PBF, and VAI are independent variables for FPG, while BMI, WHR, VAI, and the risk of NAFLD are independent variables for TG, TC, HDL, and LDL. Linear stepwise regression analysis was conducted separately. It was found that PBF is an independent risk factor for increased FPG and TC, while PBF has a significant impact on HDL (Table 5).

Discussion

In this research, we adopted a new method that combines relevant detection indicators of human body composition to analyze the estimation of blood lipid abnormalities and NAFLD. This method has not been widely applied in previous research. Our research also has a degree of novelty in its conclusions. These findings provide new non-invasive monitoring indicators for the diagnosis and prevention of dyslipidemia. The distribution and content of human body components vary depending on gender, age, and health status, and are considered key characteristics of the human body in various situations (13-14). Studying the relationship between human body composition and diseases can provide crucial evidence for understanding the pathogenesis, diagnosis, and treatment of diseases. BMI is an established risk factor for the development of cardiovascular disease (CVD) and related comorbidities. Combining BMI with other measures of adiposity, such as waist circumference or body composition, provides stronger predictive power for metabolic and

Table 1. Baseline characteristics of the subjects in the study

	FPG				Blood lipid				Glycolipid metabolism			
Project	**Normal**	**Abnormal**	**χ2**	**P**	**Normal**	**Abnormal**	**χ2**	**P**	**Normal**	**All abnormal**	**χ2**	**P**
SEX			5.425	0.02			2.078	0.149			2.653	0.103
female	76	12			41	47			79	9		
male	74	28			37	65			83	19		
Age			10.702	0.005			75.988	0.000			11.676	0.003
10~	20	1			9	12			21	0		
30~	80	15			34	61			84	11		
60~	50	24			35	39			57	17		
All	150	40			78	112			162	28		

Table 2. Analysis of human body composition based on different glucose and lipid metabolism of research subjects (x ± s)

Group	N	BMI kg/m^2	WHR	PBF %	VAI %	SMI Kg/m^2	SMM kg	Risk of NAFLD %
FPG								
Normal	150	20.89 ±1.33	0.84 ±0.04	22.09 ±6.06	7.45±1.95	0.51±0.10	29.75 ±7.40	21.27 ±18.18
Abnormal	40	20.97 ±1.29	0.86 ±0.06	21.42 ±6.64	7.85±2.45	0.49±0.19	28.49 ±11.31	19.75 ±17.47
t		-0.357	-2.159	0.608	-1.076	0.613	0.848	0.473
p		0.722	0.032	0.544	0.283	0.541	0.398	0.637
Blood lipid								
Normal	78	20.65±1.34	0.84±0.05	21.80±6.29	7.30±2.09	0.51±0.07	29.52±6.06	19.26±17.87
Abnormal	112	21.08±1.28	0.85±0.05	22.05±6.12	7.70±2.04	0.50±0.16	29.47±9.67	21.43±18.15
t		-2.26	-1.617	-0.276	-1.328	0.665	0.037	-0.441
p		0.025	0.108	0.783	0.186	0.507	0.971	0.060
Glycolipid metabolism								
Normal	162	20.87±1.34	0.84±0.04	21.94±6.08	7.44±1.98	0.51±0.10	29.82±7.24	19.91±18.03
All abnormal	28	21.10±1.17	0.86±0.70	21.98±6.81	8.07±2.45	0.48±0.22	27.57±13.10	21.07±18.12
t		-0.836	-1.907	-0.031	-1.465	1.288	1.317	-0.039
P		0.404	0.048	0.975	0.045	0.199	0.189	0.019

Table 3. Analysis of clinical outcomes about liver function based on different FPG and lipid metabolism of research subjects (x ± s)

Group	N	ALT U/L	AST U/L	ALB g/l	Hb g/l
FPG					
Normal	150	17.87 ±8.73	21.91 ±7.77	41.64 ±5.69	123.99±22.25
Abnormal	40	20.99 ±7.71	20.45 ±5.02	42.61 ±5.20	127.13±22.32
t		-2.050	1.131	-0.974	-0.792
p		0.042	0.260	0.322	0.429
Blood lipid					
Normal	78	17.67±8.03	21.60±5.96	42.18±5.23	125.19±21.35
Abnormal	112	19.13±8.96	21.60±8.12	41.60±5.84	124.27±22.93
t		-1.145	-0.011	0.697	0.281
p		0.054	0.991	0.487	0.779
Glycolipid metabolism					
Normal	162	17.97±8.60	20.64±5.29	41.84±5.65	124.56±22.28
All abnormal	28	21.76±7.96	21.77±7.59	41.86±5.30	125.18±22.45
t		-0.836	0.759	-0.024	-0.136
P		0.031	0.449	0.981	0.892

Table 4. Correlation between body composition indicators and FPG and blood lipids in research subjects

Indicator	BMI	WHR	PBF	SMI	SMM	Risk of NAFLD
FPG						
r	0.840	0.170	0.023	-0.561	-0.061	0.847
p	0.015	0.019	0.757	0.042	0.399	0.014
TC						
r	0.064	0.836	0.184	-0.083	-0.113	0.116
p	0.382	0.015	0.011	0.255	0.121	0.011
TG						
r	0.140	0.104	0.056	-0.790	-0.558	0.090
p	0.055	0.155	0.444	0.019	0.043	0.021
LDL						
r	0.066	0.582	0.154	-0.101	-0.115	0.098
0.098P	0.364	0.040	0.034	0.166	0.114	0.018
HDL						
r	-0.131	-0.231	0.126	0.094	0.157	-0.051
P	0.072	0.001	0.083	0.197	0.030	0.048

cardiovascular diseases than BMI alone (15-16). Increased blood pressure, fasting insulin levels, and dyslipidemia are correlated with higher values of body mass index (BMI) and waist circumference (WC). These elements together increase the risk of cardiovascular disease. However, it appears that the waist-to-height ratio (WHR) and body fat percentage (PBF) are better measures of the accumulation of central and

Table 5. Regression analysis of influencing factors of various indicators

Project	Indicator	B	SE	Beta	t	P	R^2	F
Influencing factors of FPG	PBF	0.032	0.013	0.484	2.526	0.012	0.073	2.902
Influencing factors of TC	PBF	0.107	0.038	0.541	2.799	0.006	0.059	2.306
Influencing factors of HDL	PBF	0.031	0.010	0.574	3.151	0.002	0.164	7.229

total body fat, respectively. These measures would be more accurate in predicting the risk of cardiometabolic disease (17). Although being overweight is commonly thought to be a risk factor for NAFLD, thin individuals can also develop the condition (18-19). Additionally, ectopic fat deposition and lean NAFLD are exacerbated by the loss of muscle mass and function (20). Asian populations were the first to describe cases of lean NAFLD (21), and among those with NAFLD, its prevalence is 25.2% (22-23). Metabolic diseases can be predicted early by NAFLD. The etiology of lean NAFLD has been linked to muscle loss and visceral obesity caused by inactivity or insufficient exercise (24-25). Dietary and lifestyle modifications remain the primary therapy for this condition. Lean NAFLD may be linked to a genetic predisposition, a poor dietary pattern characterized by excessive cholesterol and sugar intake, and visceral obesity rather than general obesity (26-27). Pathogen resistance, vitamin production, and digestion are all significantly influenced by the gut microbiome (28). The bioelectrical impedance analysis (BIA) method can accurately reflect the body composition of the human body, including muscle mass, fat mass, water content, inorganic salts, and more. The percentage of body fat (PBF) can indicate the amount of body fat, while the area of visceral fat can indicate the distribution of body fat. These indicators may be of great significance for evaluating health-related risks in populations. In adult studies on dyslipidemia, it has been demonstrated that disease severity is linked to the accumulation of visceral fat and the loss of muscle (29). However, current research on body composition and dyslipidemia is limited, and the relationship between changes in body composition and the risk and progression of dyslipidemia in non-obese and lean individuals is not fully understood. The analysis of human body composition in this study revealed that the muscle mass index and fat index of the groups with impaired blood glucose regulation, abnormal blood lipid metabolism, and abnormal glucose and lipid metabolism were all higher than those of their respective normal groups. Dyslipidemia presents a number of challenges due to the lack of research on the pathophysiology and natural history of the disease. It is also crucial for doctors to maintain a high level of clinical suspicion when identifying patients who may be at risk for lean dyslipidemia but do not show the typical, easily identifiable symptoms of obesity.

Conclusions

Even if the Body Mass Index (BMI) falls within the normal range, it does not necessarily indicate a healthy state of the body. Furthermore, it may lead to increased blood lipid levels and a predisposition to developing non-alcoholic fatty liver disease. When compared to obese non-alcoholic fatty liver disease patients, lean non-alcoholic liver disease patients have an even higher risk of metabolic syndrome and all-cause mortality. A decline in the quantity and quality of skeletal muscle can lead to metabolic issues and a decrease in insulin sensitivity. Skeletal muscle is an essential metabolic organ.

Despite the statistical significance of this result, further analysis with larger and more diverse sample sizes is recommended to confirm the generalizability of this proof-of-concept model.

Authors' Contributions: F.W. and T.Z. conceived and designed the study, had full access to all data, and were responsible for the integrity and accuracy of the data. W.W. collected the epidemiological and clinical data. Q.D. performed the statistical analysis. F.W. and T.Z. drafted the initial version of the manuscript. X.M. and L.J. contributed to the revision and refinement of the manuscript. All authors contributed to the analysis or interpretation of the data, and reviewed and approved the final version of the manuscript.

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Ethical Compliance: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Conflict of Interest Declaration: The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Informed Consent: This study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University (Ethics No. 2019SR-722), and all patients willingly consented to the use of their clinical data for the study. All patients or their duly appointed representatives signed site-specific approved consent forms.

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