

Associations of Dietary UPF Intake With Abdominal Ultrasonic Parameters and Glycemic Parameters in T2DM Patients With Abdominal Obesity

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Background: Over the past 50 years, the consumption of ultra-processed food (UPF) has increased significantly, paralleling the rising trend in obesity. UPF has been shown to have numerous adverse health outcomes and is associated with various lifestyle-related diseases. Although the relationship between UPF and visceral adipose tissue has been explored, comprehensive analyses of UPF in relation to abdominal ultrasound parameters and glycemic parameters in patients with abdominal obesity and type 2 diabetes mellitus (T2DM) remain limited. Therefore, this study was conducted to investigate the aforementioned relationship in this specific patient population.

Methods: A retrospective study was conducted on 286 T2DM patients admitted to our hospital from January 2021 to December 2024, consisting of 172 patients with abdominal obesity. The T2DM patients with abdominal obesity were divided into two groups: low UPF intake group (n = 74) and high UPF intake group (n = 98). Spearman's rank correlation was used to assess associations between variables. The receiver operating characteristic (ROC) curve was employed to evaluate the predictive value of relevant indicators in T2DM patients with or without abdominal obesity.

Results: There were no statistically significant differences in age, gender, hypertension, smoking status, alcohol consumption, Triglycerides (TG), Glycosylated hemoglobin (HbA1c), and interleukin-6 (IL-6) between the low UPF intake group and the high UPF intake group ($p > 0.05$). However, differences in Body Mass Index (BMI); Glucose (GLU); Total Cholesterol (TC), Hyper-sensitive C-reactive Protein (hsCRP), Subcutaneous Adipose Tissue (SAT), and visceral adipose tissue (VAT) were statistically significant ($p < 0.05$). Correlation analysis indicated that UPF intake was positively correlated with Glucose (GLU), TC, hsCRP, SAT, and VAT ($r = 0.437, 0.287, 0.192, 0.372, 0.447; p < 0.05$). Furthermore, BMI, SAT, VAT, and UPF intake significantly differed between patients with and without abdominal obesity ($p < 0.05$). Binary Logistics regression analysis revealed that SAT, VAT, and UPF intake were independent influencing factors for abdominal obesity in T2DM patients ($p < 0.05$). ROC analysis demonstrated that the area under the curve of the composite index was 0.799, with a standard error of 0.027 (95% CI: 0.747–0.852), a Youden index of 0.53, sensitivity of 70.35%, and specificity of 82.46%.

Conclusion: UPF intake is positively correlated with GLU, TC, hsCRP, SAT, and VAT, and the combination of UPF intake with SAT and VAT has a high predictive value for abdominal obesity in T2DM patients.

Keywords: dietary UPF intake; abdominal obesity; T2DM; abdominal ultrasonic parameters; glycemic parameters

Introduction

Ultra-processed food (UPF), as defined by the NOVA food classification system, is described as “industrially formulated food products that are mainly or entirely made from substances derived from foods, typically modified by chemical processes and containing additives, but with little or no whole foods added”. Over the past 50 years, the consumption of UPFs has significantly increased, with this growth trend paralleling the rise in obesity rates [1]. For example, in Sweden, between 1960 and 2010, the consumption of ultra-processed food increased by 142%, with soda consumption rising by 315% and such snack foods as chips and candies increasing by 367% [2]. UPFs are typically char-

acterized by high energy density, low nutrient density, high levels of added sugars and saturated fats (SFAs), and low fiber content. Although they are inexpensive, convenient, and may contain some essential nutrients, these characteristics have raised concerns about their adverse effects on health. It has been confirmed that UPFs and their components negatively affect gut microbiota, promote systemic inflammation and insulin resistance, contribute to weight gain, and can also impair mental health [3,4]. UPFs are consistently associated with lifestyle-related diseases like cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM) [5,6]. UPFs are shown to lead to obesity and are associated with abnormal fat accumulation (e.g., hepatic and pancreatic fat) as well as visceral fat mass [7].

Prospective cohort data on the relationship between total UPF intake and T2DM are currently limited and primarily focused on European cohorts, with risk elevations ranging from 15% to 53% depending on the cohort and level of total UPF intake. In the United States, total UPF intake is much higher than in Europe, with higher intake of specific UPF subgroups (e.g., ultra-processed bread and cereals, and artificially sweetened beverages), and a study has shown that high UPF intake is associated with increased mortality [8].

Although the relationship between UPF and visceral adipose tissue (VAT) has been explored, there is limited comprehensive analysis regarding abdominal ultrasound parameters and glycemic parameters in T2DM patients with abdominal obesity. Therefore, this study aims to investigate the relationship between dietary UPF intake and abdominal ultrasound parameters, as well as glycemic parameters in T2DM patients with abdominal obesity. It is hoped that this research provides new evidence for a better understanding of the impact of UPFs on the health of T2DM patients with abdominal obesity and supports the formulation of targeted public health policies based on scientific evidence.

Methods

Research Objects

This retrospective study enrolled 286 patients with T2DM admitted to JinHua Municipal Central Hospital between January 2021 and December 2024, including 172 patients with abdominal obesity and 114 participants without abdominal obesity. Screening and grouping procedures are shown in Fig. 1. Diagnostic criterion: waist circumference ≥ 90 cm in male patients; waist circumference ≥ 85 cm in female patients. The inclusion criteria were as follows: (1) All patients met the clinical diagnosis criteria for T2DM. (2) Patients were conscious and had normal communication abilities. (3) Patients were over 18 years of age. The exclusion criteria were as follows: (1) Patients with type 1 diabetes mellitus, pregnant or lactating women, and those with secondary obesity. (2) Patients with severe diabetic complications, such as hyperglycemic hyperosmolar state, lactic acidosis, or ketoacidosis. (3) Patients with malignant tumors or organic pancreatic lesions. This study was conducted in accordance with the Declaration of Helsinki, and approved by the Medical Ethics Committee of JinHua Municipal Central Hospital (2025-153). The principles of informed consent were followed throughout the experiment. Detailed information about the study was provided to patients or their families, and written informed consent was obtained.

Research Methods

Abdominal Ultrasonography

In this study, the Mindray M9 color Doppler ultrasound (Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China) diagnostic apparatus was used to de-

tected. Participants were required to fast for 12 hours prior to the test. During the examination, a convex array probe with a frequency range of 3.5–5.0 MHz was selected. The patient was positioned supine with no pillow, legs straight, and hands naturally placed on both sides of the body to maintain relaxation and avoid tension or abdominal deformation affecting the test results. The operator gently placed the ultrasound probe vertically on the patient's abdominal skin surface, minimizing applied pressure to avoid underestimation of actual fat thickness caused by probe compression. For measuring subcutaneous adipose tissue thickness, a high-resolution linear probe with a frequency range of 5–8 MHz was used. The probe was positioned transversely 1 cm above the umbilicus along the midline, and the image was captured at the end of the patient's exhalation. The distance from the skin to the outer edge of the abdominal muscle layer was measured, representing the subcutaneous fat thickness. To measure visceral adipose tissue thickness, a convex probe with a frequency range of 1–4 MHz was used. It was also placed 1 cm above the umbilicus along the midline, and the image was captured at the end of the patient's exhalation. The distance from the midline of the peritoneum to the anterior wall of the abdominal aorta was measured, representing the visceral fat thickness [9]. To minimize measurement errors, each participant was measured three times, and the mean of the three measurements was recorded as the final data.

Dietary Survey and UPF Grouping Criteria

A simplified Food Frequency Questionnaire (FFQ) [10] was used to obtain information on the food intake frequencies of the study subjects over the past 6 months. The validated FFQ items were classified using the NOVA classification system. The Nova classification includes 4 groups: Group 1 (unprocessed or lightly processed foods): fresh, dried or frozen fruits or vegetables, grains, beans, meat, fish and milk that are either unprocessed or processed only by methods such as grinding, roasting, pasteurization, or freezing; Group 2 (processed culinary ingredients): substances extracted or refined from Group 1 or from nature, such as sugar, oil, fat, salt, used in cooking preparations; Group 3 (processed foods): foods made by combining unprocessed or lightly processed foods with Group 2 ingredients to enhance durability or palatability (e.g., canned fruits; hand-made breads and cheese; and salted, smoked or cured meat or fish). Group 4 (ultra-processed foods): industrial formulations contain several ingredients, including Group 2 ingredients, with little or no whole foods. They usually contain food cosmetic additives not used in culinary preparation, such as seasonings, colorings, sweeteners, emulsifiers and other substances used to mask the poor quality or mimic the sensory properties of Group 1 culinary preparation [11]. Patients with T2DM with abdominal obesity are divided into two groups based on the above classification: Low UPF intake is defined as less than 55% of the



Fig. 1. Flowchart of Screening and grouping procedures.

total intake of ultraprocessed foods reported in the classification. As a low UPF intake group (n = 74). Ultraprocessed foods reported in the definition category of high UPF intake accounted for $\geq 55\%$ of the total intake level and were included in the high UPF intake group (n = 98) [12]. UPF intake proportion was calculated as the percentage of total energy intake (The sum of all food intakes recorded by the FFQ in kilocalories) derived from NOVA Group 4 foods.

General Data Collection

Patients’ age, gender, smoking status, alcohol consumption, and other relevant information were collected with the electronic medical record system.

Laboratory Index Collection

On the day of admission, fasting venous blood samples were collected from all patients. Fasting glucose (GLU) was measured with the glucose oxidase method. The detection of triglycerides (TG) and total cholesterol (TC) was performed using a fully automated biochemical analyzer (OLYMPUS AU640 Fully Automated Biochemical Analyzer, Japan OLYMPUS OPTICAL Co., Ltd., Registration Certificate Number: Guo Shi Yao Jian Xie (Import) No. 2003-2400598). Glycosylated hemoglobin (HbA1c) was measured using the immunoturbidimetric method. In terms of inflammatory factors, enzyme-linked immunosorbent assay (ELISA) was employed to accurately measure the con-

centrations of hypersensitive C-reactive protein (hsCRP) and interleukin-6 (IL-6). Materials for testing included High-sensitivity C-reactive protein assay kit (Siemens Healthcare Diagnostics Inc, NMPA registration number 20192400514, specification REF 03108390: 2 × 220 tests/box); Human interleukin 6 (IL-6) enzyme-linked immunosorbent assay kit (Shanghai Enzyme-linked Biotechnology Co., Ltd., 96 tests, catalog number ml058097). Measurements were performed using a microplate reader at a wavelength of 450 nm.

Statistical Analysis

The experimental data collected were analyzed using SPSS 27.0 (International Business Machines Corporation, Armonk, NY, USA). The Shapiro-Wilk test was employed for normality testing. For normally distributed continuous data in the experimental data, results are presented as Mean ± Standard Deviation (SD). Independent sample *t*-tests were used for comparisons. Count data were presented as frequencies or rates, and comparisons were conducted with χ^2 test or Fisher's exact test. For non-normally distributed data, Spearman's rank correlation was used to assess associations between variables. Influencing factors were analyzed by single-factor and multivariate Logistic regression. The receiver operating characteristic (ROC) curve was used to evaluate the predictive value of indicators in distinguishing T2DM patients with and without abdominal obesity. A significance level of $p < 0.05$ was considered statistically significant for differences.

Results

General Data Analysis of Patients with Abdominal Obesity

The comparison of age, gender, hypertension, smoking status, alcohol consumption, TG, HbA1c, and IL-6 between the low UPF intake group and the high UPF intake group showed no statistically significant differences ($p > 0.05$). However, the comparison of BMI, GLU, TC, hsCRP, SAT, and VAT levels revealed statistically significant differences ($p < 0.05$), as shown in Table 1.

Spearman Correlation Analysis of Relationship Between UPF Intake and Abdominal Ultrasound Parameters and Glycemic Parameters in T2DM Patients With Abdominal Obesity

The results of the correlation analysis indicate a positive correlation between UPF intake and GLU, TC, hsCRP, SAT, and VAT levels ($r = 0.437, 0.287, 0.192, 0.372, 0.447$; $p < 0.05$). See Table 2 for details.

Differences in Clinical Data Between the Non-Abdominal-Obesity Group and the Abdominal-Obesity Group

Statistical analysis comparing BMI, SAT, VAT, and UPF intake between the non-abdominal-obesity group and the abdominal-obesity group revealed significant differences ($p < 0.05$). See Table 3 for details.

Multivariate Logistic Regression Analysis of Factors Influencing Abdominal Obesity in T2DM Patients

The significant factors identified in the analysis between the Non-Abdominal-Obesity Group and the Abdominal-Obesity Group were tested for collinearity, and then used as independent variables in a multiple logistic regression analysis, with abdominal obesity as the dependent variable (abdominal obesity = 1, no abdominal obesity = 0). Variable assignment method: UPF intake was coded as High = 1 and Low = 0, while BMI, SAT, and VAT were all brought in the original value. The results of the binary Logistics regression analysis indicated that SAT, VAT, and UPF intake were independent influencing factors for abdominal obesity in T2DM patients ($p < 0.05$). See Table 4 for details.

ROC Curve Analysis of Predictive Value of Indicators

The ROC analysis demonstrated that the composite indicator yielded an area under the curve (AUC) of 0.799 (standard error; 95% CI: 0.747–0.852), with a Youden's index of 0.53. At this point, the sensitivity was 70.35%, and specificity was 82.46%, as shown in Table 5 and Fig. 2.

Discussion

This study investigated the relationship between dietary UPF intake and both abdominal ultrasound and glycemic parameters in T2DM patients with abdominal obesity. Through retrospective analysis, we found that UPF intake was associated with multiple adverse metabolic and anthropometric indicators. Moreover, it showed predictive value for abdominal obesity in this patient population.

This study demonstrates a positive correlation between UPF consumption and GLU, TC, SAT, and VAT. Previous research by Chen Z *et al.* [13] indicated that UPF intake increased the risk of developing Type 2 Diabetes Mellitus (T2DM), which aligns closely with the findings of this study. This association is often attributed to the high glycemic index (GI) and high glycemic load (GL) characteristics of UPFs. The rapid digestion and absorption of refined carbohydrates and added sugars in UPFs lead to a rapid increase in blood glucose levels [14]. Long-term high UPF intake can alter insulin secretion patterns, thereby increasing the burden on pancreatic β cells and promoting insulin resistance, which, in turn, disrupts normal glucose metabolism and contributes to elevated blood glucose lev-

Table 1. General data analysis of patients with abdominal obesity.

Indicator	Low UPF Intake Group (n = 74)	High UPF Intake Group (n = 98)	t/ χ^2 value	p value
Age (years)	50.65 ± 7.34	50.19 ± 7.73	0.395	0.693
Gender				
Male	50	69	0.160	0.690
Female	24	29		
BMI (kg/m ²)	27.66 ± 1.78	28.84 ± 1.94	4.091	<0.001
Hypertension				
Yes	23	30	0.004	0.947
No	51	68		
Smoking status				
Yes	19	22	0.242	0.623
No	55	76		
Alcohol Consumption				
Yes	20	26	0.005	0.942
No	54	72		
GLU (mmol/L)	8.23 ± 1.72	9.99 ± 1.68	6.733	<0.001
TG (mmol/L)	1.55 ± 0.19	1.60 ± 0.24	1.476	0.142
TC (mmol/L)	4.27 ± 0.24	4.43 ± 0.22	4.541	<0.001
HbA1c (%)	7.49 ± 1.21	7.56 ± 1.29	0.362	0.718
hsCRP (mg/L)	5.44 ± 0.21	5.55 ± 0.27	2.903	0.004
IL-6 (ng/L)	9.26 ± 0.74	9.22 ± 0.70	0.362	0.718
SAT (cm ²)	112.65 ± 6.81	119.41 ± 8.91	5.436	<0.001
VAT (cm ²)	137.60 ± 9.30	148.17 ± 10.30	6.945	<0.001

Note: BMI, Body Mass Index; GLU, Glucose; TG, Triglycerides; TC, Total Cholesterol; HbA1c, Glycosylated Hemoglobin; hsCRP, Hypersensitive C-reactive Protein; IL-6, Interleukin-6; SAT, Subcutaneous Adipose Tissue; VAT, Visceral Adipose Tissue; UPF, ultra-processed food.

Table 2. Spearman correlation analysis of relationship between UPF intake and abdominal ultrasound parameters and glycemic parameters in T2DM patients with abdominal obesity.

Item	UPF Intake		GLU		TG		TC		HbA1c		hsCRP		IL-6		SAT		VAT	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p
UPF Intake	1.0	-	0.4	<0.0	0.1	0.1	0.2	<0.0	0.0	0.7	0.1	0.0	-0.0	0.8	0.3	<0.0	0.4	<0.0
	00		37	01	23	07	87	01	25	48	92	12	19	04	72	01	47	01

els, including increased glycemic index units (like GLU). Previous studies by Henney AE *et al.* [15] suggested that excessive UPF intake is associated with non-alcoholic fatty liver disease, a finding consistent with the present study, as UPFs are rich in saturated fatty acids (SFA) and trans fatty acids. SFA elevates low-density lipoprotein cholesterol (LDL-C) levels in the bloodstream, while trans fatty acids not only increase LDL-C but also lower high-density lipoprotein cholesterol (HDL-C) levels, resulting in elevated total cholesterol (TC). Moreover, components such as high salt and sugar in UPFs may indirectly interfere with lipid metabolism pathways in the body, exacerbating lipid abnormalities [16,17]. High in energy density and low in nutrient density, excessive intake of UPF over the long term can lead to energy surplus, which is converted into fat stored in the body. SAT and VAT are the main sites of fat storage, and this study reveals a positive correlation between UPF intake and SAT as well as VAT, indicating that in-

creased UPF consumption promotes abdominal fat accumulation. Research by Fridén M *et al.* [18] also demonstrated positive correlations between UPF intake and liver and pancreas fat, VAT, VAT/SAT ratio, and total fat mass. Even after full adjustment, the association with VAT remained ($\beta = 0.01$ (95% CI: 0.002–0.02) corroborating the findings of this study. Certain components in UPF, such as high fructose corn syrup, may particularly promote the accumulation of visceral fat. Visceral fat cells have higher metabolic activity, secreting various cytokines and inflammatory mediators that further influence metabolism and inflammatory responses in the body. Additionally, the study indicates a positive correlation between UPF consumption and hsCRP levels, possibly linked to additives and preservatives in UPFs that possess immune-stimulating properties that activate internal inflammatory responses. Chronic low-grade inflammation resulting from long-term UPF intake elevates inflammatory markers such as hsCRP levels. Con-

Table 3. Differences in clinical data between the non-abdominal-obesity group and the abdominal-obesity group.

Indicator	Non-Abdominal-Obesity Group (n = 114)	Abdominal-Obesity Group (n = 172)	<i>t</i> / χ^2 value	<i>p</i> value
Age (years)	50.52 ± 6.96	50.49 ± 7.31	0.035	0.972
Gender				
Male	80	119	0.032	0.859
Female	34	53		
BMI (kg/m ²)	27.72 ± 1.83	28.33 ± 1.95	2.654	0.008
Hypertension				
Yes	39	53	0.362	0.547
No	75	119		
Smoking status				
Yes	30	41	0.226	0.635
No	84	131		
Alcohol Consumption				
Yes	32	46	0.061	0.805
No	82	126		
GLU	8.83 ± 1.62	9.23 ± 1.91	1.840	0.067
TG	1.54 ± 0.21	1.58 ± 0.23	1.490	0.137
TC	4.28 ± 0.23	4.32 ± 0.31	1.179	0.239
HbA1c	7.35 ± 1.20	7.53 ± 1.25	1.211	0.227
hsCRP	5.49 ± 0.23	5.50 ± 0.25	0.342	0.733
IL-6	9.39 ± 0.72	9.24 ± 0.71	1.740	0.083
SAT	113.12 ± 7.40	116.50 ± 8.72	3.405	0.001
VAT	136.27 ± 8.45	143.62 ± 11.17	5.981	<0.001
UPF Intake				
High	25	98	34.356	<0.001
Low	89	74		

Table 4. Multivariate logistic regression analysis of influencing factors.

Factor	β	SE	Wald	<i>p</i>	Exp(β)	95% CI		Collinearity Test	
						Lower Limit	Upper Limit	Tolerance	VIF
BMI	0.136	0.073	3.468	0.063	1.145	0.993	1.322	0.961	1.041
SAT	0.045	0.018	6.459	0.011	1.046	1.010	1.084	0.955	1.047
VAT	0.069	0.015	22.872	<0.001	1.072	1.042	1.103	0.958	1.044
UPF Intake	1.676	0.300	31.107	<0.001	5.344	2.965	9.630	0.993	1.007

VIF, variance inflation factor.

Table 5. ROC analysis results.

Indicator	AUC	Standard Error	95% CI	Youden	Sensitivity	Specificity	Optimal Cutoff Value	<i>p</i>
SAT	0.604	0.033	0.539–0.670	0.22	22.67	99.10	124.27	0.003
VAT	0.683	0.031	0.623–0.744	0.31	43.60	87.82	148.97	<0.001
UPF Intake	-	-	-	-	57.98	78.07	-	-
Composite Score	0.799	0.027	0.747–0.852	0.53	70.35	82.46	-	<0.001

currently, metabolic abnormalities induced by UPFs, such as obesity and insulin resistance, can exacerbate inflammatory responses, creating a vicious cycle [19].

This study, through binary Logistics regression analysis, identified SAT, VAT, and UPF intake as independent influencing factors for abdominal obesity in T2DM patients. Traditional predictors of abdominal obesity mainly focus on single indicators such as weight and waist circumference. However, this study combines UPF intake with abdominal

ultrasound parameters, providing a comprehensive consideration of dietary factors and fat distribution. The ROC analysis results yielded an area under the curve of 0.799 with a standard error of Composite Score (95% CI: 0.747–0.852), a Youden index of 0.53, sensitivity of 70.35%, and specificity of 82.46%. This suggests that the combined index can more accurately predict whether T2DM patients have abdominal obesity, thereby improving predictive accuracy. Understanding the relationship between UPF intake

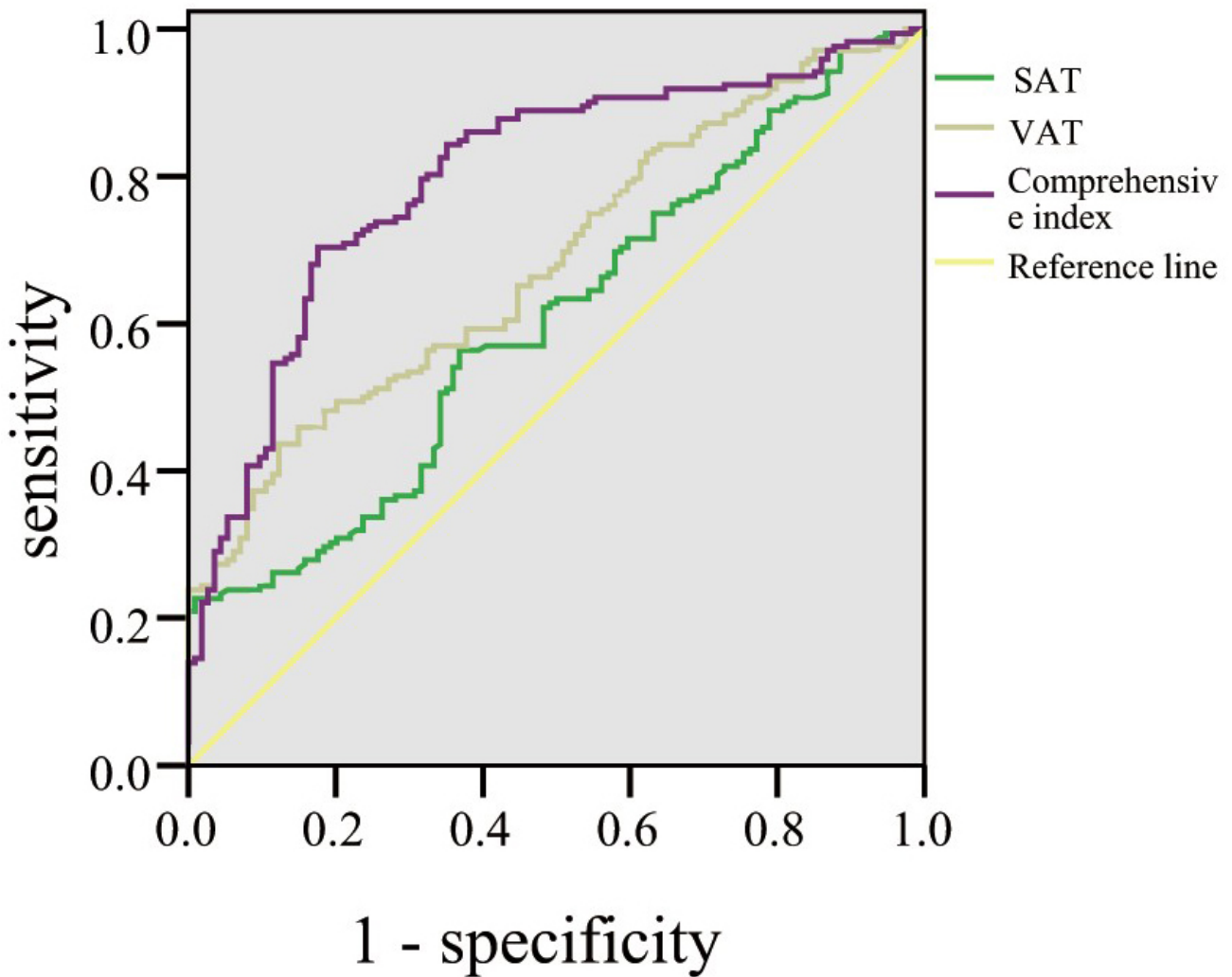


Fig. 2. ROC Curve. ROC, receiver operating characteristic.

and abdominal ultrasound parameters and blood glucose parameters can assist clinicians in developing personalized intervention plans based on individual patient circumstances. For T2DM patients with high UPF intake and abdominal obesity, dietary guidance can be provided to reduce UPF consumption and increase the intake of whole grains, vegetables, fruits, and other foods rich in dietary fiber and healthy fats to improve fat distribution and metabolic indicators. Monitoring changes in abdominal ultrasound parameters and adjusting intervention measures accordingly can enhance the effectiveness of interventions. The results of this study provide a scientific basis for the formulation of public health policies. Furthermore, implementing health education activities to raise public awareness of the risks associated with UPF intake and guiding the public towards healthier dietary choices can help reduce the incidence of abdominal obesity in T2DM patients and alleviate the societal healthcare burden.

This study has several limitations. First, its retrospective design may introduce information and selection bias.

Second, the UPF intake data in this study relied on patient self-report, which may be subject to recall bias and social desirability bias, potentially affecting the accuracy of the intake assessment. Third, the relatively limited sample size could affect the generalizability of the findings. Fourth, this study examined only the relationship between UPF intake and selected indicators, without considering other potential factors influencing abdominal obesity in T2DM patients, such as genetic predisposition and physical activity levels. Future research could employ prospective cohort study designs to further validate the relationship between UPF intake and abdominal obesity in T2DM patients, thereby minimizing information and selection bias. Expanding the sample size and including populations from different regions and ethnicities could enhance the generalizability of the research findings. Additionally, further investigation into the specific components of UPFs and their impacts on abdominal obesity in T2DM patients could provide a theoretical basis for developing more effective intervention strategies.

Conclusion

In conclusion, among T2DM patients with abdominal obesity, dietary UPF intake was positively correlated with abdominal fat deposition (SAT, VAT) and fasting glucose levels. A predictive model combining UPF intake with abdominal ultrasound parameters showed significant value, offering potential insights for personalized dietary interventions and informing public health strategies to reduce UPF consumption. Despite the limitations of this study, it serves as a crucial reference for further research. Future high-quality research is needed to delve deeper into the relationship between UPF and abdominal obesity in T2DM patients, aiming to enhance the prevention and management of abdominal obesity and its related complications.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding author upon request.

Author Contributions

DYN and XYL designed the research study. DYN performed the research. DYN analyzed the data and wrote the first draft. Both authors contributed to important editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki, and approved by the Medical Ethics Committee of JinHua Municipal Central Hospital (2025-153). The principle of informed consent was followed throughout the experiment, information about the study was provided to patients or their families, and consent was obtained.

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Conflict of Interest

The authors declare no conflict of interest.

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