Diabetes, Metabolic Syndrome and Obesity

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ORIGINAL RESEARCH

Correlation Analysis Between Obesity Index and Glycosylated Hemoglobin Level in Type 2 Diabetes Patients: A Cross-Sectional Study

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Introduction: The global prevalence of type 2 diabetes mellitus (T2DM) is increasing rapidly. However, the relationship between obesity indexes and Glycosylated hemoglobin (HbA1c) levels remains unclear.

Methods: This cross-sectional study included 3,898 patients with T2DM who were treated in the Department of Endocrinology at Yuxi People's Hospital between March 2018 and December 2024. Participants were grouped according to whether their HbA1c levels were below 7.0%. Linear regression analysis was performed to evaluate the associations between body mass index (BMI), visceral fat area (VFA), and waist circumference (WC) with glycosylated hemoglobin. In addition, a correlation matrix was generated.

Results: Participants with HbA1c ≥ 7.0% were slightly younger (52.9 ± 11.3 vs 53.9 ± 11.7 years, p = 0.017) and had higher BMI (25.4 ± 3.6 vs 25.1 ± 3.5 kg/m^2, p = 0.037), WC (88.9 ± 9.5 vs 88.1 ± 8.8 cm, p = 0.021), and VFA (88.2 ± 39.4 vs 85.1 ± 36.6 cm^2, p = 0.029) than those with HbA1c < 7.0%. However, no statistically significant associations were observed between HbA1c and BMI (β = –0.0029, 95% CI: –0.0243 to 0.0185, p = 0.79), WC (β = –0.0037, 95% CI: –0.012 to 0.0047, p = 0.38), or VFA (β = –0.0012, 95% CI: –0.0032 to 0.0008, p = 0.24).

Conclusion: There was no significant correlation between obesity indexes and HbA1c levels among patients with T2DM.

Keywords: BMI, HbA1c, T2DM

Introduction

The global prevalence of type 2 diabetes mellitus (T2DM) is increasing rapidly, posing a serious public health challenge. In recent years, along with China's rapid economic development, the prevalence of diabetes has also risen markedly. Reports indicate that the prevalence of diabetes among mainland Chinese adults aged 18 years and older increased from 1% in 1980 to 12.4% in 2018.[1] One of the primary clinical challenges in managing T2DM is achieving optimal glycemic control to prevent diabetes-related complications.

Glycosylated hemoglobin (HbA1c) is formed through the binding of glucose to hemoglobin in red blood cells, and its level is positively correlated with blood glucose concentration. It serves as a stable indicator of the average blood glucose level over the previous 2–3 months.[2] According to the American Diabetes Association, an HbA1c level below 7% indicates good glycemic control.[3] Body mass index (BMI), waist circumference (WC), and visceral fat area (VFA) are commonly used anthropometric indicators that are closely associated with insulin resistance and glycemic control.[4,5] A study conducted in an American population demonstrated a positive correlation between BMI and HbA1c levels among participants without diabetes; however, this association was not significant in individuals with diabetes.[6] In contrast to BMI, which reflects overall adiposity but not fat distribution, VFA provides a direct measure of abdominal obesity and has been shown to be closely associated with a range of metabolic and cardiovascular diseases.[7,8]

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Although numerous studies have examined the relationship between obesity and T2DM, findings remain inconsistent due to differences in study populations and research designs. These inconsistencies hinder the accurate development of individualized glycemic management strategies based on obesity-related indicators in clinical practice.Therefore, based on a cohort of patients with T2DM, this study aims to clarify the relationship between obesity indexes and HbA1c levels. The findings are expected to provide an evidence-based foundation for integrating weight management into precision treatment strategies for diabetes.

Methods

Study Design and Participants

This cross-sectional study retrospectively collected baseline data from 6,240 patients treated in the Department of Endocrinology at Yuxi People's Hospital between March 2018 and December 2024. After excluding individuals with incomplete data and those younger than 18 years, a total of 3,898 patients were included in the final analysis. Baseline information encompassed lifestyle factors, dietary habits, and a comprehensive set of laboratory tests. The study was approved by the Ethics Committee of the Sixth Affiliated Hospital of Kunming Medical University (No. 2023 KMYKDX6F089) and was conducted in accordance with the Declaration of Helsinki. As this study was a retrospective analysis without direct patient contact, only patients' examination results were collected. The findings were used solely for analytical and exploratory purposes, without serving as a basis for clinical diagnosis or involving any commercial interests, so the Ethics Committee approved the waiver of informed consent.

Measurements and Definitions

Height and weight were measured using an automated ultrasonic height–weight scale (HNH-318, Omron, China) while participants wore lightweight clothing, stood barefoot with an erect posture, and maintained relaxed abdominal breathing. BMI was calculated as weight in kilograms divided by height in meters squared. WC was measured at the midpoint between the inferior costal margin and the iliac crest using a non-elastic tape during quiet expiration. VFA and subcutaneous fat area (SFA) were assessed using direct segmental multi-frequency bioelectrical impedance analysis (HDS-2000, Omron, China). HbA1c levels were determined via immunoturbidimetric assay on the Cobas c502 analyzer (Roche Diagnostics, Germany). All measurements were conducted by trained technicians following standardized operating procedures to ensure data reliability and consistency.

According to the Chinese guidelines, body mass index (BMI) is classified into four categories: underweight (BMI < 18.5), normal weight (BMI 18.5–<24.0), overweight (BMI 24.0–<28.0), and obesity (BMI ≥ 28.0).[9] In accordance with the recommendations of the American Diabetes Association, most non-pregnant adults with diabetes should maintain an HbA1c level below 7%; therefore, patients were grouped based on this criterion.[3]

Statistical Analysis

In this study, participants were stratified according to BMI and HbA1c levels. Continuous variables with a normal distribution were expressed as the mean ± standard deviation (SD), whereas those with a skewed distribution were reported as the median and interquartile range (IQR). Categorical variables were presented as percentages. Comparisons of continuous variables were performed using Student's *t*-test or the Mann–Whitney *U*-test, while categorical variables were compared using the chi-square test. Linear regression analysis was conducted to assess the relationship between BMI, VFA, WC, and HbA1c. Additionally, a correlation matrix was generated to visualize these associations. $P < 0.05$ was considered significant. All the analyses were performed with the statistical software packages R (http://www.R-project.org, The R Foundation) and Free Statistics software version 1.9.

Results

Baseline Characteristics

Participants grouped by HbA1c levels showed significant differences in several baseline characteristics. Individuals with HbA1c ≥ 7.0% were slightly younger (52.9 ± 11.3 vs 53.9 ± 11.7 years, p = 0.017) and had higher BMI (25.4 ± 3.6 vs

25.1 ± 3.5 kg/m^2, p = 0.037), WC (88.9 ± 9.5 vs 88.1 ± 8.8 cm, p = 0.021), and VFA (88.2 ± 39.4 vs 85.1 ± 36.6 cm^2, p = 0.029) compared with participants with HbA1c < 7.0%. No significant differences were observed in gender distribution or SFA between the groups (Table 1).

When participants were categorized by BMI, significant differences were observed in baseline characteristics. Males were more prevalent in the overweight and obese categories (p < 0.001). Age decreased significantly across BMI groups, with the obese group being the youngest (50.0 ± 12.4 years) and the underweight group the oldest (54.6 ± 14.2 years, p < 0.001). WC, VFA, and SFA all increased progressively with higher BMI (p < 0.001 for all), indicating greater abdominal fat accumulation among heavier individuals. However, HbA1c levels did not differ significantly across BMI categories (p = 0.279) (Table 2).

Main Outcomes

Linear regression analysis assessing the effects of BMI, WC, and VFA on HbA1c levels revealed no statistically significant associations. The β coefficients for BMI (−0.0029, 95% CI: −0.0243 to 0.0185, p = 0.79), WC (−0.0037, 95% CI: −0.012 to 0.0047, p = 0.38), and VFA (−0.0012, 95% CI: −0.0032 to 8 × 10^{-4}, p = 0.24) all indicated non-significant relationships with HbA1c (Table 3). These results suggest that although BMI, WC, and VFA are interrelated and correlate with other health parameters, they may not directly influence HbA1c levels in this study population.

Table 1 Baseline Characteristics When Grouped by HbA1c

Variables	HbA1c			P
	Total (n = 3898)	< 7.0 (n = 1022)	≥ 7.0 (n = 2876)	
Gender, n (%)				0.398
Males	2476 (63.5)	638 (62.4)	1838 (63.9)	
Females	1422 (36.5)	384 (37.6)	1038 (36.1)	
Age (years)	53.2 ± 11.4	53.9 ± 11.7	52.9 ± 11.3	0.017
BMI (kg/m^2)	25.3 ± 3.6	25.1 ± 3.5	25.4 ± 3.6	0.037
WC (cm)	88.7 ± 9.3	88.1 ± 8.8	88.9 ± 9.5	0.021
VFA (cm^2)	87.4 ± 38.7	85.1 ± 36.6	88.2 ± 39.4	0.029
SFA (cm^2)	175.6 ± 61.0	173.8 ± 57.9	176.3 ± 62.0	0.259

Abbreviations: BMI body mass index, WC waist circumference, VFA visceral fat area, SFA subcutaneous fat area.

Table 2 Baseline Characteristics When Grouped by BMI

Variables	BMI (kg/m^2)				P
	underweight (n = 71)	normal weight (n = 1374)	overweight (n = 1687)	obesity (n = 766)	
Gender, n (%)					< 0.001
Males	31 (43.7)	801 (58.3)	1155 (68.5)	489 (63.8)	
Females	40 (56.3)	573 (41.7)	532 (31.5)	277 (36.2)	
Age (years)	54.6 ± 14.2	54.7 ± 10.8	53.3 ± 10.9	50.0 ± 12.4	< 0.001
WC (cm)	71.3 ± 6.7	81.6 ± 6.4	90.1 ± 5.5	99.6 ± 7.3	< 0.001
VFA (cm^2)	19.3 ± 18.6	61.2 ± 26.9	91.8 ± 26.7	130.2 ± 35.0	< 0.001
SFA (cm^2)	73.1 ± 20.5	130.9 ± 33.0	180.9 ± 34.7	252.7 ± 61.2	< 0.001
HbA1C	9.5 ± 2.9	9.0 ± 2.6	9.0 ± 2.3	9.0 ± 2.5	0.279

Abbreviations: BMI body mass index, WC waist circumference, VFA visceral fat area, SFA subcutaneous fat area.

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Table 3 Liner Regression Analysis for HbA1c

	β (95% CI)	P
BMI	−0.0029 (−0.0243,0.0185)	0.79
WC	−0.0037 (−0.012,0.0047)	0.38
VFA	−0.0012 (−0.0032,8e-04)	0.24

Abbreviations: BMI body mass index, WC waist circumference, VFA visceral fat area.

Correlation analysis demonstrated no significant associations between HbA1c and several anthropometric parameters (Figure 1).

Discussion

In this study, although BMI, WC, and VFA were significantly correlated in patients with T2DM, linear regression analysis revealed no significant associations between these indexes and HbA1c levels. These findings suggest that BMI, WC, and VFA may not be primary factors directly influencing HbA1c control in patients with T2DM.

The traditional view posits that obesity exacerbates hyperglycemia through insulin resistance, leading to increased HbA1c levels.[10–12] However, this study did not observe a direct statistical relationship along this pathway. Previous research has indicated that, in both humans and mice, obesity is associated with insulin resistance, dyslipidemia, and T2DM.[13] Additionally, a cross-sectional study of nationally representative data from 685,616 adults demonstrated that increasing BMI is associated with a higher risk of T2DM.[14] However, these studies focused on healthy individuals rather than patients with T2DM. A follow-up study of patients with T2DM on a moderately low-carbohydrate diet found that reductions in HbA1c were not related to baseline BMI.[15] Similarly, a study of individuals with type 1 diabetes reported no association between BMI and HbA1c levels.[16]

All participants in this study were diagnosed with T2DM, and most had received varying degrees of therapy prior to the study. This characteristic may obscure the original biological relationship between obesity and blood glucose. Hypoglycemic medications can directly improve glycemic control through mechanisms independent of body weight. For example, metformin lowers blood glucose by inhibiting hepatic glucose production and enhancing insulin sensitivity,[17] while SGLT-2 inhibitors reduce glucose load by promoting urinary glucose excretion,[18] both effects being independent of body weight changes.

Pharmacological interventions may also alter the natural relationship between obesity and blood glucose. Sulfonylureas, for instance, lower blood glucose by stimulating insulin secretion but may simultaneously promote fat synthesis and weight gain, creating a complex feedback loop of "treatment–weight–blood glucose."[19,20] Although GLP-1 receptor agonists reduce both weight and blood glucose,[21] their effects may mask the original influence of obesity on glycemic control in untreated individuals. Furthermore, lifestyle modifications, such as dietary changes and increased physical activity, may confound the evaluation of the relationship between obesity and blood glucose. For example, some patients may voluntarily lose weight after diagnosis, resulting in current weight measurements that do not accurately reflect metabolic status during the early stages of disease.

Although this study provides valuable insights into the relationship between BMI, WC, VFA, and HbA1c in patients with T2DM, several limitations exist in the research design. First, this study employed a cross-sectional design, which can only capture associations at a single time point and cannot clarify causal direction or temporal relationships between variables. Future studies should aim to verify causal relationships through prospective cohort studies or Mendelian randomization analyses. Second, due to the constraints of a retrospective analysis, this study did not collect key confounding factors, including participants' dietary patterns, exercise frequency, and types and doses of hypoglycemic medications, which may introduce residual bias in evaluating the pathway linking obesity, metabolic indicators, and glycemic control. Finally, as a single-center study, the limited diversity of the sample may restrict the generalizability of the findings. To more

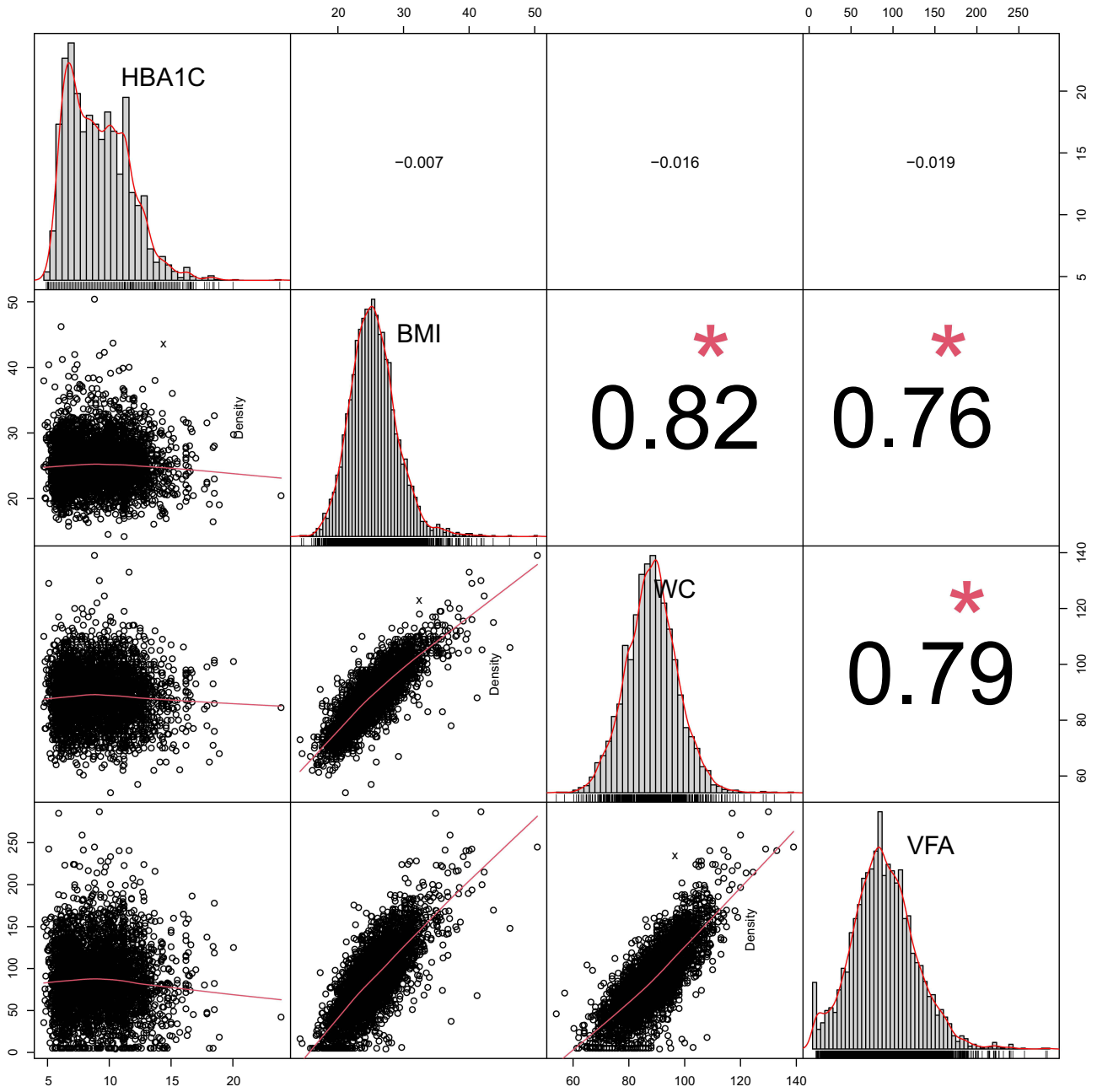

Figure 1 Correlation coefficients between the varies. *P values <0.05.

comprehensively examine the dynamic relationships between metabolic indexes and glycemic control, future research should incorporate multi-center, large-sample, longitudinal designs with strict control of confounding variables.

Conclusion

No significant correlation was observed between BMI and HbA1c levels in patients with T2DM, nor between WC and VFA. Targeting obesity indices alone may be insufficient for optimal glycemic control in T2DM and should be complemented by regular blood glucose monitoring, pharmacological treatment, and comprehensive lifestyle interventions. Patients with T2DM are encouraged to engage in daily self-monitoring of blood glucose and to communicate promptly with their healthcare providers to adjust treatment plans according to fluctuations in glucose levels, thereby improving overall disease management.

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Data Sharing Statement

The datasets generated and/or analyzed during the current study are not publicly available due to privacy concerns, but are available from the corresponding author.

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Author Contributions

Conceptualization, Pei Gang; formal analysis, Jianfeng Zhu, Bing Zhang; methodology, Yanxiao Zhao, Xiaowei Zhao; writing—original draft, Pei Gang, Jianfeng Zhu, Bing Zhang, Yanxiao Zhao, Xiaowei Zhao; data curation, Beibei Luo; writing–review and editing, Beibei Luo. All authors gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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