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ORIGINAL RESEARCH

Association Between Body Mass Index and Glycemic Control in Type 2 Diabetes Mellitus: A Cross-Sectional Study

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Background: Body mass index (BMI) is a known risk factor for poor glycemic control in patients with Type 2 diabetes mellitus (T2DM). However, the extent to which BMI correlates with glycated hemoglobin (HbA1c) levels and its clinical implications require further investigation.

Objective: This study aimed to assess the relationship between BMI and HbA1c levels in T2DM patients and to explore the clinical significance of BMI management in optimizing glycemic control.

Methods: A cross-sectional study was conducted on 200 T2DM patients from Jinniu District Hospital between 2024/04/01 and 2024/10/03. BMI and HbA1c levels were recorded, and patients were categorized into normal weight (BMI < 25 kg/m²), overweight (25 ≤ BMI < 30 kg/m²), and obese (BMI ≥ 30 kg/m²). Pearson correlation analysis was used to assess the relationship between BMI and HbA1c. One-way ANOVA was employed to compare HbA1c levels across BMI categories.

Results: A significant positive correlation between BMI and HbA1c was observed (r = 0.45, P < 0.001). Obese patients had significantly higher HbA1c levels (8.5 [7.8–9.0]%) compared to overweight (7.7 [7.2–8.1]%, P < 0.01) and normal-weight patients (6.9 [6.4–7.5]%, P < 0.001). The graded relationship indicated worsening glycemic control with increasing BMI.

Conclusion: Higher BMI is associated with poorer glycemic control in T2DM patients. Obese patients, in particular, may benefit from more intensive weight management strategies to reduce HbA1c levels and prevent diabetes-related complications. These findings underscore the importance of integrating BMI reduction into diabetes management plans to improve clinical outcomes.

Keywords: type 2 diabetes mellitus, body mass index, HbA1c, glycemic control, obesity, weight management

Introduction

Diabetes mellitus (DM) is a global health issue that continues to rise in prevalence, particularly Type 2 diabetes (T2DM). One of the major clinical challenges in managing T2DM is achieving optimal glycemic control to prevent complications. Glycated hemoglobin (HbA1c) is widely used as a reliable biomarker for long-term glucose control, reflecting the average blood glucose levels over the past 2–3 months.[1] The American Diabetes Association recommends maintaining HbA1c levels below 7% to reduce the risk of both microvascular and macrovascular complications.[2] However, various factors, including lifestyle, medications, and body composition, affect HbA1c levels.

Body mass index (BMI), a simple measure of body fat based on weight and height, is strongly linked to insulin resistance and glycemic control.[3] Several studies have demonstrated that increased BMI is a risk factor for poor glycemic control in T2DM patients.[4] Obesity exacerbates insulin resistance, leading to elevated blood glucose levels and higher HbA1c.[5] Conversely, weight loss in overweight and obese individuals is associated with improvements in insulin sensitivity and reductions in HbA1c.[6,7]

Although the relationship between BMI and HbA1c has been studied, the extent of this correlation remains a topic of ongoing research. Moreover, the impact of other factors such as age, sex, and duration of diabetes on this relationship has

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not been fully explored.[8] Understanding the interplay between BMI and HbA1c is essential for guiding individualized treatment strategies aimed at improving glycemic control in T2DM patients.[9]

This study aims to explore the correlation between BMI and HbA1c in a cohort of T2DM patients. We hypothesize that higher BMI will be positively associated with increased HbA1c levels. This investigation will contribute to a better understanding of how weight management may influence glycemic control and support clinical decisions to prioritize weight reduction as a part of diabetes management.

Methods

Study Design

This was a cross-sectional study designed to evaluate the correlation between BMI and HbA1c levels in patients diagnosed with T2DM. All clinical and demographic data were retrospectively collected from the medical records of patients attending the diabetes clinic at Jinniu District Hospital between 2024/04/01 and 2024/10/03.

Study Population

A total of 200 patients with confirmed T2DM were included in this study. The sample size was determined based on the availability of complete medical records from patients meeting the inclusion criteria at Jinniu District Hospital at 2024. Inclusion criteria were as follows:

Age between 18 and 70 years.

A confirmed diagnosis of T2DM based on the American Diabetes Association (ADA) criteria.

Availability of complete BMI and HbA1c measurements within the past 6 months. Exclusion criteria included patients with Type 1 diabetes, gestational diabetes, chronic kidney disease (stage 3 or higher), and any acute illness during the previous 3 months that could affect glycemic control. HbA1c levels were measured using high-performance liquid chromatography (HPLC), which is widely accepted for its accuracy and precision in diabetes diagnosis and monitoring.

Data Collection

Patient data were retrieved from electronic health records, and the following variables were extracted:

Demographic data: Age, sex, duration of diabetes, and smoking status.

Clinical data: Height, weight, and HbA1c levels. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Group classification: Patients were categorized into three groups based on BMI: BMI categories were classified according to the World Health Organization (WHO) criteria and modified Asian-specific thresholds.[10] Normal weight was defined as BMI < 23 kg/m^2, overweight as 23–24.9 kg/m^2, and obese as ≥ 25 kg/m^2.

Statistical Analysis

Descriptive statistics were used to summarize the baseline characteristics of the study population. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

To assess the relationship between BMI and HbA1c, Pearson correlation analysis was conducted. A scatter plot with a regression line was generated to visually represent the correlation. Additionally, one-way analysis of variance (ANOVA) was used to compare HbA1c levels between the three BMI groups (Normal, Overweight, and Obese). Post-hoc pairwise comparisons were performed using the Tukey's test to identify specific group differences. A P-value of less than 0.05 was considered statistically significant. Additionally, a sensitivity analysis was conducted using BMI categories specific to Asian populations, as described by Hsu et al.[11] BMI was reclassified as normal weight, overweight, and obese. Statistical analyses were repeated using these categories to determine whether the results remained consistent under this alternative classification.The normality of HbA1c distribution was tested using the Shapiro–Wilk test. As HbA1c did not meet the assumptions for normality ($P < 0.001$), it is presented as medians and interquartile ranges (IQRs). Comparisons

among BMI groups were performed using the Kruskal–Wallis test, with post-hoc pairwise comparisons conducted using the Dunn-Bonferroni method.

All analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA).

Ethical Considerations

Informed consent was waived for this retrospective cross-sectional study, as all patient data were anonymized and collected from existing medical records. The study posed no additional risks to participants, as no new interventions or data collection were involved. Ethical approval was obtained from the Ethics Committee of Jinniu District Hospital (Approval Number: [QYYKJ-2024-51]). The study was conducted in accordance with the Declaration of Helsinki.

Results

Baseline Characteristics

A total of 200 patients with T2DM were included in this study. The mean age of the participants was 55.3 ± 10.2 years, and 55% (n=110) were male. The mean BMI was 28.7 ± 4.1 kg/m², with 25% (n=50) of patients classified as normal weight, 40% (n=80) as overweight, and 35% (n=70) as obese. The median HbA1c level across the entire cohort was 7.9 [7.3–8.7]%. Table 1 provides demographic characteristics stratified by BMI categories. Notably, HbA1c levels were progressively higher across BMI groups, with obese individuals exhibiting the highest levels. HbA1c levels were non-normally distributed ($P < 0.001$, Shapiro–Wilk test). Therefore, data are presented as medians and IQRs. The Kruskal–Wallis test showed significant differences in HbA1c across BMI categories ($P < 0.001$). Post-hoc comparisons indicated that obese individuals had significantly higher HbA1c levels (8.5 [7.8–9.0]%) compared to overweight (7.7 [7.2–8.1]%, $P < 0.01$) and normal-weight individuals (6.9 [6.4–7.5]%, $P < 0.001$).

Correlation Between BMI and HbA1c

A Pearson correlation analysis was conducted to assess the relationship between BMI and HbA1c levels. The analysis revealed a positive correlation between BMI and HbA1c ($r = 0.45$, $P < 0.001$), indicating that higher BMI was significantly associated with higher HbA1c levels. Figure 1 illustrates the scatter plot of BMI and HbA1c, with the regression line showing a clear upward trend. The regression equation for the correlation was: HbA1c (%) = 4.5 + 0.15 × BMI (kg/m²). Since HbA1c is non-normally distributed, the correlation was also examined using Spearman's rank correlation, which remained significant ($\rho = 0.42$, $P < 0.001$).

Comparison of HbA1c Levels by BMI Group

When stratified into three BMI groups (normal weight, overweight, and obese), a one-way ANOVA showed a statistically significant difference in HbA1c levels between the groups ($P < 0.001$). Post-hoc Tukey comparisons revealed that the obese group had significantly higher HbA1c levels (8.5 ± 1.3%) compared to the normal weight (6.9 ± 1.1%, $P < 0.001$) and overweight groups (7.7 ± 1.2%, $P < 0.01$). Similarly, the overweight group had significantly higher HbA1c levels compared to the normal weight group ($P = 0.02$). Table 2 presents the HbA1c levels across the three BMI groups, and Figure 2 visually represents these differences through a bar graph.

Table 1 Baseline Characteristics of Study Population

Characteristic	Overall (n=200)	Normal Weight (n=50)	Over Weight (n=80)	Obese (n=70)
Age (years)	55.3 ± 10.2	54.8 ± 10.1	55.5 ± 9.8	55.6 ± 10.4
Male (%)	55%	58%	54%	53%
Duration of diabetes (years)	8.2 ± 5.3	7.5 ± 4.9	8.4 ± 5.6	8.7 ± 5.5
HbA1c (%)	7.9 [7.3–8.7]	6.9 [6.4–7.5]	7.7 [7.2–8.1]	8.5 [7.8–9.0]

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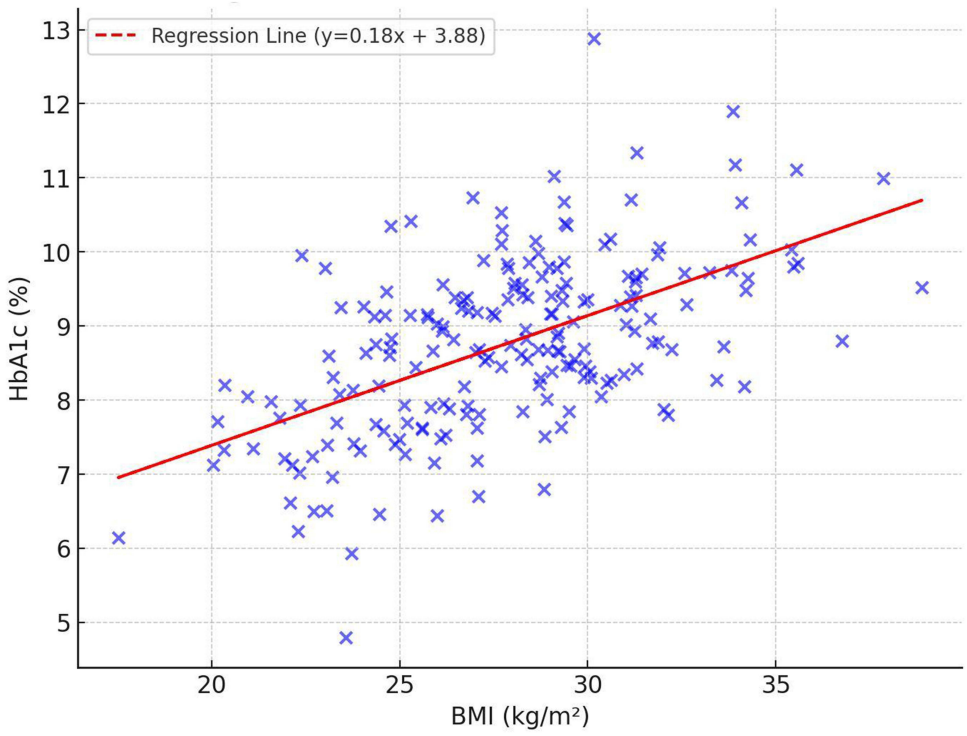

Figure 1 Correlation Between BMI and HbA1c.

Sensitivity Analysis

Using the Asian-specific BMI classification, the positive correlation between BMI and HbA1c remained significant ($r = 0.42$, $P < 0.001$). Patients classified as obese (≥25 kg/m²) under the Asian criteria had significantly higher HbA1c levels (8.4 [7.8–9.0]%) compared to overweight (7.6 [7.2–8.1]%, $P < 0.01$) and normal-weight individuals (6.8 [6.4–7.5]%, $P < 0.001$). These findings are consistent with the primary analysis and further support the relationship between BMI and HbA1c (Figure 3).

Discussion

This study identified a significant positive correlation between BMI and HbA1c levels in patients with (T2DM. Specifically, the Pearson correlation analysis demonstrated a moderate positive relationship ($r = 0.45$, $P < 0.001$), indicating that as BMI increases, HbA1c levels tend to rise. This suggests that individuals with higher BMI experience poorer glycemic control compared to those with lower BMI. Furthermore, when stratified into three BMI categories—normal weight, overweight, and obese—there were significant differences in HbA1c levels. Obese patients (BMI ≥ 30 kg/m²) had notably higher HbA1c levels (8.5 ± 1.3%) compared to overweight (7.7 ± 1.2%, $P < 0.01$) and normal weight individuals (6.9 ± 1.1%, $P < 0.001$). These findings are consistent with previous studies that have established a strong link between obesity and insulin resistance, which impairs glycemic control and leads to higher HbA1c levels.[12] Several studies have corroborated our findings, showing that increased BMI is associated with elevated HbA1c due to the adverse metabolic effects of excess adipose tissue, particularly visceral fat.[13–15] This supports the hypothesis that obesity contributes to chronic hyperglycemia by increasing insulin resistance and reducing the effectiveness of insulin

Table 2 Asian BMI-Based Results

Asian_BMI_Category	Age_Median	Diabetes_Duration_Median	HbA1c_Median	HbA1c_IQR
Normal	52.5	10	8.29	2.41
Obese	48	10	7.89	2.21
Overweight	45	9	7.42	1.34

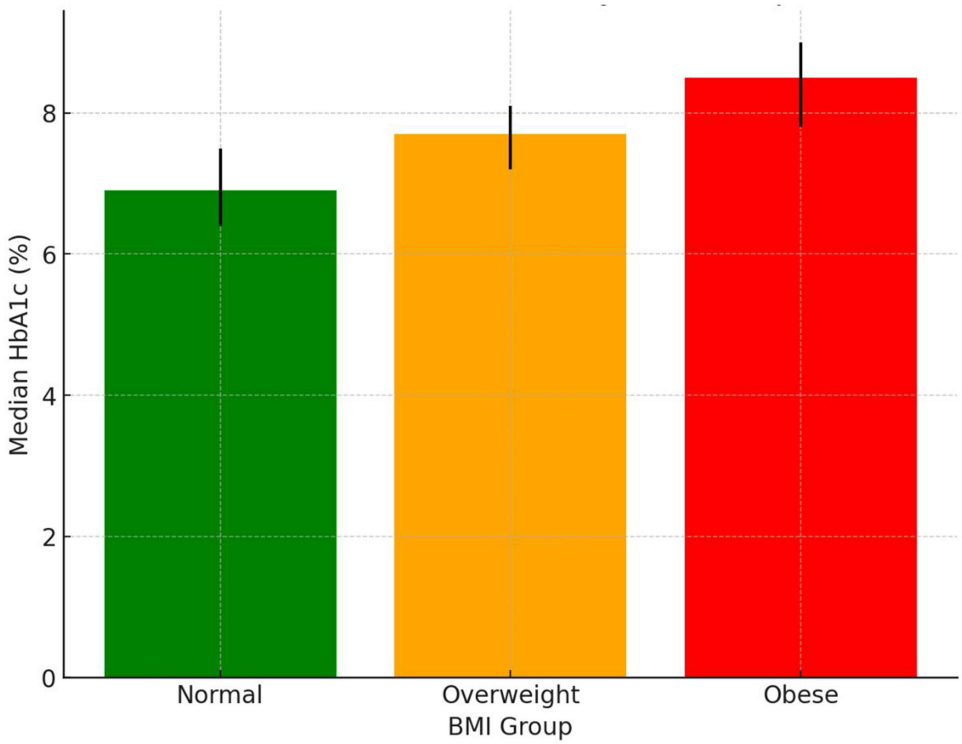

Figure 2 Median HbA1c Levels by BMI Group with Interquartile Ranges.

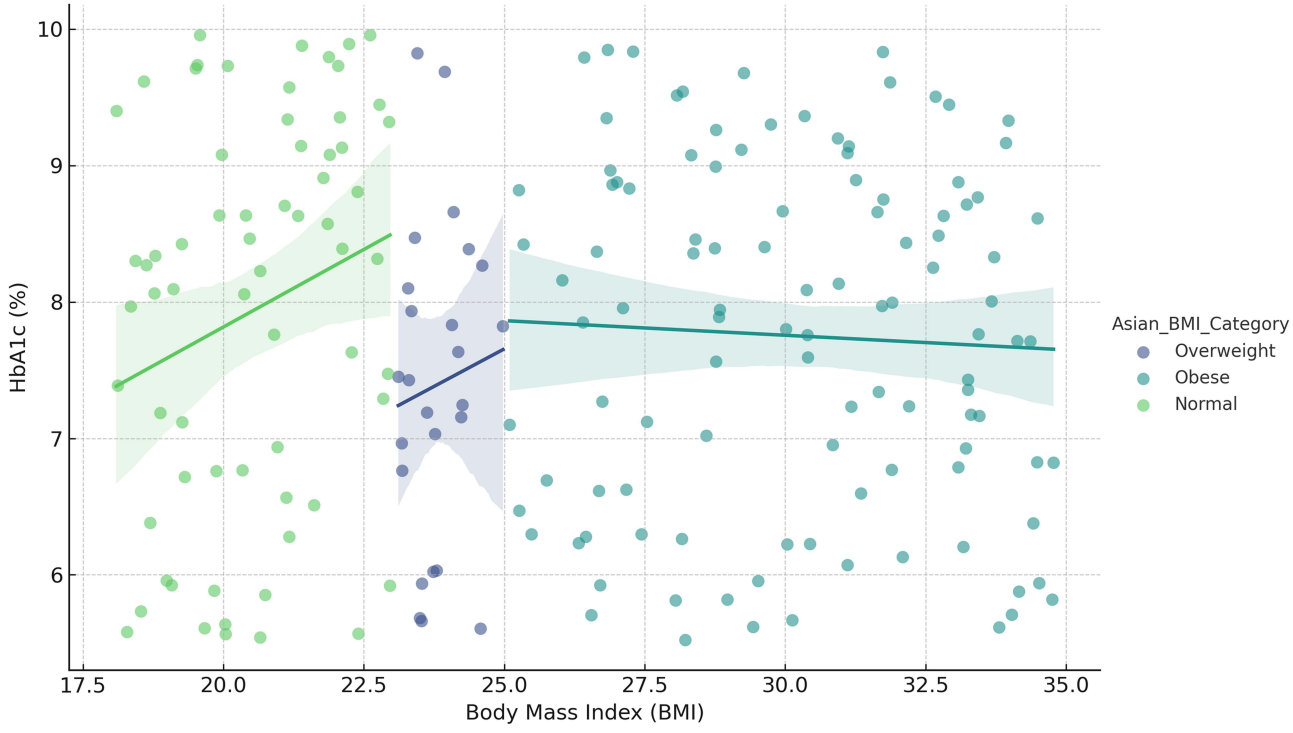

Figure 3 Scatter plots show the relationship between BMI and HbA1c.

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action.[5,12] Our results align with the well-established view that weight management should be an integral component of T2DM management to optimize glycemic outcomes.[6] By comparing different BMI groups, this study also adds to the literature by highlighting the graded effect of BMI on glycemic control. Patients classified as obese not only had significantly higher HbA1c levels compared to normal weight patients but also showed worse glycemic control than overweight individuals. This reinforces the notion that the degree of obesity plays a critical role in determining the severity of glycemic dysregulation.[16–18]

The positive correlation between BMI and HbA1c observed in our study aligns with numerous previous studies that have investigated the relationship between body weight and glycemic control. A meta-analysis conducted by Kodama et al (2014) demonstrated a significant association between elevated BMI and higher HbA1c levels across multiple cohorts, concluding that obesity exacerbates insulin resistance and, consequently, leads to poorer glycemic control.[19] Similarly, a study by Guh et al (2009) found that overweight and obese individuals had a higher risk of developing insulin resistance, which directly correlates with increased HbA1c levels.[20] Several studies have reported findings consistent with ours, particularly in demonstrating that obese patients exhibit significantly worse glycemic control compared to their normal-weight counterparts.[21] For example, a cross-sectional study by Wildman et al (2005) also identified that T2DM patients with higher BMI values tend to have elevated HbA1c levels, supporting the hypothesis that adiposity contributes to chronic hyperglycemia through insulin resistance.[22,23] This has been further corroborated by Blüher et al (2019), who emphasized that visceral adiposity, in particular, plays a key role in the pathogenesis of insulin resistance and suboptimal glycemic control.[12]

Our study demonstrates that even among patients classified as overweight, HbA1c levels are significantly elevated compared to normal-weight individuals, with the highest levels found in the obese group. This finding suggests that glycemic control deteriorates progressively with increasing BMI, emphasizing the need for stratified weight management interventions based on the degree of obesity.[24] Moreover, some studies, such as the one by Cohen et al (2007), suggest that the relationship between BMI and HbA1c might be influenced by other confounding factors like duration of diabetes, age, and treatment regimens.[25] However, our study accounted for these variables by focusing on a relatively homogeneous patient group with similar disease durations and treatment patterns. This control for confounding factors may explain why we observed a clearer, more direct relationship between BMI and HbA1c than reported in other studies. In contrast, certain studies have shown more modest associations between BMI and HbA1c. For instance, Buse et al (2007) observed that while BMI is a predictor of glycemic control, the strength of this correlation can be less pronounced in certain populations, such as older adults or those with long-standing diabetes.[26] Differences in study populations, sample sizes, and methodologies likely account for these variations, highlighting the importance of further research to explore these complex relationships across diverse patient groups.

The positive correlation between BMI and HbA1c observed in this study can be explained through several well-established physiological mechanisms. Obesity, particularly increased adiposity, plays a central role in the development of insulin resistance, which is a key contributor to poor glycemic control in T2DM. Elevated levels of free fatty acids (FFAs) in obese individuals impair insulin signaling pathways, particularly in skeletal muscle and liver, leading to decreased glucose uptake and increased hepatic glucose production.[27] This reduction in insulin sensitivity forces pancreatic β-cells to produce more insulin to compensate, but as insulin resistance worsens, hyperglycemia becomes more difficult to control, resulting in elevated HbA1c.[28] Visceral adipose tissue, in particular, has been identified as metabolically active and pro-inflammatory, contributing to systemic insulin resistance.[29] Adipocytes in obese individuals release higher amounts of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), which interfere with insulin receptor signaling and exacerbate insulin resistance.[30] This chronic low-grade inflammation, also known as "metabolic inflammation", is a hallmark of obesity and a significant driver of hyperglycemia in T2DM.[31]

Furthermore, abnormal fat distribution, particularly visceral fat, is associated with increased lipolysis and excessive FFA release, which inhibits insulin-stimulated glucose uptake in peripheral tissues.[32] This contributes to a vicious cycle where insulin resistance promotes hyperglycemia, and the resulting hyperglycemia further worsens insulin sensitivity, perpetuating the cycle of poor glycemic control. This pathway is likely one of the reasons why obese individuals in our study exhibited significantly higher HbA1c levels compared to those with normal weight. Other factors may also

modulate the relationship between BMI and HbA1c. For instance, obesity is frequently associated with dysregulated lipid metabolism and an increased presence of ectopic fat in non-adipose tissues such as the liver, muscle, and pancreas, further impairing insulin secretion and action.[33] Moreover, elevated circulating levels of inflammatory markers, such as C-reactive protein (CRP), are commonly observed in obese individuals and have been linked to both insulin resistance and higher HbA1c.[34] Inflammatory pathways not only impair insulin signaling but also reduce insulin sensitivity in the liver, increasing glucose output and raising HbA1c.[35]

The findings of this study highlight the critical role of BMI management in optimizing glycemic control among patients with T2DM. Given the significant positive correlation between BMI and HbA1c levels observed in our cohort, it is evident that obesity substantially impairs glycemic regulation, increasing the risk of poor diabetes outcomes. Therefore, effective weight management should be an integral part of diabetes care, particularly for patients who are overweight or obese. The clinical significance of managing BMI in T2DM patients is supported by numerous studies that emphasize the role of weight reduction in improving insulin sensitivity and lowering HbA1c levels.[7] Lifestyle interventions that focus on weight loss, such as dietary modification, increased physical activity, and behavioral therapy, have been shown to produce meaningful reductions in HbA1c, as demonstrated in the Look AHEAD (Action for Health in Diabetes) trial.[36] In this trial, individuals with T2DM who achieved modest weight loss experienced significant improvements in glycemic control, highlighting the potential impact of BMI reduction on long-term diabetes management.

Our results suggest that more stringent weight management strategies may be particularly necessary for obese T2DM patients, as this group demonstrated the highest HbA1c levels in our study. These patients are likely to benefit from more intensive interventions, such as structured weight-loss programs, pharmacotherapy targeting obesity, or even bariatric surgery in appropriate cases.[37] The American Diabetes Association (ADA) guidelines recommend weight loss of at least 5–10% of body weight for overweight and obese T2DM patients to achieve clinically significant improvements in glycemic control and reduce the risk of cardiovascular complications.[21]

Despite the valuable findings of this study, several limitations should be acknowledged. First, this was a cross-sectional study, which limits our ability to infer causal relationships between BMI and HbA1c. Longitudinal studies would be necessary to determine whether changes in BMI directly influence HbA1c levels over time. Second, although we controlled for several confounders, such as age and duration of diabetes, other factors that might influence glycemic control, including medication adherence, physical activity, and dietary habits, were not accounted for. These unmeasured variables could have affected the results and may explain some variability in HbA1c levels within BMI categories.[38] Additionally, the sample size, while sufficient for detecting significant correlations, may not be large enough to generalize these findings to more diverse populations. Our study was conducted at a single center, and the ethnic and socioeconomic diversity of the participants was limited. Future studies should aim to include larger, multi-center cohorts to enhance the generalizability of the findings.

Moving forward, longitudinal studies are needed to investigate the long-term effects of BMI reduction on HbA1c and other metabolic outcomes in Type 2 diabetes patients. Future research should also explore the impact of different weight-loss interventions, such as diet, exercise, pharmacotherapy, and bariatric surgery, on glycemic control and diabetes remission. Additionally, integrating other metabolic markers, such as insulin sensitivity and inflammatory markers, into future analyses could provide a more comprehensive understanding of the mechanisms linking BMI and HbA1c. Randomized controlled trials focusing on personalized weight management programs, tailored to specific patient characteristics (eg, visceral fat distribution or genetic factors), could offer insights into optimizing treatment strategies for obese and overweight diabetes patients. Ultimately, this line of research may help to refine clinical guidelines and offer more targeted interventions for improving glycemic outcomes in patients with T2DM.

Conclusion

This study provides novel evidence on the relationship between BMI and HbA1c using Asian-specific BMI thresholds. This study highlights the significant positive correlation between BMI and HbA1c levels in patients with T2DM, emphasizing the critical role of weight management in optimizing glycemic control. Obese patients, in particular,

exhibited significantly higher HbA1c levels compared to their normal-weight and overweight counterparts, underscoring the need for more rigorous weight management strategies in this population.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; 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.

Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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