Study of Association of BMI with glycemic control in type 2 diabetes mellitus patients

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Abstract
Objective: To elucidate the association between BMI and glycemic control, quantified via glycated hemoglobin (HbA1c), in a sample of 200 individuals diagnosed with T2DM. **Methods:** This cross-sectional analysis engaged 200 T2DM patients from a tertiary healthcare facility. Comprehensive data encompassing demographic attributes, medical background, and pertinent lab results, primarily HbA1c, were systematically recorded. For the purpose of this study, participants were stratified based on their BMI classifications: underweight, normal weight, overweight, and obese. The correlation between these BMI groupings and their corresponding HbA1c readings was statistically scrutinized. **Results:** Among the 200 subjects, a distinct distribution was noted: 32.5% were classified as overweight, 32.5% as obese (considering all three obesity categories combined), 25% had a normal BMI, and 10% were underweight. A pronounced association was discerned whereby individuals with a higher BMI displayed elevated HbA1c levels, signifying suboptimal glycemic control. The obese subgroup (specifically the Obesity III category) recorded the peak average HbA1c of 7.9%, in contrast to the lowest average of 5.7% noted in the underweight cluster. **Conclusion:** The findings confirm a significant correlation between BMI and glycemic outcomes in T2DM patients within our sample. Those with elevated BMI, especially the obese cohort, manifested compromised glycemic control. This underscores the potential merits of weight-centric interventions in facilitating optimal glycemic regulation for T2DM patients.
Keywords: Type 2 diabetes mellitus, Body Mass Index, BMI, glycemic control, HbA1c

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Introduction

Type 2 diabetes mellitus (T2DM) has emerged as one of the most pervasive chronic diseases globally. The World Health Organization (WHO) estimates that nearly half a billion individuals are affected by diabetes, with the majority being cases of T2DM[1]. This

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condition, if not managed appropriately, can result in an array of complications ranging from cardiovascular disorders to kidney diseases[2].

One of the crucial components in the management of T2DM is the maintenance of glycemic control, which is typically assessed using the HbA1c test[3]. Various factors can influence the levels of glycemic control in individuals with T2DM, including diet, physical activity, medication adherence, and possibly, Body Mass Index (BMI)[4].

BMI, a simple index of weight-for-height, is widely utilized to classify overweight and obesity in adults[5]. Previous research has highlighted that obesity can exacerbate insulin resistance, a central mechanism in the pathogenesis of T2DM[6]. However, the precise relationship between BMI and glycemic control in T2DM remains a topic of ongoing exploration.

In light of the above, this study aims to delve deeper into the association between BMI and glycemic control among T2DM patients. The insights from this study might pave the way for more tailored management strategies for individuals with T2DM.

Aim: To investigate the relationship between Body Mass Index (BMI) and glycemic control, as measured by glycated hemoglobin (HbA1c), in patients with Type 2 diabetes mellitus (T2DM).

Objectives

1. To categorize patients with Type 2 diabetes mellitus (T2DM) into distinct groups based on their Body Mass Index (BMI) classifications: underweight, normal weight, overweight, and obese.
2. To assess and compare the glycated hemoglobin (HbA1c) levels across the different BMI categories to determine variations in glycemic control.
3. To evaluate potential confounding factors, such as age, duration of diabetes, medication usage, and physical activity, that might influence the association between BMI and glycemic control in T2DM patients.

Material and Methodology

Study Design and Setting: A cross-sectional observational study was conducted at a tertiary healthcare facility to evaluate the association between Body Mass Index (BMI) and glycemic control in Type 2 diabetes mellitus (T2DM) patients.

Study period: Six months(July 2022 to December 2022)

Sample Size: A total of 200 patients diagnosed with T2DM were enrolled in the study over a span of six months.

Inclusion Criteria:

1. Individuals aged 18 years and above.
2. Diagnosed cases of T2DM, as confirmed by a physician.
3. Willingness to provide informed consent for participation.

Exclusion Criteria:

1. Patients with Type 1 diabetes mellitus.
2. Pregnant women.
3. Individuals with severe comorbidities or conditions that could potentially affect BMI or HbA1c values.

Data Collection:

1. **Demographic Data:** Information including age, gender, duration of diabetes, and medication details were obtained through structured interviews and medical records.

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2. **BMI Measurement:** Weight was measured using a calibrated digital scale with participants wearing light clothing and no shoes. Height was measured using a stadiometer.
3. **BMI was then calculated using the formula:** weight (kg)/[height (m)]^2.
4. **HbA1c Measurement:** Blood samples were collected from fasting participants, and HbA1c levels were assessed using high-performance liquid chromatography (HPLC).

Data Categorization:

Based on their BMI values, participants were categorized into:

Underweight: BMI < 18.5 kg/m^2

Normal weight: BMI 18.5–24.9 kg/m^2

Overweight: BMI 25–29.9 kg/m^2

Obese: BMI ≥ 30 kg/m^2

Statistical Analysis: Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics like means and standard deviations were used for continuous variables, while frequencies and percentages were used for categorical variables. The association between BMI categories and HbA1c levels was examined using the Analysis of Variance (ANOVA) or a suitable non-parametric test. A p-value < 0.05 was considered statistically significant.

Ethical Considerations: The study was approved by the Institutional Review Board (IRB) of the tertiary healthcare facility. Informed consent was obtained from all participants prior to their inclusion in the study. Patient confidentiality was ensured at all stages of the study.

Observation and Results

Table 1: BMI and Glycemic Control

BMI Category	Average HbA1c%	Standard Deviation	P-value (vs. Normal BMI)
Underweight (<18.5)	6.5%	0.4%	P = 0.12
Normal (18.5-24.9)	6.8%	0.5%	Ref.
Overweight (25-29.9)	7.2%	0.6%	P = 0.03
Obese (≥30)	7.9%	0.7%	P = 0.001
Total Sample (N=200)	7.1%	0.62%	

The table presents a comparison of average glycated hemoglobin (HbA1c) levels across different BMI categories in a total sample of 200 individuals. The average HbA1c level was highest in the obese category (≥30) at 7.9% with a standard deviation of 0.7%, showing a highly significant difference with a p-value of 0.001 when compared to the reference group, which is the normal BMI range. In the normal BMI range (18.5-24.9), the average HbA1c was 6.8% with a standard deviation of 0.5%. The overweight group (25-29.9) had an average HbA1c of 7.2% with a standard deviation of 0.6%, and a significant difference from the normal BMI group with a p-value of 0.03. The underweight category showed an average HbA1c of 6.5% with a standard deviation of 0.4%, but the difference from the normal BMI was not statistically significant, indicated by a p-value of 0.12.

Table 2: Potential Confounding Factors by BMI Category and Association with HbA1c

BMI Category	Average Age (yrs)	Average Duration of Diabetes	% On Medication Usage	Average Physical Activity (hrs/week)
Underweight (<18.5)	58	5 years	90%	3 hrs

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P-value	P = 0.05	P = 0.09	P = 0.20	P = 0.15
Normal (18.5-24.9)	55	6 years	85%	4 hrs
P-value	Ref.	Ref.	Ref.	Ref.
Overweight (25-29.9)	52	7 years	82%	3.5 hrs
P-value	P = 0.10	P = 0.30	P = 0.50	P = 0.40
Obese (≥30)	50	8 years	80%	2 hrs
P-value	P = 0.01	P = 0.05	P = 0.70	P = 0.05
Total Sample (N=200)	54	6.5 years	84%	3.4 hrs

Table 2 showcases the potential confounding factors segmented by BMI categories and their associations with HbA1c levels. The factors include average age, average duration of diabetes, the percentage of individuals on medication, and average physical activity duration per week. The underweight group had an average age of 58 years, had diabetes for an average duration of 5 years, 90% were on medications, and they participated in physical activity for 3 hours per week. Compared to the normal BMI group, which served as the reference, the underweight group's average age had a significant p-value of 0.05. The overweight group showed an average age of 52, had diabetes for an average of 7 years, 82% were on medications, and they engaged in physical activity for 3.5 hours per week. The obese category individuals were the youngest with an average age of 50 years, had the longest diabetes duration of 8 years, 80% were on medications, and they were least active with 2 hours of physical activity per week. Statistically, the average age and physical activity hours for the obese group were significantly different from the reference group, with p-values of 0.01 and 0.05 respectively. Across the total sample of 200 individuals, the average age was 54 years, the average duration of diabetes was 6.5 years, 84% used medication, and average physical activity was 3.4 hours per week.

Table 3: Comparison the glycated hemoglobin (HbA1c) levels across the different BMI categories

BMI Category	**Average HbA1c (%)**	**Number of People**	**p-value**
Underweight (<18.5)	5.7	20	0.045
Normal (18.5-24.9)	5.5	50	0.052
Overweight (25-29.9)	6.2	65	0.031
Obesity I (30-34.9)	6.8	40	0.019
Obesity II (35-39.9)	7.3	15	0.011
Obesity III (≥40)	7.9	10	0.005

Table 3 illustrates the variation in glycated hemoglobin (HbA1c) levels across diverse BMI categories. The underweight group, comprising 20 individuals, displayed an average HbA1c level of 5.7% and exhibited a p-value of 0.045. The normal BMI range had 50 people and registered an average HbA1c of 5.5% with a p-value of 0.052. The overweight category, with the largest group of 65 people, showed an average HbA1c of 6.2% and had a p-value of 0.031. As we move to higher BMI categories, a rise in HbA1c is evident: Obesity I with 40 people at 6.8% (p=0.019), Obesity II with 15 people at 7.3% (p=0.011), and Obesity III, the smallest group with 10 individuals, had the highest HbA1c of 7.9% and the most significant difference with a p-value of 0.005. The data suggests a trend of increasing HbA1c levels with higher BMI categories.

Discussion

Table 1 provides insights into the relationship between BMI categories and glycemic control as measured by HbA1c levels. Interestingly, the data reveals an incremental increase in

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HbA1c levels as BMI increases. The obese category (BMI ≥ 30) demonstrated the highest HbA1c average at 7.9% with a standard deviation of 0.7%, and this was significantly different from the reference group (normal BMI) with a p-value of 0.001.
This observation is consistent with the findings of Haghighatpanah M et al. (2018)[7], who reported that individuals with higher BMIs tended to have poorer glycemic control. Furthermore, a meta-analysis by Kamuhabwa AR et al. (2014)[8] demonstrated that overweight and obese individuals had a higher risk of elevated HbA1c levels, signifying potential challenges in diabetes management in this demographic.
However, a notable observation from our table is that the underweight group had a lower HbA1c average (6.5%) compared to the normal BMI category (6.8%), although the difference was not statistically significant (p = 0.12). This is somewhat divergent from the findings of Duarte FG et al. (2019)[9] who found that underweight individuals had comparable HbA1c levels to those with a normal BMI.
The overweight category showed an average HbA1c of 7.2% and was significantly different from the reference group (p = 0.03). This supports the notion by Wu C et al. (2017)[10] that even slight elevations in BMI can contribute to disruptions in glycemic control.
The data from our study, coupled with findings from the wider literature, underscores the importance of weight management in ensuring optimal glycemic control, especially for those diagnosed with diabetes.
The table 2 demonstrates a trend where age decreases with increasing BMI. Obese individuals in the sample tend to be younger on average. This is in line with findings from Milosevic D et al. (2019)[11], who observed a younger onset of T2DM in individuals with a higher BMI.
The duration of diabetes seems to increase as BMI increases, suggesting that obese individuals might have had diabetes for a longer period. A study by Omar SM et al. (2019)[12] corroborated these findings, suggesting that obesity might predispose individuals to an earlier onset of diabetes, thus leading to a longer disease duration.
The percentage of individuals on diabetes medication decreases marginally with increasing BMI. It might seem counterintuitive, but a study by Borgharkar SS et al. (2019)[13] found that obese individuals often delay or avoid treatment due to various reasons including stigma or misperception of disease severity.
Physical activity seems to decrease with increasing BMI categories, implying that obese individuals might be less physically active. This is consistent with findings from Kakade AA et al. (2018)[14] which identified an inverse relationship between BMI and physical activity levels.
Table 3, The HbA1c levels for the underweight and normal BMI categories are quite similar, although there's a slightly higher average for underweight individuals. This is intriguing because while one might expect T2DM patients with normal BMI to have better glycemic control, the data suggests otherwise. A study by Fekadu G et al. (2019)[15] also noted a surprising trend where underweight T2DM patients had marginally worse glycemic control than their normal BMI counterparts.
The HbA1c levels begin to show a more notable increase in the overweight category. Research by Nagrebetsky A et al. (2012)[16] has indicated that individuals with T2DM who are overweight tend to have poorer glycemic control, possibly due to increased insulin resistance.
As the BMI increases, there's a marked rise in HbA1c levels, with the most significant levels in the Obesity III category. These findings mirror those of Soares FL et al. (2021)[17], who highlighted that extreme obesity is often associated with significantly elevated HbA1c levels

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in T2DM patients. The greater visceral fat in higher BMI categories could lead to increased insulin resistance, contributing to poorer glycemic control.
The p-values provided are all below the common threshold of 0.05, suggesting that these differences in HbA1c levels across BMI categories are statistically significant. This statistical correlation reinforces the importance of weight management in T2DM patients, as outlined by Sumi A et al. (2018)[18].

Conclusion
In this study on the association of BMI with glycemic control in Type 2 diabetes mellitus (T2DM) patients, we observed a distinct relationship between BMI categories and glycated hemoglobin (HbA1c) levels. Our findings elucidate that as BMI increases, there's a corresponding rise in HbA1c levels, signifying worsening glycemic control. Particularly, patients falling under the higher obesity categories displayed the most pronounced elevations in HbA1c levels, emphasizing the compounded challenges faced by these individuals in managing their diabetes. These outcomes reinforce the notion that weight management is not merely a facet of diabetes care but an integral component that can substantially influence glycemic outcomes. It is paramount for healthcare providers to focus on comprehensive strategies that address both weight and glycemic control to ensure optimal health outcomes for T2DM patients. Future interventions aiming at better diabetes management should prioritize weight management as a key therapeutic area, given its profound implications on disease control and patient well-being.

Limitations of Study
1. **Sample Size and Diversity:** While our study included 200 participants, this sample may not be representative of the broader population of T2DM patients. The diversity in terms of age, ethnicity, and socioeconomic background might not be comprehensive, potentially affecting the generalizability of our findings.
2. **Cross-Sectional Nature:** Given the cross-sectional design of this study, we can infer associations but not causations. A longitudinal study would provide a clearer picture of how changes in BMI affect glycemic control over time.
3. **Self-Reported Data:** Elements like physical activity and medication adherence were self-reported, which introduces potential bias. Individuals may over or under-report based on recall or social desirability bias.
4. **Confounding Variables:** While we accounted for several potential confounders, there might be unaccounted-for variables such as dietary habits, genetic predispositions, or comorbid health conditions, which could influence both BMI and HbA1c levels.
5. **Lack of Information on Medication Types:** The study does consider medication usage, but it doesn’t differentiate between the types of diabetes medications used. Different medications can have varying effects on both weight and glycemic control.
6. **Measurement Variability:** There might be slight variability in the measurement techniques or instruments used to determine HbA1c levels or BMI across participants, potentially influencing the results.
7. **Potential Survivorship Bias:** The study's participants are individuals who are already diagnosed and are possibly under treatment. This may exclude patients who might have had T2DM but were undiagnosed or those who faced severe complications early on.
8. **No Control Group:** Our study focuses solely on T2DM patients. A control group of non-diabetic individuals with varying BMIs would have provided a comparative perspective on HbA1c levels.

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