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Original Research Paper

Correlation between BMI and HbA1c in Type 2 diabetes patients in Surabaya

Zerlina Wina Elfaretta[1], Tri Hartini Yuliawati[2*], Hermawan Susanto[3*]
[1] Study Program of Medical, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[2] Department of Anatomy, Histology and Pharmacology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[3] Department of Internal Medicine, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
yulihisto@fk.unair.ac.id

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Abstract
Obesity is a well-established risk factor for Type 2 Diabetes Mellitus (DMT2), influencing disease severity and increasing the risk of complications. Regular HbA1c monitoring is a key component of effective diabetes management. Previous studies have indicated that individuals with higher Body Mass Index (BMI) tend to have elevated HbA1c levels, but this relationship has not been explored within the Surabaya population. This study aims to analyze the correlation between BMI and HbA1c levels in DMT2 patients at Dr. Soetomo Hospital in Surabaya. A cross-sectional, observational study was conducted to assess the correlation between BMI and HbA1c levels in DMT2 patients at the Endocrine Clinic of Dr. Soetomo Hospital. Data on weight, height, and HbA1c were collected and analyzed using the Spearman correlation test, with a p-value < 0.05 considered statistically significant. The study population consisted primarily of women aged over 40. Most patients were classified as obese (BMI ≥ 25 kg/m²), and the majority had uncontrolled HbA1c levels (>7%). A positive, linear correlation between BMI and HbA1c was found in the overall population ($r = 0.228$, $p = 0.022$) and in male patients ($r = 0.29$, $p = 0.043$). However, no significant correlation was observed in female patients ($r = 0.125$, $p = 0.377$). A significant positive correlation exists between BMI and HbA1c levels in DMT2 patients at Dr. Soetomo Hospital. Elevated BMI is associated with poorer glycemic control, particularly in male patients.

Keywords: Body Mass Index (BMI); Hemoglobin A1c; non-communicable disease; Type 2 diabetes mellitus

1. Introduction

Diabetes Mellitus (DM) is a prevalent metabolic disorder with a high global prevalence. The hallmark of DM is prolonged elevated blood glucose levels, which can lead to various symptoms such as polypagia (increased hunger), polydipsia (increased thirst), and polyuria (frequent urination) (Shouip, 2020). If left untreated, diabetes can cause severe acute complications like diabetic ketoacidosis and hyperosmolar non-ketotic coma, as well as serious long-term complications including heart disease, stroke, kidney failure, foot ulcers, and vision impairment (de Boer et al., 2017). Globally, the prevalence of diabetes is increasing rapidly, particularly in low- and middle-income countries. In Indonesia, diabetes affects 19.47 million people, and projections suggest this number will rise by 47% to reach 28.57 million by 2045 (Sun et al., 2022). Obesity, commonly measured by Body Mass Index (BMI), is a significant risk factor for DMT2. According to the WHO, BMI classifications for the Asia-Pacific region are as follows: underweight (<18.5), normal weight (18.5-22.9), overweight (23-24.9), and obesity (≥25) (Lim et al., 2021). Individuals with higher BMI are twice as likely to develop DMT2 compared to those with lower BMI (Adnan et al., 2013).

The underlying causes of diabetes involve either insufficient insulin production by the pancreas or the body's inability to effectively use the insulin it produces (Shouip, 2020). Diabetes is classified into several types: Type 1 Diabetes Mellitus (DMT1), where the body fails to produce adequate insulin; Type 2 Diabetes Mellitus (DMT2), where insulin resistance leads to weight gain and reduced physical activity; Gestational Diabetes Mellitus (GDM), which occurs during pregnancy; and other types (Kardika et al., 2015). According to the International Diabetes Federation (IDF), in 2015, 415 million people were living with diabetes, with 98% of those affected by DMT2 (Nuraisyah, 2018). Risk factors for DMT2 are classified into non-modifiable and modifiable categories. Non-modifiable risk factors include a family history of diabetes, age over 45 years, and a history of gestational diabetes. Modifiable risk factors, which can be addressed through lifestyle changes, include obesity, dyslipidemia, hypertension, and poor dietary habits. Despite this, many individuals fail to recognize the potential dangers of these risk factors, often leading to obesity, which is a major contributor to diabetes development. Obesity, which is defined as a BMI of ≥ 30 kg/m², is a significant risk factor for the development of DMT2 and is often associated with poor glycemic control. BMI is a commonly used measure to assess obesity, and it is known to correlate with body fat percentage and insulin resistance. Increased BMI is believed to exacerbate insulin resistance, which can contribute to elevated blood glucose levels, leading to higher HbA1c values. This relationship forms the basis for investigating the potential correlation between BMI and HbA1c levels in this population (Fatimah, 2015).

For patients with DMT2, long-term uncontrolled blood glucose levels contribute significantly to the severity of the disease. One effective measure for monitoring blood glucose control is HbA1c (Hemoglobin A1c), which provides an average blood glucose level over the past three months. This test is preferred over fasting blood glucose because it is less susceptible to short-term fluctuations (Nabila, 2018). Regular HbA1c testing is recommended for diabetes patients to evaluate therapeutic responses and assess the risk of long-term complications (Sherwani et al., 2016). Given the significant role of obesity in the development and progression of diabetes, this study aims to investigate the relationship between BMI and HbA1c levels in Type 2 Diabetes Mellitus patients.

Although numerous studies have explored the relationship between Body Mass Index (BMI) and HbA1c levels, most of this research has been conducted in diverse populations, and there is limited data specific to Surabaya or even Indonesia. Surabaya, as a rapidly urbanizing city with distinct lifestyle patterns, such as changes in dietary habits and physical activity levels, may exhibit unique factors influencing the BMI-HbA1c correlation. These regional variations in lifestyle, healthcare access, and cultural practices could potentially affect the management of Type 2 Diabetes Mellitus (DMT2) in this population. Therefore, this study aims to fill this gap by focusing on Surabaya, providing insights into how local factors may contribute to the relationship between BMI and HbA1c in DMT2 patients. Furthermore, while previous research shows a positive correlation between BMI and HbA1c, variations in findings based on sex and other demographic factors have not been consistently addressed. In particular, the lack of region-specific studies limits our understanding of how these factors interact in the Indonesian context. Therefore, this study aims to fill these gaps by analyzing the correlation between BMI and HbA1c levels specifically in Type 2 Diabetes Mellitus (DMT2) patients at Dr. Soetomo Hospital, Surabaya. By doing so, this research seeks to provide more accurate, localized data that could enhance diabetes management strategies and contribute to better understanding of risk factors in the Indonesian population.

2. Research Method

2.1.Research Design

This study employed an observational design with a cross-sectional approach, analyzing secondary data from medical records of male and female patients diagnosed with Type 2 Diabetes Mellitus (DMT2) at Dr. Soetomo Hospital, Surabaya. Data were collected between June 2022 and December 2023, offering valuable insights into the relationship between Body Mass Index (BMI) and HbA1c levels among these patients. Utilizing secondary data from medical records enabled an efficient assessment of patient characteristics, providing a broad and representative sample of the hospital's DMT2 population.

2.2.Population and Sample

The population of this study consisted of patients aged 21 years and older diagnosed with Type 2 Diabetes Mellitus (DMT2) and registered in the medical records database at Dr. Soetomo Hospital, Surabaya. This research employed a purposive sampling method, where the sample was selected based on the inclusion and exclusion criteria, utilizing medical record data from patients who met these criteria from June 2022 to December 2023. The study focused on patients whose records were complete and relevant to the research objectives, ensuring a representative sample for analysis.

2.3.Sampling Technique and Data Collection

The sample for this study was selected using the minimal sampling technique, with the minimum sample size determined using MedCalc v20.111 software for Windows. Secondary data were obtained from the medical records of Type 2 Diabetes Mellitus (DMT2) patients at Dr. Soetomo Hospital, Surabaya. The data collected included age, gender, Body Mass Index (BMI), and HbA1c levels. The sample comprised patients who had received treatment at Dr. Soetomo Hospital during the 2022 period and met the inclusion criteria of being diagnosed with Type 2 Diabetes Mellitus. Exclusion criteria included pregnant patients, patients with anemia, those with incomplete medical records, and patients with weight-related complications such as ascites.

2.4.Data Analysis

The collected data were analyzed using the Statistical Product and Service Solutions (SPSS) software. To examine the relationship between BMI and HbA1c levels, Pearson's correlation test was employed. The results were presented in tabular form, accompanied by detailed explanations. This analysis aimed to determine whether a significant correlation exists between BMI and HbA1c levels in patients with DMT2.

2.5.Ethical Approval

Ethical approval for the study was obtained from the Research Ethics Committee, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia, with the ethics number 2214/101/4/VI/2023.

3. Results and Discussion

3.1.Results

This study uses a population of Type 2 Diabetes Mellitus patients recorded in the Medical Records Installation of RSUD Dr. Soetomo Surabaya for the period January 2022 – Januari 2023. The result of the minimum sampling formula calculation was 19, but in this study, the researcher collected data from 101 samples that met the inclusion criteria of this study. The characteristics of the research sample can be distinguished based on categories of gender, age, Body Mass Index, HbA1c levels, and lipid profiles.

Table 1. Distribution of Subject Characteristics

Characteristics		Total	Percentage (%)
Gender	Male	49	48.5
	Female	52	51.5
	< 40	1	1
Age	≥ 40	100	99

Table 1 shows that the sample size of females is larger compared to males. Furthermore, it can be seen that the majority of the research subjects belong to the age group of ≥ 40 years (99%).

Table 2. Characteristics of Categorical Variables of Research Subjects Based on Gender: Male and Female

Characteristics		Male	Female	Overall
Weight group, n(%)		**(n=49)**	**(n=52)**	**(n=101)**
Underweight	<18,5	0 (0%)	0 (0%)	0 (0%)
Normal	18,5 – 22,9	6 (12.3%)	16 (30.7%)	22 (21.8%)
Overweight	23 – 24,9	14 (28.5%)	12 (23.1%)	26 (25.7%)
Obesity	≥ 25	29 (59.2%)	24 (46.2%)	53 (52.5%)
HbA1c value, n (%)				
≤ 7		16 (32.7%)	25 (48.1%)	41 (40.6%)
> 7		33 (67.3%)	27 (51.9%)	60 (59.4%)

Table 2 shows the comparison of categorical variable values based on male and female genders as well as overall. Based on the table above, it was found that out of the 101 samples used for the study, in terms of BMI, there were 0 respondents with underweight status (0%), 22 respondents with normal weight criteria (21.8%), 26 respondents with overweight criteria (25.7%), and 53 respondents with obesity criteria (52.5%). Additionally, it was found that out of the 101 samples used for the study, the majority had HbA1c levels >7% with a sample size of 60 (59.4%).

Table 3. Characteristics of Value and Distribution of Research Subjects Based on All Variables

Characteristics (N=101)	Mean ± SD	Median (Min – Max)
Anthropometry		
Body weight	65,1 ± 11,3	62 (46 – 96)
Height	158,1 ± 6,1	156 (146 – 175)
Body mass index	25,9 ± 3,7	25,2 (19 – 37,3)
Blood sugar test		
Fasting blood sugar	153,8 ± 76,5	128,8 (72,1 – 492)
Blood sugar 2 hours postprandial	207,7 ± 90,5	195 (62 – 584)
HbA1c	7,8 ± 1,8	7,4 (4,7 – 13,2)
Lipid test		
Trigliserida	163,1 ± 128,6	129,7 (42,7 – 999,4)
Total cholesterol	192 ± 66,2	178 (68,4 – 417)
LDL	120,1 ± 47,9	114 (27,5 – 366)
HDL	43,9 ± 11,1	43 (20 – 79)

Based on Table 3, it can be seen that there is a data distribution from several output variables in the form of minimum value, maximum value, mean, and standard deviation.

Table 4. Results of the Normality Test Variable

Overall		Sig.	
Test Variable		**Male**	**Female**
Body mass index	<0.001	0,009	0,017
HbA1c value	<0.001	0,062	0,008

In this study, the normality test using statistical analysis employs the Kolmogorov Smirnov test because the data is >30. To make a decision in the Kolmogorov Smirnov normality test, the Sig. value is compared with the significance level used, α=0.05. The following are the results of the normality test using statistical analysis presented in the table below.

Based on the results of the normality test with Kolmogorov Smirnov in the table above, it is known that the probability value p or Sig. for BMI and HbA1c overall is <0.05. Then, for the probability value by gender, one of the sig values is <0.05. This means that the assumption of normality is not met. Because the data is not normally distributed, the correlation test uses Spearman correlation.

Table 5. Spearman Correlation Test

Relationship BMI with HbA1C	Correlation Coefficient	Sig.
Overall	0.228	0.022
Male	0.290	0.043
Female	0.125	0.377

Based on the table above, the relationship between Body Mass Index and HbA1c levels overall yielded a significant value of 0.022. This value is <0.05, so it was decided that H_0 is rejected and H_1 is accepted, meaning there is a relationship between BMI and HbA1c. Then, for the relationship between BMI and HbA1c levels in men, a significance value of 0.043 was obtained. This value is <0.05, so it was decided that H_0 is rejected and H_1 is accepted, meaning there is a relationship between BMI and HbA1c in the male sample. In contrast, the relationship in the female group showed a significant value of 0.377. This value is >0.05, so it was decided that H_0 is accepted and H_1 is rejected, meaning there is no relationship between BMI and HbA1c in the female sample. Because the correlation coefficient value is positive, the relationship between the two variables is direct. Thus, it can be concluded that the higher the BMI value, the higher the HbA1C level will be, whereas if the BMI value is low, the HbA1C level will also decrease.

Table 6. Results of the Relationship Test in the Overweight and Obese Group

Test Variable		Nilai		*p* (Sig.)
		Hb	A1c	
Overweight		≤ 7	> 7	
	Overall	41.7%	66.7%	0.929
Male		54.5%	88.9%	0.590
Female		30.8%	53.3%	0.896
Obesity				
	Overall	70.8%	81.8%	0.194
Male*		50%	96%	0.963
Female		57.1%	63.2%	0.252

Based on Table 6, it can be seen that from the overweight and obese groups, whether differentiated by gender or not, the p (Sig) value is > 0.05, which means there is no relationship between the test variable and the increase in HbA1c.

3.2.Discussion

Based on the sample in this study, it was found that the number of female participants was higher than that of males, accounting for 51.5%. This result aligns with the 2018 Riskesdas survey, which indicated a higher prevalence of diabetes among women compared to men, with a difference of 1.8% (Kemenkes RI, 2021). Similarly, Purwandari's research reported a higher percentage of female participants (73.33%) in her study. Women are physiologically at a higher risk of developing diabetes than men, particularly due to the hormonal changes associated with the menstrual cycle and menopause, which can promote fat accumulation (Irawan, 2019). The insulin response in the body is influenced by estrogen and progesterone, and during menopause, the decline in these hormones leads to reduced insulin sensitivity, which can increase the risk of developing Type 2 Diabetes Mellitus (DMT2) (Arania et al., 2021). The combination of aging and the onset of menopause significantly affects glucose tolerance, making women more susceptible to metabolic disturbances (Ciarambino et al., 2022). However, the findings of this study contradict the research conducted by Boku (2019), which found no significant correlation between gender and blood glucose levels in DMT2 patients ($p = 0.865$) (Boku et al., 2019). Likewise, Nur, Wilya, and Ramadhan (2016) reported a p-value of 0.709, indicating no significant relationship between gender and blood glucose levels (Nur et al., 2016).

Regarding age, this study found that the majority of patients (99%) were aged 40 years or older, which is consistent with findings from a study at Haji Hospital in Surabaya, where 94.7% of DMT2 patients were over 40 years old (Bestari, 2020). According to the American Diabetes Association (de Boer et al., 2017), age is a critical factor in increasing the risk of DMT2, particularly because abdominal fat accumulation tends to increase with age. This accumulation leads to central obesity, a key risk factor for insulin resistance, which is a precursor to DMT2 (Suastika et al., 2012). The International Diabetes Federation (IDF) states that the prevalence of diabetes is lowest among adults aged 20-24 years, with only 2.2% affected (Sun et al., 2022). WHO also highlights that after the age of 40, fasting blood glucose levels increase by approximately 1-2 mg% annually, with postprandial glucose levels rising by 5.6–13 mg% (Klein et al., 2021). Consequently, Perkeni (2021) recommends screening for DMT2 for individuals over 40 years, as the risk of developing glucose intolerance significantly increases with age (Perkeni, 2021).

In this study, 52.5% of the sample was classified as obese ($BMI \geq 25$), which supports findings by Boku (2019), who found that patients with $BMI > 25$ kg/m² were more likely to have higher blood glucose levels ($p = 0.02$), with a correlation coefficient of 0.274, indicating a positive relationship between BMI and uncontrolled blood glucose levels (>125 mg/dL) (Boku et al., 2019). Excess fat accumulation in the body, particularly in the abdominal region, affects insulin sensitivity, resulting in insulin resistance. Adipose tissue is an endocrine organ that releases cytokines, which impact insulin signaling and contribute to the development of DMT2 (Boku et al., 2019). The IDF acknowledges the strong association between excess weight and the development of Type 2 Diabetes, noting that individuals with a high caloric intake tend to have impaired beta-cell function in the pancreas, resulting in the inability to regulate blood glucose effectively (Sugiritama et al., 2015; Sun et al., 2022).

When examining HbA1c levels, this study found that the majority of participants had uncontrolled HbA1c levels (>7%), which is in line with the findings of Ginting (2022), who reported that most DMT2 patients had poor glycemic control (Suranta Ginting et al., 2024). Uncontrolled HbA1c levels are often due to inconsistent blood glucose monitoring, poor adherence to treatment regimens, insufficient physical activity, and unhealthy dietary habits. Perkeni (2021) has stressed that consistently uncontrolled HbA1c levels can lead to significant complications, both microvascular and macrovascular, further underlining the importance of proper management (Suranta Ginting et al., 2024).

The correlation between BMI and HbA1c levels in this study was statistically significant, indicating a linear relationship between these two variables. This finding aligns with previous research, such as Sisodia (2019), who reported a positive correlation between BMI and HbA1c levels in DMT2 patients (Sisodia & Chouhan, 2019). The underlying physiological mechanisms connecting BMI to HbA1c levels are multifactorial. Increased adiposity, particularly visceral fat, leads to elevated levels of adipokines, such as leptin and resistin, which contribute to insulin resistance. This resistance reduces the effectiveness of insulin in regulating blood glucose, leading to higher HbA1c levels. Additionally, excess body fat promotes chronic low-grade inflammation, which further exacerbates insulin resistance by increasing the production of pro-inflammatory cytokines like TNF-α and IL-6. These inflammatory markers impair insulin signaling pathways, leading to poor glycemic control. Furthermore, elevated BMI may also affect the rate of hemoglobin glycation, as higher blood glucose levels, commonly associated with increased insulin resistance, lead to greater non-enzymatic glycation of hemoglobin, resulting in higher HbA1c levels. Other studies, such as the Look AHEAD Research Group (2007), have demonstrated that lifestyle interventions, including weight loss, can significantly reduce HbA1c levels and improve glycemic control in patients with DMT2. Similarly, Saputra et al. (2020) emphasized the importance of monitoring both BMI and HbA1c levels, as higher BMI values are closely linked to poor diabetes control and an increased risk of complications (Saputra et al., 2020.

An interesting finding of this study is that the correlation between BMI and HbA1c was significant in the male group but not in the female group. This discrepancy may be attributed to biological, cultural, lifestyle, environmental, and socioeconomic differences that affect body composition and the clinical presentation of DMT2 in men and women. Genetic factors, epigenetic mechanisms, diet, and lifestyle play a crucial role in influencing the risk and progression of diabetes in both genders, but their effects may vary (Ciarambino et al., 2022). Central obesity, defined as a waist circumference ≥ 90 cm in men and ≥ 80 cm in women (Cleeman et al., 2001), has been shown to contribute to the onset of DMT2 (Priyani & Makful, 2018). There are two types of adipose tissue—white adipose tissue (WAT) and brown adipose tissue (BAT)—with BAT being involved in energy expenditure and offering protection against diabetes (Cypess et al., 2009). The amount of BAT is higher in women, which could be one of the reasons why women generally have lower visceral fat compared to men, which may reduce the risk of developing DMT2 (Wang et al., 2015). Therefore, the presence of more brown adipose tissue in women could provide a protective effect against diabetes, offering a potential explanation for the lack of significant correlation between BMI and HbA1c in this study's female population (Ciarambino et al., 2022).

Study Limitation

This study has several limitations. First, there was no control over other potentially confounding variables, such as diet, eating habits, physical activity, and the duration of diabetes in the patients. These factors could have a significant impact on BMI and glycemic control, but data on these variables were not available for analysis. Second, this study did not include information on the amount of brown adipose tissue (BAT), which may play a role in regulating glucose metabolism and could provide additional insight into the relationship between obesity and diabetes management. The lack of BAT data is a limitation, as this tissue type is known to have a protective effect against metabolic disorders, including DMT2. Moreover, this study was limited to secondary data from medical records, which restricts the ability to obtain real-time, more granular details on patients' lifestyle factors. Future studies should address these gaps by incorporating a broader range of variables, including dietary habits, physical activity, and the presence of brown adipose tissue, to obtain a more comprehensive understanding of the factors influencing BMI and HbA1c control in DMT2 patients. Additionally, prospective studies that track patients over time may help identify causal relationships and provide more robust conclusions.

4. Conclusion

This study demonstrates a significant positive correlation between Body Mass Index (BMI) and HbA1c levels in patients with Type 2 Diabetes Mellitus (DMT2) at Dr. Soetomo Hospital in Surabaya. The findings suggest that higher BMI is associated with poorer glycemic control, particularly in male patients, reinforcing the importance of managing weight as a key component of diabetes care. The underlying physiological mechanisms, including insulin resistance, elevated adipokines, chronic inflammation, and hemoglobin glycation, contribute to this relationship, highlighting the complex interplay between obesity and diabetes management. Given these results, regular monitoring of both BMI and HbA1c levels is crucial for optimizing treatment strategies and preventing complications in DMT2 patients. Future research should focus on exploring interventions that address both BMI and glycemic control, with an emphasis on tailored strategies for different demographic groups, including age and gender.

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