# Glycemic Control Status as a Predictor of Blood Pressure in Patients with Type 2 Diabetes Mellitus

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## ABSTRACT
Type 2 diabetes mellitus is a chronic metabolic disorder with a rising global prevalence and is frequently accompanied by hypertension. Adequate glycemic control plays a crucial role in preventing elevated blood pressure among patients with T2DM. This study aimed to compare systolic and diastolic blood pressure between patients with controlled and uncontrolled glycemic status. An analytical cross-sectional design was employed involving 71 patients with T2DM from three primary healthcare centers. Data were collected through measurement of glycated hemoglobin (HbA1c) levels to determine glycemic control status, along with blood pressure measurements. The data were analyzed using the Independent Samples t-test in JASP software. The statistical analysis revealed a significant difference in systolic blood pressure ($p = 0.020$) and diastolic blood pressure ($p = 0.039$) between the controlled and uncontrolled groups. Patients with uncontrolled HbA1c levels exhibited higher systolic and diastolic blood pressure compared to those with controlled HbA1c levels. These findings highlight the importance of routine HbA1c monitoring in primary healthcare settings to prevent hypertension among patients with T2DM. In conclusion, glycemic control status may serve as a significant predictor of blood pressure levels in patients with type 2 diabetes mellitus.
**Keywords:** blood pressure; type 2 diabetes mellitus; glycated hemoglobin; hypertension; primary healthcare centers

## INTRODUCTION
Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and impaired insulin secretion, resulting in persistent hyperglycemia [1]. Globally, the incidence of T2DM continues to rise significantly. In 2021, approximately 537 million adults were living with diabetes worldwide, and this number is projected to increase to 783 million by 2045 [2]. This upward trend underscores that T2DM remains a major global public health concern.

In Indonesia, data from the National Basic Health Research (Riskesdas) reported a national diabetes prevalence of 2%. At the regional level, the Province of East Nusa Tenggara recorded a prevalence of 0.57%, while Kupang City reported a prevalence of 0.68% [3]. These findings indicate that T2DM is also a relevant health issue at the local level and has the potential to impose a substantial burden on healthcare services, particularly in primary healthcare facilities. The growing number of individuals affected by T2DM necessitates strengthened preventive and management strategies at the community and primary care levels.

The high prevalence of T2DM contributes to an increased incidence of hypertension as a common comorbidity. Several studies have reported that hypertension is present in more than half of patients with diabetes and plays a significant role in exacerbating cardiovascular complications and increasing mortality risk [4]. This condition highlights the importance of controlling factors associated with blood pressure in patients with T2DM to prevent further complications and reduce long-term morbidity and mortality. Effective management of both glycemic status and blood pressure is therefore essential in comprehensive diabetes care.

A number of studies have investigated the relationship between glycemic control and blood pressure in patients with T2DM; however, the findings remain inconsistent. Edward et al. (2024) reported a strong positive correlation between HbA1c levels and hypertension ($r = 0.719$; $p < 0.001$), suggesting that poor glycemic control may contribute to elevated blood pressure. Other studies conducted by Haryati et al. (2022) and Latif et al. (2023) also found significant differences in HbA1c levels between diabetic patients with and without hypertension [4–7]. In contrast, Husni et al. (2022) reported no significant association between HbA1c levels and systolic blood pressure among diabetic patients with hypertension [4–7].

These inconsistencies in previous findings indicate a research gap regarding the association between glycemic control and blood pressure among patients with T2DM, particularly at the primary healthcare level. Moreover, most prior studies were conducted in hospital settings, limiting the understanding of patient conditions in primary care facilities. Therefore, this study is important to compare systolic and diastolic blood pressure among patients with T2DM with controlled and uncontrolled glycemic status in primary healthcare centers. The findings are expected to provide a more representative overview of T2DM patients in primary care and to serve as a basis for evaluating and strengthening promotive and preventive programs for non-communicable diseases at the primary healthcare level. So, this study aimed to compare systolic and diastolic blood pressure between patients with controlled and uncontrolled glycemic status

## METHODS
This study employed an analytical observational design with a cross-sectional approach to compare systolic and diastolic blood pressure among patients with Type 2 Diabetes Mellitus (T2DM) based on controlled and uncontrolled glycemic status. The study was conducted from July 24 to August 9, 2025, at three primary healthcare centers in Kupang City: Puskesmas Oepoi, Puskesmas Sikumana, and Puskesmas Bakunase.

The study population consisted of all patients with T2DM registered and receiving care at the three primary healthcare centers. The sample size was determined using the formula for comparing categorical–numerical variables in independent groups, with a 95% confidence level and 80% statistical power. The minimum required sample size was calculated to be 61 respondents. Sampling was performed using a consecutive sampling technique, in which all patients meeting the inclusion criteria and not meeting the exclusion criteria during the study period were recruited. In total, 71 respondents agreed to participate and were included until the completion of the study. The inclusion criteria were patients diagnosed with T2DM, aged 18–59 years, not pregnant, and willing to participate by signing a written informed consent form. The exclusion criteria included patients with severe anemia, kidney disease, liver disease, thyroid disorders, or heart disease, as well as patients with communication barriers that could interfere with the data collection process.

The variables assessed in this study were blood pressure and HbA1c levels. Blood pressure was measured using a digital sphygmomanometer in accordance with the procedures recommended by the American College of Cardiology and the American Heart Association (ACC/AHA) 2025 guidelines. Blood pressure results were classified into normal, elevated, stage 1 hypertension, and stage 2 hypertension categories [8]. HbA1c levels were examined using the High-Performance Liquid Chromatography (HPLC) method with a 3 mL venous blood sample. HbA1c results were categorized as controlled (<7%) and uncontrolled (≥7%) [9].

Data collection was conducted in collaboration with the non-communicable disease program coordinators at each primary healthcare center. Eligible patients were contacted via text messages or telephone calls to receive information about the study and to confirm their willingness to participate. Written informed consent was obtained directly from participants prior to data collection. Data analysis was performed using descriptive and inferential statistical methods. Categorical data were presented as frequency distributions and percentages, while numerical data were presented as means and standard deviations. Normality testing was conducted using the Kolmogorov–Smirnov test, which indicated that systolic blood pressure ($p = 0.585$) and diastolic blood pressure ($p = 0.827$) were normally distributed. Based on these results, comparative analysis was conducted using the independent samples t-test, using JASP software.

## RESULTS

The initial number of respondents identified from the three primary healthcare centers was 567 individuals. Following the screening process conducted according to the inclusion and exclusion criteria, contact confirmation, validation, and assessment of willingness to participate, a total of 71 respondents completed the study. The reduction in sample size was due to non-attendance, refusal to participate, and communication barriers encountered during the recruitment process.

Based on Table 1, most respondents were aged 50–59 years (63.4%). The majority were female (74.6%). According BMI, most respondents were classified as overweight (56.3%). The majority of respondents were from Sikumana Primary Healthcare Center (45.07%). Most respondents were housewives (57.75%).

Table 1. Distribution of respondents' demographic characteristics

| Variable | Category | Frequency | Percentage |
|---|---|---|---|
| Age | 30–39 years | 4 | 5.6 |
| | 40–49 years | 22 | 31 |
| | 50–59 years | 45 | 63.4 |
| Sex | Male | 18 | 25.4 |
| | Female | 53 | 74.6 |
| BMI | Normal | 31 | 43.7 |
| | Overweight | 40 | 56.3 |
| Primary healthcare center | Oepoi | 16 | 22.54 |
| | Sikumana | 32 | 45.07 |
| | Bakunase | 23 | 32.39 |
| Occupation | Housewife | 41 | 57.75 |
| | Civil servant | 7 | 9.86 |
| | Self-employed | 4 | 5.63 |
| | Teacher | 3 | 4.23 |
| | Retired | 3 | 4.23 |
| | Farmer | 2 | 2.82 |
| | Entrepreneur | 2 | 2.82 |
| | Others | 9 | 12.66 |

Table 2. Distribution of blood pressure

| Blood Pressure | Frequency | Percentage |
|---|---|---|
| Normal | 15 | 21.13 |
| Elevated | 9 | 12.68 |
| Stage 1 hypertension | 24 | 33.80 |
| Stage 2 hypertension | 23 | 32.39 |

Table 3. Distribution of HbA1c levels

| HbA1c level | Frequency | Percentage |
|---|---|---|
| Controlled | 19 | 26.76 |
| Uncontrolled | 52 | 73.24 |

Table 4. The comparative analysis results

| HbA1c level | blood pressure (mmHg) | | | |
|---|---|---|---|---|
| | Systolic | | Diastolic | |
| | Mean | p | Mean | p |
| Controlled | 125.11 | 0.020 | 79.42 | 0,039 |
| Uncontrolled | 136.20 | | 83.88 | |

Based on Tables 2 and Table 3, the largest proportion of respondents were classified as having Stage 1 hypertension (33.80%), and most respondents had uncontrolled HbA1c levels (73.24%). Table 4 shows that the p-value for systolic blood pressure was 0.020 and for diastolic blood pressure was 0.039, indicating statistically significant differences between patients with controlled and uncontrolled HbA1c levels.

## DISCUSSION

The results of this study indicate a significant difference in systolic and diastolic blood pressure between patients with Type 2 Diabetes Mellitus (T2DM) with controlled and uncontrolled glycemic status. Higher blood pressure was particularly observed in patients with HbA1c levels ≥7%, suggesting that poor glycemic control is associated with elevated blood pressure. These findings reinforce the hypothesis that glycemic status plays a crucial role in blood pressure regulation among patients with T2DM.

Physiologically, the relationship between chronic hyperglycemia and increased blood pressure can be explained through several mechanisms. Persistent hyperglycemia is associated with increased circulating blood volume and peripheral vascular resistance, mediated by secondary hyperinsulinemia resulting from insulin resistance [9]. Additionally, elevated blood pressure in T2DM patients is linked to vascular smooth muscle cell (VSMC) hypertrophy and extracellular matrix (ECM) fibrosis. This process is mediated by the activation of the AGE–RAGE (advanced glycation end products–receptor) pathway, which upregulates TGF-β1 expression and Smad2/3 phosphorylation, thereby stimulating collagen type I and III production. Further activation of the MAPK/ERK signaling pathway is associated with VSMC proliferation and increased ECM synthesis, contributing to arterial stiffness and elevated vascular resistance [10]. Endothelial dysfunction also plays a critical role. Reduced nitric oxide (NO) availability diminishes vasodilatory capacity, while increased endothelin-1 (ET-1) promotes vascular contraction via ETA/B receptor activation and enhanced intracellular $Ca^{2+}$ influx, collectively contributing to elevated vascular pressure in T2DM patients [11].

Beyond vascular mechanisms, hyperinsulinemia caused by insulin resistance contributes to increased blood pressure through enhanced renal sodium reabsorption mediated by $Na^+/K^+$-ATPase and $Na^+/H^+$ exchanger activation, thereby increasing plasma volume [9]. Chronic hyperglycemia is also associated with systemic and intrarenal activation of the renin–angiotensin–aldosterone system (RAAS). Elevated glucose levels increase renal angiotensinogen (AGT) expression via transcription mediated by C/EBP and NF-κB, induced by reactive oxygen species (ROS), resulting in excessive angiotensin II (Ang II) production via angiotensin-converting enzyme (ACE) [12]. In addition to its pressor, pro-inflammatory, pro-oxidative, and sodium-retaining effects, Ang II can impair insulin action in vascular and skeletal muscle tissues through type 1 angiotensin receptors (AT1R), disrupting insulin signaling via phosphatidylinositol 3-kinase (PI3K) and protein kinase B pathways. This inhibition leads to reduced endothelial NO production, increased vasoconstriction, and decreased glucose uptake in skeletal muscles. RAAS overactivation also induces metabolic changes that affect both blood pressure and insulin resistance by enhancing vasoconstriction, stimulating renal sodium reabsorption, and promoting aldosterone secretion [13,14].

These findings are consistent with previous studies reporting a relationship between HbA1c levels and blood pressure in T2DM patients. Studies by Edward and Ochavia (2024), Haryati (2022), and Latif (2023) demonstrated that patients with higher HbA1c levels tended to have higher blood pressure compared to patients with better glycemic control [4,5,7]. Collectively, these results underscore the role of HbA1c as an indicator of glycemic control associated with blood pressure regulation via endothelial and hormonal mechanisms.

In addition to glycemic control, factors such as age, sex, and lifestyle may also influence blood pressure in T2DM patients. Aging is associated with reduced arterial elasticity and endothelial dysfunction, while postmenopausal women experience decreased estrogen levels, which may reduce vasodilatory capacity and increase the risk of atherosclerosis [15–17]. Lifestyle factors, including high-calorie diets, low physical activity, and metabolic stress, are also associated with elevated blood pressure in T2DM patients [18–21]. Lifestyle modifications through regular physical activity and balanced diet management are key strategies in achieving optimal glycemic control [22]. In addition to lifestyle, adherence to medication and dietary regulations remains crucial for maintaining glycemic control [23-26].

The clinical implications of these findings highlight the importance of routine monitoring of HbA1c and blood pressure as part of T2DM management in primary healthcare settings. Early detection of poor glycemic control may help identify patients at risk of elevated blood pressure, allowing for timely lifestyle interventions and comprehensive management to prevent macrovascular complications [9].

This study has several limitations. The cross-sectional design only allows for the identification of associations or differences between variables without establishing causal relationships. Moreover, the study did not account for potential confounding factors affecting blood pressure, such as the use of antihypertensive medications, smoking habits, and alcohol consumption.

## CONCLUSION

Glycemic control status appears to be a significant predictor of systolic and diastolic blood pressure in patients with T2DM. Patients with uncontrolled glycemic levels exhibited higher blood pressure, highlighting the association between poor glycemic control and elevated cardiovascular risk. These findings emphasize the importance of regular HbA1c monitoring, patient education, and lifestyle interventions in primary healthcare to manage both blood glucose and blood pressure effectively.

## Ethical consideration, competing interest and source of funding

-This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine and Veterinary Medicine, Universitas Nusa Cendana, under approval number 47/UN15.21/KEPK-FKKH/2025.
-There is no conflict of interest related to this publication.
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