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The relationship between HbA1c levels and erythrocyte sedimentation rate in type 2 diabetes mellitus patients based on hypertension status

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Abstract

Background: Measuring random or fasting blood glucose levels does not fully reflect the quality of long-term blood glucose control. Therefore, more accurate monitoring of glycemic status in patients with diabetes mellitus is performed through the HbA1c test. This test is used as an indicator of successful diabetes mellitus control and to minimize the risk of cardiovascular complications and improve patients' quality of life.

Purpose: To determine the relationship between HbA1c levels and erythrocyte sedimentation rate (ESR) values in type 2 Diabetes Mellitus patients based on hypertension status at the Bunda Thamrin Medical Laboratory, Medan.

Method: A quantitative approach was employed with a descriptive correlational analytical design. The population was 70 patients with type 2 diabetes mellitus, with a sample size of 70 obtained through a specific sampling method. Data on HbA1c levels and ESR values were analyzed to determine their relationship to the patients' hypertension status.

Results: No significant differences in HbA1c levels ($p=0.746$) or ESR values ($p=0.259$) were found between the hypertensive and normotensive patient groups. However, a clinically significant trend was found in ESR values, with the hypertensive group having a higher proportion of normal ESR values ($p=0.066$).

Conclusion: No significant differences were found between HbA1c levels and ESR values based on hypertension status. Nevertheless, HbA1c has the potential to be an indirect predictor of inflammatory status. Optimal glycemic control remains crucial to reduce the risk of cardiovascular complications through anti-inflammatory mechanisms, especially in patients with hypertension who require more comprehensive management.

Keywords: Erythrocyte Sedimentation Rate; HBA1C Level; Type 2 Diabetes Mellitus.

INTRODUCTION

Diabetes mellitus is a chronic disease caused by the pancreas' inability to produce adequate insulin or the body's ineffective use of insulin. Insulin plays a crucial role in regulating blood glucose levels. Chronic hyperglycemia in uncontrolled diabetes can cause damage to various body systems, particularly the nervous and vascular systems (World Health Organization, 2025). One of the main parameters for assessing long-term glycemic control is glycated hemoglobin (HbA1c). HbA1c is a fraction of hemoglobin formed through non-enzymatic glycation, when glucose irreversibly binds to hemoglobin in erythrocytes, and its levels increase with increasing average blood glucose concentrations over time (Tan, Schneek, Garhyan, Chan, & Tham, 2025). Because hemoglobin resides in red blood cells, which have a lifespan of approximately 90–120 days, HbA1c values reflect average plasma glucose levels over approximately the past 2–3 months, with the greatest weighting coming from the most recent 4–8 weeks prior to the test. These characteristics make HbA1c the gold standard indicator for monitoring long-term glycemic control and predicting the risk of chronic complications of diabetes (DiMeglio, Acerini, Codner Dujovne, Craig, Hofer, Pillay, & Maahs, 2018).

Measurement of random or fasting blood glucose levels only reflects glucose levels at a single point in time and is therefore inadequate for assessing the quality of long-term glucose regulation. More accurate monitoring of the glycemic status of diabetes mellitus patients is performed through the examination of glycated hemoglobin (HbA1c), as this parameter reflects the average blood glucose level over the past 2–3 months and is strongly correlated with the risk of chronic complications, including cardiovascular disease (Al-hashimi, Merie, & Mustafa, 2025). Therefore, HbA1c is widely used as a benchmark for successful diabetes mellitus control, serves as a standard for adjusting therapy, and plays a crucial role in efforts to reduce the incidence of macro- and microvascular complications and improve clinical outcomes and patient quality of life (Boye, Thieu, Lage, Miller, & Paczkowski, 2022).

According to a report by the World Health Organization (WHO), diabetes mellitus is one of the most prevalent diseases worldwide. The WHO estimates that more than 346 million people

worldwide live with diabetes, with a death rate of approximately 6.7 million people per year, equivalent to one death every five seconds. The countries with the highest number of diabetes sufferers include China, India, Pakistan, the United States, and Indonesia, with Indonesia among the top five countries with the highest diabetes populations in the world (World Health Organization, 2025).

In Indonesia, the 2018 Basic Health Research showed a national prevalence of doctor-diagnosed diabetes mellitus of 1.5% across all ages and 2.0% among those aged ≥ 15 years, with an increasing trend compared to the previous survey (Riviani, Mutiara, Santosa, & Masyitah, 2025). Analysis by province showed significant variation, with DKI Jakarta recorded as the province with the highest prevalence, reaching around 3.4%, followed by the Special Region of Yogyakarta and East Kalimantan at around 3.1%, while the province with the lowest prevalence was East Nusa Tenggara (Oktora & Butar, 2022). The 2023 Indonesian Health Survey reported that the national prevalence of diabetes in the age group ≥ 15 years increased to 2.2%, while in North Sumatra Province it was recorded at 1.9% for those aged ≥ 15 years and around 1.4% for all ages, approaching the previous national prevalence rate of 1.5% (Riviani et al., 2025). Medan city was reported to have the highest prevalence of diabetes in the province of North Sumatera (Ministry of Health of the Republic of Indonesia, 2023).

At the provincial level, the prevalence of diabetes mellitus in North Sumatra reached 1.9%, slightly lower than the national figure of 2.2% in the population aged ≥ 15 years. Case distribution tends to be higher in densely populated urban areas such as Medan, Deli Serdang, and Langkat, which are categorized as areas with a very high caseload, while several island and rural districts show a lower proportion of cases. This difference is related to unhealthy lifestyles (consumption of fast food, lack of physical activity), non-physical work types in cities, and the availability of better health facilities, which leads to more frequent early detection of diabetes (Riviani et al., 2025). In the context of clinical management, optimal metabolic control in diabetes patients aims to maintain blood glucose levels as close to normal as possible without causing hypoglycemia, with HbA1c recognized as the

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gold standard for assessing long-term glycemic control (Mehta, Prasad, Kalapureddy, Narayanam, & Kondaveeti, 2025). Various international organizations, including the American Diabetes Association, generally recommend an HbA1c target of around <7% as an indicator of good metabolic control to reduce the risk of micro- and macrovascular complications and the burden of cardiovascular disease (Kaiafa, Veneti, Polychronopoulos, Pilalas, Daos, Kanellos, & Savopoulos, 2021).

In patients diagnosed with diabetes mellitus, pharmacological therapy in the form of antidiabetic drugs or insulin is required to achieve optimal metabolic control. An increase in HbA1c levels above 7% indicates uncontrolled diabetes and increases the risk of vascular complications due to endothelial dysfunction, which can subsequently progress to atherosclerosis as a result of hyperglycemia and chronic inflammation (Sari, & Sayekti, 2023). This vascular inflammatory process is characterized by increased fibrinogen levels, which can lead to an increase in the erythrocyte sedimentation rate (ESR). In addition to blood glucose and urinary glucose measurements, HbA1c remains the main indicator in assessing long-term glycemic control and has been widely associated with average blood glucose levels (Latif, Anggraeni, & Ismarwati, 2025). This study aims to determine the relationship between HbA1c levels and ESR in patients with type 2 diabetes mellitus based on hypertension status at the Bunda Thamrin Medical Laboratory in Medan.

RESEARCH METHOD

A quantitative approach with a descriptive correlational analytical design was employed to determine the relationship between HbA1c levels and erythrocyte sedimentation rate in patients with type 2 diabetes mellitus. The quantitative approach was chosen because it allows researchers to systematically analyze numerical data to objectively observe the relationship between variables without performing any treatment or manipulation on the

research subjects. The study was conducted at Bunda Thamrin Hospital, Medan, with data collection from April to November 2025.

The population in this study were all patients diagnosed with type 2 diabetes mellitus and undergoing laboratory tests at Bunda Thamrin Hospital, Medan, during the study period. The sampling technique used a total sampling method, so that all patient data that met the inclusion criteria and were not included in the exclusion criteria were used as the study sample. Inclusion criteria included patients diagnosed with type 2 diabetes, undergoing HbA1c and erythrocyte sedimentation rate tests, and agreeing to participate as research respondents. Meanwhile, patients with blood disorders such as thalassemia and blood malignancies such as leukemia and aplastic anemia were not included in this study.

Data collection was conducted through recording laboratory test results, namely HbA1c levels measured using the High Performance Liquid Chromatography (HPLC) method with a Bio-Rad D-10 instrument, and erythrocyte sedimentation rate examination using the photometric with infrared method on a Mindray BC-780 instrument. The data obtained were then analyzed using SPSS software. Univariate analysis was conducted to describe the characteristics of respondents such as age, gender, HbA1c levels, and erythrocyte sedimentation rate. Next, bivariate analysis was conducted to assess the relationship between HbA1c levels and erythrocyte sedimentation rate using statistical tests appropriate to the data distribution, namely the Pearson or Spearman test, with a significance level of $p < 0.05$ and a confidence level of 95%.

This study also paid attention to the ethical aspects of the study by obtaining approval from the ethics committee of Universitas Prima Indonesia under the number DK/KEP/139/IV/2026, informed consent from respondents, and ensuring the confidentiality of the data used.

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RESEARCH RESULTS

Table 1. Characteristics of the Respondents (N=70)

Variable	Results
Age (Mean±SD)(Range)(Year)	(53.61±12.18)
Age (n/%)	
<45	12/17.1
45 – 59	38/54.3
≥ 60	20/28.6
Gender (n/%)	
Female	37/52.9
Male	33/47.1
Blood Pressure Category (n/%)	
Normotension	51/72.9
Hypertension	19/27.1
HbA1c Category (n/%)	
Controlled	35/50.0
Uncontrolled	35/50.0
ESR Category (n/%)	
Normal	43/61.4
Elevated	27/38.6

Table 1 presents the baseline characteristics of the respondents. The mean age was (53.61 ± 12.18) with the age range of 45 - 59 years was dominant (54.3%). In terms of gender distribution, the majority were female, accounting for 37 individuals (52.9%). Most participants were classified as normotensive, comprising 51 respondents (72.9%). Glycemic control, assessed by HbA1c levels, was evenly divided, with 35 respondents (50.0%) demonstrating controlled HbA1c and an equal proportion (50.0%) exhibiting uncontrolled HbA1c. Regarding the erythrocyte sedimentation rate (ESR), the majority of respondents, 43 individuals (61.4%), fell within the normal category.

Table 2. Numerical Comparative Analysis on Blood Pressure Category

Variable	Blood Pressure Category (Median (Mean±SD))		p-value
	Normotension (n=51)	Hypertension (n=19)	
HbA1c levels	10.60 (8.66±3.91)	5.70 (7.76±3.84)	0.746
Erythrocyte Sedimentation Rate	18.00 (23.96±17.496)	14.00 (19.89±18.089)	0.259

Table 2 presents the results of a comparative analysis of HbA1c levels between the normotensive and hypertensive patient groups. The normotensive group, consisting of 51 respondents, showed a median HbA1c value of 10.60% with an average value

of 8.66% (SD±3.91%). Meanwhile, the hypertensive group, consisting of 19 respondents, showed a median HbA1c value of 5.70% with an average value of 7.76% (SD±3.84%). The results of the Mann-Whitney U test used to compare HbA1c levels

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between the two groups showed a p-value of 0.746. The p-value, which is much greater than alpha 0.05 ($p > 0.05$), indicates that the difference in HbA1c levels between the normotensive and hypertensive groups is not statistically significant. In other words, although there is a difference in the values descriptively, the difference is not strong enough to indicate a statistically significant difference between the two groups. This means that the presence of hypertension in type 2 DM patients in this study was not significantly related to the patient's HbA1c levels.

A comparative analysis of erythrocyte sedimentation rate values between groups of type 2 DM patients with normotensive and hypertensive patients. In the normotensive group consisting of 51 respondents, the median ESR value was 18.00

mm/hour with a mean value of 23.96 mm/hour ($SD \pm 17.496$). The hypertensive group with 19 respondents showed a median ESR value of 14.00 mm/hour with a mean value of 19.89 mm/hour ($SD \pm 18.089$). The results of the Mann-Whitney U test to compare ESR values between the two groups showed a p-value of 0.259. A p-value greater than alpha 0.05 ($p > 0.05$) indicates that the difference in ESR values between the normotensive and hypertensive groups is not statistically significant. Although there was a descriptive difference with a tendency for higher ESR in the normotensive group, this difference was not strong enough to achieve statistical significance. This means that the presence of hypertension in type 2 DM patients in this study was not significantly related to ESR values.

Table 3. Analysis of the Categorical Relationship between HbA1c-ESR and Blood Pressure Categories

Variable	Blood Pressure Category		p-value
	Normotension (n=51)	Hypertension (n=19)	
HbA1c Category (n/%)			
Controlled	23/45.1	12/63.2	0.179
Uncontrolled	28/54.9	7/36.8	
ESR Category (n/%)			
Normal	28/54.9	15/78.9	0.066
Elevated	23/45.1	4/21.1	

Table 3 presents an analysis of the relationship between HbA1c control categories (controlled vs. uncontrolled) and blood pressure status (normotension vs. hypertension) using a categorical approach. In the normotensive group, of the 51 respondents, 23 (45.1%) had controlled HbA1c, while 28 (54.9%) had uncontrolled HbA1c. The results of statistical tests using the chi-square or Fisher exact test showed a p-value of 0.179. A p-value greater than alpha 0.05 ($p > 0.05$) indicates that there is no statistically significant relationship between HbA1c control categories and hypertension status in type 2 DM patients in this study. Although descriptively there is a significant difference in proportions, this difference does not reach the level of statistical significance, possibly due to the relatively small sample size, especially in the hypertension group ($n=19$).

An analysis of the relationship between ESR categories (normal vs. elevated) and blood pressure status (normotension vs. hypertension) using a categorical approach. In the normotensive group of 51 respondents, 28 (54.9%) had a normal ESR, while 23 (45.1%) had an elevated ESR. This distribution indicates that the proportion of patients with a normal ESR was slightly higher than that with an elevated ESR in the normotensive group, although the difference was not significant and the two categories were still fairly balanced. The results of statistical tests using the chi-square or Fisher exact test showed a p-value of 0.066. Although this p-value is greater than the alpha of 0.05 ($p > 0.05$), it is close to the limit of significance and can be considered "marginally significant" or "borderline significant." This indicates that there is a trend or association between ESR categories and hypertension status, although it does not reach the conventional significance level of 0.05. With a p-value of 0.066, there is approximately a 6.6% probability that the observed difference is due to chance alone.

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Table 4. Comparison of Spearman HbA1c-ESR Correlation in Both Groups

Group	n	Correlation Coefficient (ρ)	p-value	Power Category	Determination (r^2)
Normotension	51	0.626	0.000	Strong	39.2%
Hypertension	19	0.701	0.001	Very Strong	49.1%

Table 4 presents a comparison of the strength of the correlation between HbA1c levels and ESR in the two groups. A key finding from this table is that both groups showed a significant positive correlation, with the hypertensive group showing a slightly stronger correlation ($\rho=0.701$) than the normotensive group ($\rho=0.626$). This difference in correlation coefficient of 0.075 indicates that the relationship between glycemic control and inflammation is slightly stronger in patients with hypertension. The coefficient of determination (r^2) indicates that HbA1c can explain 39.2% of the ESR variability in the normotensive group and 49.1% in the hypertensive group. This difference of approximately 10% indicates that in patients with hypertension, the HbA1c variable plays a slightly greater role in determining the level of inflammation as measured by ESR. The remaining (60.8% in normotensive and 50.9% in hypertensive) is influenced by other factors not measured in this study.

DISCUSSION

The study results showed a relatively balanced gender distribution, with a slightly higher proportion of women (52.9%) than men (47.1%). This finding is consistent with global epidemiological data showing that type 2 diabetes mellitus affects both sexes with relatively comparable prevalence. According to the IDF Diabetes Atlas 2021, the prevalence of diabetes in adults aged 20–79 years globally is similar between men and women, with relatively small differences, although the pattern of disease burden and increasing trends vary by region and country income level (Sun, Saeedi, Karuranga, Pinkepank, Ogurtsova, Duncan, & Magliano, 2022).

The slightly higher proportion of women in this study can be explained by several possible evidence-based explanations. First, various health care studies have shown that women generally utilize health care facilities more frequently, schedule and attend more medical visits, and are more active in chronic disease management follow-up than men, thus increasing

their likelihood of being included in clinical research and diabetes surveillance. Second, hormonal changes accompanying menopause are associated with increased visceral fat, decreased energy expenditure, and the development of insulin resistance, all of which increase the risk of type 2 diabetes mellitus in older women (Charles, Onuoha, Oso, Agongo, & Ordinocha, 2025). Third, after menopause, women are more susceptible to central obesity and metabolic syndrome than before menopause, and obesity, particularly visceral fat, is a major risk factor for insulin resistance and type 2 diabetes (Lambrinoudaki, Paschou, Armeni, & Goulis, 2022).

The majority of respondents in this study were normotensive (72.9%), while 27.1% had hypertension. The proportion of hypertension comorbidity of 27.1% in this study is much lower than the findings of international literature studies, where hypertension is reported as the most common comorbidity in patients with type 2 diabetes, with a prevalence generally exceeding 50% and often reaching 60–80% in various countries and care settings, both in individual studies and systematic reviews (Akın & Bölük, 2020). This difference may be due to several factors, including study inclusion criteria that may have excluded patients with uncontrolled hypertension, differences in population characteristics, or the effectiveness of hypertension management at the health facilities where the studies were conducted.

A recent study showed that the sequence of events between DM and hypertension influences the risk of cardiovascular disease, with those who developed DM first and then hypertension having a higher risk of myocardial infarction and ischemic stroke (Park, Han, Lee, Chang, & Shin, 2025). This highlights the importance of close monitoring and integrative management in patients with this dual morbidity. From a nursing perspective, patients with comorbid type 2 DM and hypertension require a

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holistic approach that includes education on lifestyle modifications, close blood pressure and blood glucose monitoring, complex medication management, and routine screening for cardiovascular and renal complications. The role of nurses as educators and care coordinators is crucial in improving outcomes for patients with this comorbid condition (ElSayed, Aleppo, Aroda, Bannuru, Brown, Bruemmer, & Gabbay, 2022).

The distribution of glycemic control in this study showed a balanced proportion, with 50% of respondents having controlled HbA1c and 50% having uncontrolled HbA1c. This finding reflects the global challenge in achieving glycemic control targets in patients with type 2 diabetes. According to analysis of National Health and Nutrition Examination Survey (NHANES) data in the United States, the proportion of diabetes patients achieving the target HbA1c of <7% is still limited; in patients using insulin, only around 25–35% managed to achieve HbA1c <7% depending on the survey period and insulin regimen (Hankosky, Schapiro, Gunn, Lubelczyk, Mitroi, & Nelson, 2023). This condition is in line with findings from various countries in Asia, where the success rate of optimal glycemic control in patients with type 2 diabetes generally only ranges from around Suboptimal glycemic control can be caused by a variety of complex and multifactorial factors. These factors can be categorized into patient-related factors (non-adherence to medication, lack of knowledge about the disease, unhealthy lifestyle, economic problems in accessing medication), disease-related factors (long duration of diabetes, progressive decline in pancreatic beta cell function), treatment-related factors (drug side effects, complex regimens, costs), and health system factors (access to healthcare, quality of diabetes education, continuity of care) (Khunti, Gomes, Pocock, Shestakova, Pintat, Fenici, & Medina, 2018).

The results showed that 61.4% of respondents had normal ESR values, while 38.6% had elevated ESR. The proportion of patients with elevated ESR, which reached nearly 40%, is an important finding indicating the presence of a systemic inflammatory process in the majority of type 2 DM patients in this study. This finding is consistent with previous research showing that type 2 DM patients often experience elevated inflammatory markers, including

ESR (Elbaruni, Abdulwahed, Khalfalla, Alsudany, Jerbi, Alwaseea, & Abuagela, 2023). Elevated ESR in type 2 DM patients reflects the presence of chronic low-grade inflammation, which is an important characteristic of the pathophysiology of type 2 DM. This chronic inflammation is associated with insulin resistance, beta cell dysfunction, and the development of diabetic complications. Chronic hyperglycemia induces oxidative stress and the formation of advanced glycation end products (AGEs), which further activates inflammatory pathways through the activation of nuclear factor- κ B (NF- κ B) and the production of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor- α (TNF- α) (Berbudi, Rahmadika, Tjahjadi, & Ruslami, 2020).

Spearman correlation analysis in the normotensive group showed a strong positive correlation between HbA1c levels and ESR values ($p=0.626$; $p=0.000$). This finding indicates that in patients with type 2 diabetes without hypertension, increased HbA1c levels are associated with increased ESR values. The correlation coefficient of 0.626 is categorized as a strong correlation (Dancey & Reidy, 2007), indicating that the degree of chronic hyperglycemia has a significant and substantial relationship with increased systemic inflammatory status, in line with the concept that chronic dysglycemia and hyperglycemia act as "fuel" that maintains a low-grade inflammatory state in diabetes and exacerbates target organ damage (Galantini, Ribeiro, Gonçalves, Muniz, Lima, Santos, & da Silva, 2022). This positive relationship can be explained by several pathophysiological mechanisms. Chronic hyperglycemia, reflected in high HbA1c levels, increases the production of reactive oxygen species (ROS) through various glucose metabolic pathways and disrupts the balance of the antioxidant system, resulting in prolonged oxidative stress. This oxidative stress then activates inflammatory pathways, including the activation of NF- κ B as a major transcription factor that regulates the expression of various pro-inflammatory and pro-oxidant genes in hyperglycemia and type 2 diabetes (González, Lozano, Ros, & Solano, 2023).

The findings of this study are consistent with previous research showing a relationship between glycemic control and inflammatory markers. In a

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cross-sectional study of 41 patients with type 2 diabetes, it was found a significant association between HbA1c levels and ESR, where patients with HbA1c >7.5% were more likely to have a higher ESR (Elbaruni et al., 2023). Another research also showed a significant positive correlation between HbA1c and inflammatory markers, including hs-CRP, reinforcing the concept that poor glycemic control is associated with increased systemic inflammatory status (Berbudi et al., 2020). The coefficient of determination ($r^2=0.392$) indicated that the HbA1c variable could explain approximately 39.2% of the variability in ESR values in the normotensive group. Although there was still 60.8% of the variability explained by factors other than HbA1c, the contribution of HbA1c to ESR was quite substantial. Other factors that may contribute to ESR/LED variability in people with diabetes include the duration of diabetes, the degree of adiposity, especially central obesity associated with metabolic syndrome, smoking habits, physical activity levels, dietary intake patterns and quality, the presence of metabolic comorbidities such as dyslipidemia or metabolic syndrome, as well as genetic susceptibility and gene-lifestyle interactions that influence metabolic and inflammatory profiles (Ceriello & Praticchizzo, 2021).

The clinical implications of these findings are significant for nursing practice. In patients with type 2 diabetes without hypertension, HbA1c monitoring is not only crucial for assessing glycemic control but can also provide an indirect indication of the patient's inflammatory status. Persistently elevated HbA1c may indicate the need for further evaluation of inflammatory parameters and a higher risk of complications. Conversely, efforts to lower HbA1c through pharmacological therapy (such as metformin, which has anti-inflammatory effects) and lifestyle modifications (healthy diet, regular physical activity, weight management) may also have a positive impact on reducing inflammation levels, as reflected in lower ESR values (Cameron, Morrison, Levin, Mohan, Forteach, Beall, & Rena, 2016).

In the hypertension group, Spearman correlation analysis showed a higher correlation coefficient ($p=0.701$; $p=0.001$) compared to the normotensive group ($p=0.626$), indicating a very strong positive correlation between HbA1c levels and ESR values. These findings suggest that in patients with type 2

diabetes with comorbid hypertension, the relationship between glycemic control and inflammatory status is even stronger than in patients without hypertension. The stronger correlation in the hypertension group can be explained by the concept of a "double hit," or the synergistic effect of both conditions on inflammatory pathways. Hypertension itself is a condition associated with vascular inflammation, endothelial dysfunction, and activation of the renin-angiotensin-aldosterone system (RAAS), which also has pro-inflammatory effects (Caillon, Paradis, & Schiffrin, 2019). When combined with chronic hyperglycemia, which is also pro-inflammatory, there is a greater amplification of the inflammatory process compared to each condition alone.

Research confirmed that diabetes and hypertension share complex pathophysiological mechanisms, including inflammation, oxidative stress, and endothelial dysfunction (Argano & Scaglione, 2025). The combination of these two conditions increases the risk of cardiovascular and kidney disease multiplicatively, not simply additively. Hyperglycemia in patients with hypertension exacerbates pre-existing endothelial dysfunction, increases arterial stiffness, and promotes atherosclerosis through a perpetuating inflammatory pathway. The higher coefficient of determination in the hypertensive group ($r^2=0.491$) indicates that HbA1c can explain approximately 49.1% of the variability in ESR values, compared with 39.2% in the normotensive group. This difference of approximately 10% indicates that in patients with hypertension, HbA1c plays a slightly greater role in determining the level of inflammation as measured by ESR. This is likely because in patients with dual morbidity, glycemic control becomes a more determinant factor in inflammatory status, given that both conditions (diabetes and hypertension) contribute to the same inflammatory pathway.

The clinical implications of these findings are significant. In patients with type 2 diabetes mellitus (DM) and comorbid hypertension, optimal glycemic control is crucial not only for preventing DM complications but also for controlling systemic inflammation that can worsen cardiovascular conditions. Research suggests that improving glycemic control in patients with hypertension can reduce inflammatory markers and improve endothelial

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function. A comparison of the correlation strength between the two groups revealed an interesting finding: the hypertensive group showed a stronger correlation ($p=0.701$) than the normotensive group ($p=0.626$), with a difference in correlation coefficient of 0.075. Although both groups showed a significant and strong correlation, this difference indicates that the presence of comorbid hypertension strengthens the relationship between glycemic control and inflammatory status.

The finding that both groups exhibited a strong and significant correlation has fundamental implications for understanding the pathophysiology of type 2 diabetes. This demonstrates that the relationship between chronic hyperglycemia and inflammation is consistent and robust, regardless of the presence or absence of comorbid hypertension. This confirms the concept that chronic low-grade inflammation is an integral component of the pathophysiology of type 2 diabetes, not merely an epiphenomenon or secondary consequence (Galantini et al., 2022).

However, the higher correlation strength in the hypertension group suggests that comorbid hypertension contributes additionally to the inflammatory pathway. This is in line with the concept of the "multiple hit" model in the pathogenesis of diabetic complications, in which the major cardiovascular risk factors chronic hyperglycemia, hypertension, dyslipidemia, and obesity/central obesity often coexist, interacting through oxidative stress pathways, endothelial dysfunction, and chronic low-grade inflammation, so that their atherogenic and cardiotoxic effects reinforce each other and accelerate the development of cardiovascular disease in diabetes (Zakir, Ahuja, Surksha, Sachdev, Kalariya, Nasir, & Ali, 2023). Research showed that patients with the combination of DM and hypertension have a significantly higher cardiovascular risk compared to those with each condition alone, which can be partly explained by higher levels of systemic inflammation (Park et al., 2025).

The difference in the coefficient of determination between the two groups (39.2% vs. 49.1%) indicates that in patients with hypertension, factors other than HbA1c have a relatively smaller contribution to ESR variability than in the normotensive group. This may be because in the hypertensive group, the synergistic

interaction between hyperglycemia and hypertension becomes the primary driver of inflammation, thereby reducing the relative contribution of other factors. Alternatively, this may reflect that in the group with comorbidities, glycemic control becomes a bottleneck or limiting factor that is more determinant of overall inflammatory status.

These findings have important practical implications for risk stratification and management. Patients with type 2 diabetes and comorbid hypertension should be considered a high-cardiovascular risk group requiring more intensive management and HbA1c reduction below guideline-recommended target values, with an individualized approach based on age, diabetes duration, comorbidities, and estimated long-term CVD risk (Bertoluci, Silva Junior, Valente, Araujo, Lyra, de Castro, & Carvalho, 2023). From a research perspective, these findings open the door to further study of the molecular mechanisms underlying the interaction between hyperglycemia and hypertension in triggering inflammation. Prospective studies measuring more specific inflammatory markers (such as IL-6, TNF- α , hs-CRP) could provide a deeper understanding of the inflammatory pathways involved. Interventional studies evaluating the effect of improved glycemic control on inflammatory markers in groups with and without hypertension would also be valuable for testing causal hypotheses and identifying the most effective intervention strategies.

CONCLUSION

The results of the study showed that the relationship between HbA1c and ESR with Hypertension Status: no significant differences were found in HbA1c levels ($p=0.746$) or ESR values ($p=0.259$) between the hypertensive and normotensive groups. However, there was a clinical trend approaching significance in ESR, where the hypertensive group had a higher proportion of normal ESR (78.9% and 54.9%; $p=0.066$). Correlation of HbA1c with ESR: The main finding of this study was a strong and highly significant positive correlation between HbA1c and ESR in both groups: Normotension: $p=0.626$; $p<0.001$ (strong correlation) and Hypertension: $p=0.701$; $p<0.001$ (very strong correlation). This suggests that poor glycemic control is correlated with higher levels of inflammation, with a

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The relationship between HbA1c levels and erythrocyte sedimentation rate in type 2 diabetes mellitus patients based on hypertension status

greater strength of association in Type 2 DM patients with comorbid hypertension. HbA1c may be an indirect predictor of inflammatory status. Optimal glycemic control is important to suppress the risk of cardiovascular complications through anti-inflammatory mechanisms, especially in patients with hypertension who require more comprehensive management.

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