Research Article
Sciences of Pharmacy

Comparative Glycemic Effectiveness of Long- and Rapid-Acting Insulin in Patients with Type 2 Diabetes Mellitus

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[The author informations are in the declarations section. This article is published by ETFLIN in Sciences of Pharmacy, Volume 4, Issue 4, 2025, Page 338-344. DOI 10.58920/sciphar0404502]

Received: 06 November 2025
Revised: 12 December 2025
Accepted: 22 December 2025
Published: 31 December 2025

Editor: Taehwan Park

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Keywords: Type 2 diabetes mellitus, Insulin effectiveness, Glycemic control.

Abstract: Insulin therapy is essential for managing type 2 diabetes mellitus (T2DM), particularly in patients who fail to achieve glycemic targets with oral antidiabetic agents. Long-acting insulin is primarily used to control basal glucose levels, while rapid-acting insulin targets postprandial hyperglycemia. However, comparative real-world evidence regarding their effectiveness on glycated hemoglobin (HbA1c) and fasting blood glucose (FBG) remains limited. This study aimed to evaluate and compare the effectiveness of long-acting and rapid-acting insulin in improving HbA1c and FBG levels among patients with T2DM. A retrospective before–and–after observational study was conducted involving 122 T2DM patients treated at the outpatient unit of Majalaya Regional General Hospital between January and December 2024. Patients received either long-acting insulin (e.g., insulin glargine) or rapid-acting insulin (e.g., insulin lispro and insulin aspart) as monotherapy. Changes in HbA1c and FBG before and after therapy were analyzed using paired t-tests or Wilcoxon signed-rank tests. Clinical effectiveness was defined according to American Diabetes Association criteria as a reduction of ≥1% in HbA1c or ≥30 mg/dL in FBG. Insulin therapy significantly reduced HbA1c (-7.77 ± 3.09, $p < 0.001$) and FBG levels ($Z = -5.53$, $p < 0.001$). Based on ADA criteria, 90.3% of patients achieved an effective reduction in HbA1c, while 43.5% achieved an effective reduction in FBG. Insulin lispro and insulin glargine showed the highest HbA1c-based effectiveness (100%), whereas FBG-based effectiveness varied across formulations. Insulin therapy significantly improves long-term and short-term glycemic control in T2DM patients, with insulin lispro and insulin glargine demonstrating the most consistent effectiveness.

Introduction

Type 2 diabetes mellitus (T2DM) remains a major clinical challenge because a large proportion of patients fail to achieve recommended glycemic targets in routine clinical practice. Evidence from real-world studies indicates that many individuals with T2DM continue to have poor glycemic control, as reflected by persistently elevated glycated hemoglobin (HbA1c) levels and fasting blood glucose (FBG) concentrations (1). Inadequate control of these glycemic markers significantly increases the risk of microvascular complications such as neuropathy and retinopathy, as well as macrovascular events, including cardiovascular disease (2). Poor target achievement is often observed even among patients receiving pharmacological treatment, indicating limitations in current therapeutic strategies (3). This condition underscores the need for more effective and targeted interventions to optimize glycemic outcomes (4). Therefore, evaluating therapies that directly influence key glycemic markers remains clinically relevant.

Insulin therapy plays a crucial role in the management of T2DM, particularly in patients who do not achieve adequate glycemic control with oral antidiabetic agents. Insulin directly lowers blood glucose levels by suppressing hepatic glucose production and enhancing glucose uptake in peripheral tissues. Previous studies have demonstrated that insulin therapy is effective in reducing HbA1c levels over sustained treatment periods, reflecting improved long-term glycemic control (1,5). In addition, insulin contributes to lowering fasting blood glucose by stabilizing basal glucose regulation, especially through long-acting formulations. These pharmacological effects make insulin an essential therapeutic option for patients with poorly controlled diabetes. Consequently, insulin remains a cornerstone therapy in advanced stages of T2DM management (5).

HbA1c and fasting blood glucose were selected as key variables in this study because they represent complementary indicators of glycemic control. HbA1c reflects the average blood glucose concentration over the previous two to three months and is widely used to evaluate long-term treatment effectiveness (6). This marker is strongly associated with the risk of diabetes-related complications and is commonly used as a primary therapeutic target. In contrast, fasting blood glucose reflects

short-term glycemic regulation and provides insight into basal glucose control. Fasting glucose levels are particularly sensitive to insulin therapy, especially long-acting insulin formulations (5). Assessing both parameters allows a more comprehensive evaluation of insulin effectiveness in clinical practice.

Research by Vonna *et al*. found that 92.1% of information on insulin pen usage was obtained from physicians, with 56.8% of respondents demonstrating good knowledge (6). However, 97.7% of respondents still injected insulin pens incorrectly. Such improper use could result in hyperglycemic or hypoglycemic crises. This highlights the importance of proper insulin administration to ensure treatment effectiveness and patient safety. Such errors can result in hyperglycemic or hypoglycemic crises, compromising treatment outcomes and patient safety. This issue is particularly relevant among middle-aged and older adults, who often experience age-related declines in vision, manual dexterity, and cognitive function that may hinder accurate insulin administration. Furthermore, physiological changes in insulin sensitivity and renal function in older adults can alter pharmacodynamic responses, increasing the risk of both poor glycemic control and hypoglycemia. These factors highlight the importance of evaluating the real-world effectiveness of different insulin formulations in this age group to ensure both therapeutic efficacy and safety.

Despite the established role of insulin therapy in type 2 diabetes mellitus, real-world evidence shows that many patients fail to achieve recommended glycemic targets after insulin initiation. Previous studies have largely focused on controlled trial settings or relied on a single glycemic marker, mainly HbA1c, with limited evaluation of fasting blood glucose (FBG) as a complementary indicator of basal glycemic control. Moreover, real-world data comparing the effectiveness of long-acting and rapid-acting insulin used as monotherapy in outpatient settings remains scarce, highlighting the need for comprehensive evaluations using both HbA1c and FBG.

Methodology

This study employed a retrospective, paired before–after observational design using secondary data obtained from medical records of patients with type 2 diabetes mellitus (T2DM). The comparison groups in this study were defined based on insulin pharmacological classification rather than treatment combinations. Patients were categorized into long-acting insulin monotherapy and rapid-acting insulin monotherapy groups to ensure comparability of therapeutic indications. No comparisons were made between insulin monotherapy and combination insulin regimens. This classification was applied to minimize clinical heterogeneity and to allow a meaningful evaluation of insulin effectiveness across pharmacologically distinct insulin classes. Such grouping is consistent with prior real-world studies evaluating insulin outcomes based on insulin action profiles. Outcome measures were assessed using standardized clinical criteria.

Study Population and Sampling

The study population comprised all patients diagnosed with T2DM who received insulin therapy during the study period. A total of 122 eligible patients were included using a total sampling approach. Inclusion criteria were: [1] male or female patients aged ≥40 years; [2] confirmed diagnosis of type 2 diabetes mellitus; [3] receipt of insulin monotherapy for at least three months; and [4] complete medical records containing HbA1c and FBG measurements before and after therapy. Exclusion criteria were incomplete data, discontinuation of insulin therapy, or concurrent use of other injectable or oral antihyperglycemic agents during the observation period. No formal sample size calculation was performed, as all eligible patients meeting the inclusion criteria were included to maximize statistical power.

Before initiating insulin monotherapy, all patients had a documented history of treatment with oral antidiabetic agents. The majority of patients had received one or more oral therapies, including metformin or sulfonylureas, but failed to achieve adequate glycemic control. Insulin therapy was initiated based on persistent hyperglycemia or elevated HbA1c levels despite oral treatment. Patients who received concurrent injectable or oral antihyperglycemic agents during the observation period were excluded to ensure that glycemic changes could be attributed primarily to insulin therapy. This approach allowed a clearer assessment of insulin effectiveness in routine clinical practice. Treatment history was verified through review of prescription and medical records.

Data Collection

Laboratory data for HbA1c and fasting blood glucose were collected retrospectively from electronic medical records. Baseline measurements were obtained within one month before the initiation of insulin therapy. Follow-up laboratory assessments were performed after a minimum of three months of continuous insulin treatment, corresponding to the recommended interval for evaluating HbA1c response. All patients included in the analysis adhered to this testing interval, ensuring consistency in outcome evaluation. Patients with laboratory measurements outside this predefined timeframe were excluded. This standardized assessment period allowed for reliable comparison of pre- and post-treatment glycemic outcomes.

HbA1c and fasting blood glucose (FBG) were used as indicators of glycemic control in accordance with the American Diabetes Association (ADA) Standards of Care 2025. HbA1c control was defined as achievement toward individualized treatment targets, generally ≤7% for most non-pregnant adults, while improvement in fasting blood glucose toward recommended targets of 80–130 mg/dL was considered indicative of effective basal glycemic control. Clinical effectiveness of insulin therapy was evaluated based on changes in HbA1c and FBG from baseline rather than reliance on a single absolute threshold, in line with current ADA recommendations emphasizing individualized glycemic goals.

Fasting blood glucose was measured in the morning after an overnight fast of at least eight h to ensure stable physiological conditions and minimize short-term variability. This timing is particularly relevant for evaluating insulin effectiveness, as fasting glucose reflects hepatic glucose production and basal insulin activity. Long-acting insulin formulations primarily exert their therapeutic effect during fasting states, making FBG a clinically meaningful complementary indicator to HbA1c. The combined assessment of HbA1c and FBG provides a comprehensive evaluation of long-term and short-term glycemic control.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics

version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize patient characteristics, insulin usage patterns, and glycemic outcomes. Continuous variables were expressed as means ± standard deviations, while categorical variables were presented as frequencies and percentages. The Kolmogorov–Smirnov test was applied to assess data normality. For normally distributed variables, comparisons between pre- and post-therapy values were analyzed using the paired-sample t-test; for non-normally distributed variables, the Wilcoxon signed-rank test was used. Statistical significance was set at $p < 0.05$. Subgroup analyses were performed to compare insulin effectiveness across different formulations and classes based on ADA criteria.

Ethical Considerations

This study was approved by the Ethics Committee of Universitas Bhakti Kencana (Approval No.083/09.KEPK/UBK/VI/2025) and conducted in accordance with the ethical principles of theDeclaration of Helsinki. As this was a retrospective analysis, informed consent was waived bythe ethics committee. All data were anonymized, and patient confidentiality was strictlymaintained throughout the research process.

Results

Patient Characteristics and Glycemic Outcomes

A total of 122 patients with type 2 diabetes mellitus were included in the study, consisting of 70 females (57.4%) and 52 males (42.6%). The majority of participants were aged 51–60 years (68.0%), followed by 31.0% aged 40–50 years, and only 1.0% aged above 60 years. Regarding insulin therapy, rapid-acting formulations were more frequently used (61.5%) than long-acting types (38.5%). Among specific preparations, insulin glargine injection (30.3%) and insulin lispro (28.7%) were the most commonly administered, followed by insulin aspart injection (19.7%), insulin aspart (13.1%), and insulin glargine (8.2%).

Insulin glargine and insulin glargine G5 were categorized separately because they represent different formulations with distinct delivery systems and clinical use contexts. Insulin glargine G5 refers to a biosimilar formulation administered via prefilled injection devices, whereas insulin glargine refers to standard formulations documented in medical records. Similarly, insulin aspart and insulin aspart injection were differentiated to reflect differences in delivery method and prescription patterns. These distinctions were maintained to accurately capture real-world prescribing practices rather than to compare insulin brands. Importantly, this study did not aim to compare commercial insulin brands, but rather to evaluate glycemic outcomes across insulin action profiles. Therefore, separation of these categories was necessary for descriptive accuracy.

Rapid-acting insulin was primarily prescribed to manage postprandial hyperglycemia, particularly in patients with elevated blood glucose levels following meals. This insulin class provides a rapid onset of action that closely mimics physiological insulin secretion. In contrast, long-acting insulin was prescribed to maintain basal glycemic control by suppressing hepatic glucose production during fasting periods. Long-acting insulin is commonly indicated in patients with persistent fasting hyperglycemia or elevated HbA1c despite oral therapy. These prescribing patterns align with established clinical guidelines for insulin initiation and intensification. Thus, insulin class selection in this study reflects standard clinical indications rather than experimental allocation. Patient characteristics are shown in **Table 1**.

All patients received insulin as monotherapy during the study period. Insulin formulations were grouped based on pharmacological class (long-acting and rapid-acting insulin). HbA1c and fasting blood glucose values were measured before insulin initiation and after a minimum of three months of continuous therapy.

Before insulin initiation, the majority of patients exhibited uncontrolled glycemic profiles, with 97.6% having elevated HbA1c levels, and 82.8% showing uncontrolled fasting blood glucose. Following insulin therapy, substantial improvements were observed: the proportion of patients with controlled HbA1c increased from 2.4% to 58.1%, while those with controlled fasting glucose rose from 17.2% to 63.9%. These findings indicate that insulin therapy, across various formulations, markedly improved glycemic control among patients attending the outpatient unit of Majalaya Regional General Hospital.

Among the 122 patients included in this study, all received insulin as monotherapy during the observation period, and no patient was treated with combination insulin regimens. Patients were grouped based on insulin pharmacological class, namely long-acting and rapid-acting insulin, to ensure comparability of therapeutic indications. This classification avoids bias that may arise from comparing single-agent therapy with combination regimens. Baseline and follow-up HbA1c and fasting blood glucose values were obtained for each patient, allowing paired analysis of glycemic outcomes before and after insulin initiation. Therefore, observed reductions in HbA1c and fasting blood glucose can be attributed to single-agent insulin therapy. This approach strengthens the internal validity of the treatment effectiveness analysis.

Effectiveness of Insulin Therapy Based on HbA1c and Fasting Blood Glucose

As shown in **Figure 1**, insulin therapy demonstrated high clinical effectiveness when assessed by HbA1c reduction, with 90.3% of patients achieving a decrease of ≥1% from baseline. In contrast, only 43.5% of patients reached the fasting blood glucose reduction threshold of ≥30mg/dL, while 56.5% remained not effective by this criterion. These findings suggest that although insulin therapy substantially improved overall glycemic control, the HbA1c response rate was more robust than that observed for fasting glucose, indicating differential sensitivity of short-term and long-term glycemic parameters to insulin treatment. This difference reflects the cumulative nature of HbA1c compared with the higher variability of fasting blood glucose. Overall, insulin therapy showed greater effectiveness in improving long-term glycemic control than short-term fasting glucose measures. These findings indicate that different glycemic indicators capture distinct aspects of treatment response. Therefore, interpreting insulin effectiveness may require consideration of both HbA1c and fasting blood glucose parameters. This pattern suggests that improvements in overall glycemic exposure may be detected earlier than stabilization of fasting glucose levels. Consequently, variation between these indicators should be considered when evaluating short-term treatment outcomes.

Table 1. Baseline characteristics and glycemic profiles of patients with type 2 diabetes mellitus receiving single-agent insulin therapy, categorized by insulin class.

Characteristics	Amount	Percentage (%)
Gender		
Female	70	57.4
Male	52	42.6
Age		
40 - 50 years old	38	31.0
51- 60 years old	83	68.0
More than 60 years old	1	1.0
Insulin Type		
Insulin Glargine	10	8.2
Insulin Aspart	16	13.1
Insulin Lispro	35	28.7
Insuin Aspart Inj	24	19.7
Insulin Glargine Inj	37	30.3
Insulin Class		
Long-Acting Insulin	47	38.5
Rapid-Acting Insulin	75	61.5
Before Insulin Therapy		
HbA1c		
Controlled	3	2.4
Uncontrolled	119	97.6
Fasting Blood Sugar		
Controlled	21	17.2
Not controlled	101	82.8
After Insulin Therapy		
HbA1c		
Controlled	71	58.1
Uncontrolled	51	41.9
Fasting Blood Sugar		
Controlled	78	63.9
Not controlled	44	36.1

Comparative Effectiveness Among Different Insulin Types

Normality testing indicated that HbA1c values were normally distributed ($p = 0.200$), whereas fasting blood glucose values were not ($p = 0.005$). Accordingly, differences in HbA1c before and after therapy were analyzed using a paired-sample t-test, and fasting glucose differences were analyzed using the Wilcoxon test. For each insulin formulation, HbA1c decreased significantly following treatment (all $p < 0.001$), with mean reductions ranging from −6.2% for insulin aspart to −8.1% for insulin lispro and −7.9% for insulin glargine. Fasting blood glucose levels also declined significantly across all formulations ($Z = -4.87$ to -5.61, $p < 0.001$), although the magnitude of reduction varied by insulin type.

The classification presented in the "Changes" column of **Table 2** and **Table 3** reflects the proportion of patients achieving clinically meaningful improvement based on guideline-oriented targets. Effectiveness was categorized as high, moderate, or low according to the percentage of patients demonstrating improvement toward recommended glycemic goals. This classification was applied uniformly across all insulin formulations to facilitate comparative interpretation of treatment outcomes. The operational definition and rationale for this classification are described in detail in the Methods section under Operational Definitions. Importantly, this categorization does not indicate treatment superiority between insulin brands, but rather summarizes the magnitude of observed clinical response. This approach allows a structured comparison of glycemic effectiveness across insulin classes.

Clinical effectiveness was evaluated based on the proportion of patients demonstrating improvement toward guideline-recommended HbA1c targets. The classification of changes (high, moderate, low) reflects the percentage of patients showing clinically meaningful HbA1c reduction within each insulin group. No combination insulin therapy was included in this analysis.

Based on ADA clinical criteria, a reduction of ≥ 1% in HbA1c or ≥ 30 mg/dL in fasting glucose, HbA1c-based effectiveness was highest among patients receiving insulin lispro monotherapy and insulin glargine monotherapy, with all patients in these groups demonstrating clinically meaningful improvement, followed by insulin aspart injection (95.8%), insulin glargine injection (88.8%), and insulin aspart (70.6%). In contrast, fasting glucose effectiveness was lower, ranging from 54.3% for lispro to 28% for glargine injection.

Fasting blood glucose was measured after an overnight fast of at least eight h. Clinical effectiveness reflects improvement toward recommended fasting glucose targets. The classification of changes summarizes the proportion of patients achieving meaningful fasting glucose improvement within each insulin formulation group.

These findings demonstrate statistically significant improvements in both long-term (HbA1c) and short-term (fasting glucose) glycemic parameters across all insulin formulations. However, the magnitude of response differed significantly between insulin types ($p < 0.05$), with lispro and glargine showing the most consistent glycemic benefits. These differences may be related to variations in the pharmacokinetic and pharmacodynamic profiles of insulin formulations, which affect glucose-lowering stability and onset of action. The findings underscore the importance of considering insulin type when interpreting glycemic outcomes in clinical practice. These results highlight that individual insulin characteristics can influence treatment response even within standardized dosing protocols. Clinicians should consider these pharmacological differences when individualizing insulin therapy.

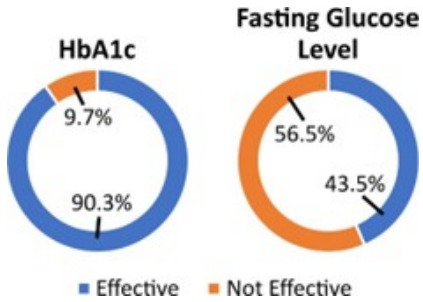

Figure 1. Proportion of insulin effectiveness based on HbA1c and fasting blood glucoselevels among patients with type 2 diabetes mellitus. Insulin therapy was considered effective when HbA1c decreased by ≥1% and fasting blood glucose decreased by ≥30 mg/dL from baseline, according to ADA criteria.

Table 2. HbA1c-based clinical effectiveness of single-agent insulin therapy among patients with type 2 diabetes mellitus.

No.	Insulin content	Effectiveness		Total	Changes
		Effective	Not Effective		
1.	Insulin Glargine-G@5	10 (100%)	0 (0%)	10	High
2.	Insulin Aspart@5	12 (70,6%)	5 (29,4%)	17	Moderate
3.	Insulin Lispro	35 (100%)	0 (0%)	35	High
4.	Insulin Aspart Inj Flexpen Inj	23 (95,8%)	1 (4,2%)	24	High
5.	Insulin Glargine inj	32 (88,8%)	4 (11,2%)	36	High
Total		**112 (90,3%)**	**10 (9,7%)**	**122 (100%)**	

ADA criterion: HbA1c decrease ≥1% from baseline.

Table 3. Fasting blood glucose–based clinical effectiveness of single-agent insulin therapy among patients with type 2 diabetes mellitus.

No	Insulin Content	Effectiveness		Total	Changes
		Efective	Not Efective		
1	Insulin Glargine-G @5	3 (30%)	7 (70%)	10	Low
2	Insulin Aspart@5	9 (52,9%)	8 (47,1%)	17	Moderate
3	Insulin Lispro	19 (54,3%)	16 (45,7%)	35	Moderate
4	Insuin Aspart Inj Flexpen Inj	12 (50%)	12 (50%)	24	Moderate
5	Insulin Glargine Inj	10 (28%)	26 (71,1%)	36	Low
Total		**53 (43,5%)**	**69 (56,5%)**	**122 (100%)**	

ADA criterion: fasting blood glucose decrease ≥30 mg/dL from baseline.

Discussion

This study demonstrates that insulin monotherapy significantly improves glycemic control among patients with type 2 diabetes mellitus (T2DM) treated in an outpatient setting. Most patients experienced meaningful reductions in HbA1c following insulin initiation, indicating effective long-term glycemic control. In contrast, improvements in fasting blood glucose were less pronounced, suggesting that short-term glycemic regulation remains more challenging. These findings confirm that insulin therapy is particularly effective in stabilizing chronic hyperglycemia, while fasting glucose outcomes may be influenced by additional clinical and behavioral factors. Importantly, all observed glycemic improvements were derived from single-agent insulin therapy, strengthening the validity of the findings.

The demographic profile of patients in this study aligns with previous research showing that older adults and women represent high-risk groups for T2DM. A higher proportion of female patients was observed, consistent with studies reporting increased diabetes susceptibility among women due to hormonal changes, particularly post-menopause, which contribute to insulin resistance and lipid metabolism disturbances (7, 8). Although some studies report inconsistent associations between gender and diabetes incidence (9), the current findings support the role of gender and age as important background characteristics. Most patients were aged 51–60 years, which is consistent with physiological evidence that aging reduces pancreatic beta-cell function and insulin sensitivity, thereby impairing glucose regulation (10). National data also corroborate that a large proportion of T2DM patients belong to older age groups (11).

Regarding insulin utilization, insulin glargine injection was the most frequently prescribed formulation, followed by insulin lispro and insulin aspart injection. The widespread use of insulin glargine may be attributed to its affordability, availability, and suitability for long-term basal glycemic control. Although rapid-acting insulins such as lispro and aspart were less frequently prescribed due to cost and access constraints, many patients relied on these formulations to manage postprandial hyperglycemia. Rapid-acting insulin mimics physiological insulin secretion following meals and is effective in controlling postprandial glucose excursions (12, 13). Meanwhile, long-acting insulin provides stable basal insulin levels, suppressing hepatic glucose production and maintaining glycemic stability throughout the day (13). These prescribing patterns reflect a combination of clinical indications, patient needs, and economic considerations.

The effectiveness of insulin therapy was more evident in HbA1c outcomes than in fasting blood glucose control. Before insulin therapy, nearly all patients exhibited uncontrolled HbA1c levels; however, more than half achieved controlled HbA1c after treatment, with most patients demonstrating clinically meaningful improvement according to established standards (12). These results are consistent with previous studies showing that insulin effectively reduces HbA1c and lowers the risk of long-term complications such as neuropathy, retinopathy, and cardiovascular disease(14,15). HbA1c reflects average glucose exposure over several months and is therefore more sensitive to sustained insulin therapy. In contrast, fasting blood glucose showed lower rates of clinical effectiveness, which may be explained by persistent hepatic glucose production, suboptimal adherence, or incorrect insulin administration techniques (17,18).

Variations in effectiveness across insulin formulations were observed; however, these differences should not be interpreted as direct comparisons between insulin brands (19,20). Differences in glycemic response are more likely related to pharmacokinetic properties, dosing strategies, and patient adherence rather than the intrinsic superiority of specific products. Rapid-acting insulin formulations demonstrated moderate effectiveness in lowering fasting blood glucose, consistent with their ability to reduce both postprandial and fasting glucose levels (22). Basal insulins such as glargine and detemir contribute to fasting glucose regulation through prolonged suppression of hepatic gluconeogenesis, with biosimilar formulations offering comparable efficacy at lower cost (23). Overall, all insulin formulations evaluated in this study demonstrated at least moderate clinical effectiveness.

Despite these positive findings, this study has several limitations. The retrospective design limits causal

interpretation and relies on the completeness and accuracy of medical records. The single-center setting may restrict the generalizability of the results to broader populations. Additionally, factors such as insulin dose titration, lifestyle modification, and patient adherence were not fully captured. The follow-up period may also have been insufficient to observe optimal fasting glucose stabilization in all patients. Future prospective multicenter studies with longer observation periods are needed to confirm these findings and further evaluate insulin effectiveness across diverse clinical contexts.

Conclusion

This study confirms that insulin monotherapy is an effective therapeutic approach for improving glycemic control in patients with type 2 diabetes mellitus, as reflected by meaningful improvement in long-term and short-term glycemic indicators. However, the variability observed in fasting blood glucose responses suggests that insulin therapy alone may be insufficient to fully optimize glycemic outcomes in all patients. Therefore, complementary interventions such as structured patient education, lifestyle modification, adherence support, and individualized insulin titration should be considered to enhance the overall effectiveness of diabetes management.

Declarations

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Conflict of Interest

The authors declare no conflicting interest.

Data Availability

The datasets generated during this study are not publicly available due to privacy but may be available from the corresponding author on reasonable request.

Ethics Statement

This study was approved by the Ethics Committee of Universitas Bhakti Kencana (Approval No. 083/09.KEPK/UBK/VI/2025) and conducted in accordance with the ethical principles of the Declaration of Helsinki.

Funding Information

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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Additional Information

How to Cite

Entris Sutrisno, Marita Kaniawati, Ilmi Intan Maharani, Jajang Japar Sodik. Comparative Glycemic Effectiveness of Long- and Rapid-Acting Insulin in Patients with Type 2 Diabetes Mellitus. *Sciences of Pharmacy*. 2025;4(4):338-344

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