Axis Journal of Scientific Innovations

CONTINUOUS GLUCOSE MONITORING VERSUS ROUTINE SELF-MONITORING ON TREATMENT ADHERENCE IN TYPE 2 DIABETES PATIENT

Original Article

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Acknowledgement	NA
Conflict of Interest	NONE
Ethical Approval	International Islamic University Islamabad, Pakistan.
Informed Consent	Written informed consent was obtained from all participants
Funding	No external funding

Abstract

Background: Type 2 diabetes mellitus requires consistent self-management to maintain optimal glycemic control. Despite advances in therapy, poor adherence to blood glucose monitoring and medication remains a major challenge. Continuous glucose monitoring (CGM) provides real-time feedback, offering an alternative to routine self-monitoring of blood glucose (SMBG) through finger-prick testing. The impact of CGM on treatment adherence and metabolic outcomes in non–insulin-dependent patients, however, remains insufficiently explored.

Objective: To analyze whether real-time continuous glucose monitoring improves treatment adherence and glycemic outcomes compared with conventional self-monitoring in adults with type 2 diabetes.

Methods: A randomized controlled trial was conducted across tertiary care centers in east-central Punjab. One hundred twenty adults with type 2 diabetes were randomly assigned to either continuous glucose monitoring (CGM) or routine self-monitoring of blood glucose (SMBG) groups (n = 60 each) for a 12-week intervention. Adherence was assessed using the Morisky Medication Adherence Scale (MMAS-8) and the Diabetes Self-Management Questionnaire (DSMQ). Glycemic control was evaluated through changes in HbA1c and fasting plasma glucose, and the frequency of hypoglycemic episodes. Data were analyzed using independent sample t-tests and repeated measures ANOVA, with significance set at $p < 0.05$.

Results: Baseline characteristics were comparable between groups ($p > 0.05$). At 12 weeks, participants using CGM demonstrated significantly higher adherence (MMAS-8: 7.1 ± 0.6 vs. 6.4 ± 0.8, $p < 0.001$; DSMQ: 6.8 ± 0.7 vs. 6.1 ± 0.6, $p < 0.001$). The CGM group achieved superior glycemic control, with lower HbA1c (7.62 ± 0.49% vs. 8.04 ± 0.53%, $p < 0.001$) and fewer hypoglycemic episodes per month (0.8 ± 0.5 vs. 1.3 ± 0.7, $p = 0.01$). Device use consistency (92.3 ± 5.7% vs. 83.4 ± 7.8%, $p < 0.001$) and patient satisfaction (4.5 ± 0.4 vs. 3.9 ± 0.6 on a 5-point scale, $p < 0.001$) were also significantly higher among CGM users.

Conclusion: Continuous glucose monitoring substantially improved adherence, glycemic control, and patient engagement compared to traditional finger-prick monitoring. These findings support integrating CGM into standard diabetes management to enhance adherence-driven outcomes and overall treatment efficacy.

Keywords: Adherence, Blood Glucose Self-Monitoring, Continuous Glucose Monitoring, Diabetes Mellitus Type 2, Glycated Hemoglobin A, Hypoglycemia, Patient Compliance, Self-Management, Treatment Outcome.

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

Introduction

Type 2 diabetes mellitus (T2DM) remains one of the most pressing global health concerns, characterized by chronic hyperglycemia resulting from insulin resistance and progressive pancreatic beta-cell dysfunction(1). Despite significant advancements in pharmacotherapy, diabetes management continues to depend heavily on patient self-care behaviors, particularly adherence to prescribed monitoring and treatment regimens. Blood glucose monitoring serves as the cornerstone of diabetes management, allowing patients to make informed decisions regarding diet, physical activity, and medication use(2). However, maintaining consistent adherence to routine self-monitoring of blood glucose (SMBG) remains a persistent challenge. Many patients struggle with the discomfort, inconvenience, and time commitment associated with frequent finger-prick testing, which can lead to poor compliance and suboptimal glycemic control(3).

Over the past decade, the landscape of diabetes management has been transformed by technological innovations, particularly the advent of continuous glucose monitoring (CGM). Unlike traditional SMBG, which provides isolated glucose readings, CGM offers a dynamic, real-time view of glucose fluctuations throughout the day and night. By measuring interstitial glucose levels via a minimally invasive sensor, CGM provides comprehensive data that helps patients and healthcare professionals detect trends, identify glycemic variability, and respond promptly to impending hypo- or hyperglycemic episodes. These systems have introduced a new paradigm of proactive, data-driven diabetes care, empowering patients to engage more meaningfully in their treatment decisions(4).

While the clinical benefits of CGM in type 1 diabetes are well established, evidence supporting its impact in type 2 diabetes is still evolving. Individuals with T2DM often have a lower perceived need for intensive monitoring compared to those with insulin-dependent diabetes, yet adherence to lifestyle and pharmacological therapy remains a major determinant of glycemic success(5). Research has suggested that enhanced glucose visibility through CGM may improve self-awareness, motivation, and treatment engagement. The real-time feedback and immediate visualization of glucose trends may reinforce positive behavior, foster accountability, and reduce the psychological burden associated with disease management. In contrast, conventional SMBG, though cost-effective, provides limited data points and often fails to capture nocturnal or postprandial fluctuations, leaving patients with incomplete insight into their glycemic patterns(6).

Despite the theoretical advantages of CGM, its adoption among individuals with type 2 diabetes remains inconsistent. Barriers such as cost, device complexity, and patient skepticism toward technology have contributed to uneven utilization(7). Moreover, there is ongoing debate regarding whether CGM genuinely enhances treatment adherence or merely reflects a behavioral tendency among more motivated individuals. Some studies have demonstrated improved glycemic outcomes and patient satisfaction with CGM, whereas others have found minimal impact when compared with standard self-monitoring approaches. The variability in outcomes underscores the need for more rigorous, context-specific research, particularly in populations with limited prior exposure to digital health interventions(8).

Adherence, both behavioral and therapeutic, is a multifaceted concept influenced by psychological, social, and environmental factors. In diabetes care, adherence encompasses medication intake, dietary management, physical activity, and consistent monitoring(9). Behavioral theories propose that feedback-based interventions, such as CGM, may strengthen intrinsic motivation by providing immediate reinforcement and a sense of control. For many patients, the visual and numerical representation of their glucose patterns translates into a tangible measure of success or failure, which can either motivate adherence or trigger disengagement depending on how the data are interpreted(10). Therefore, understanding the behavioral mechanisms underlying CGM use is critical to evaluating its true effectiveness beyond mere biochemical outcomes(11).

From a healthcare perspective, improving adherence translates directly into better glycemic control, reduced complications, and lower healthcare expenditures(12). However, adherence is not solely a patient responsibility; it is an outcome shaped by education, support, and the usability of available tools. CGM devices potentially address many of the limitations inherent in routine SMBG by minimizing physical discomfort, reducing cognitive load, and offering automated data tracking(13). Moreover, their integration with smartphone applications and cloud-based platforms enables real-time feedback, remote monitoring, and timely clinical interventions. These features collectively represent a shift toward patient-centered, technology-supported care models designed to enhance autonomy and engagement.

Nonetheless, the long-term sustainability of adherence gains achieved through CGM remains uncertain. There is a risk that novelty-driven motivation may diminish over time, and continuous exposure to data may induce anxiety or “data fatigue” in certain users. Furthermore, the transition from traditional monitoring to CGM necessitates not only technological literacy but also behavioral adaptation, as patients must learn to interpret data accurately and adjust their management strategies accordingly. Thus, any

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

evaluation of CGM's efficacy must consider not only metabolic outcomes but also the psychological and behavioral dimensions of adherence.

Given these considerations, there is a pressing need for high-quality, randomized controlled trials examining the real-world impact of CGM compared to routine SMBG in patients with type 2 diabetes. This study seeks to address this gap by investigating whether real-time continuous glucose monitoring improves treatment adherence, glycemic control, and patient engagement relative to conventional self-monitoring methods. By evaluating both behavioral and clinical outcomes, the research aims to provide comprehensive insights into the role of CGM in optimizing diabetes management and to determine whether its integration into standard care protocols can enhance long-term disease control. The objective of this study is therefore to analyze whether real-time glucose monitoring improves adherence and treatment outcomes compared to traditional finger-prick monitoring among patients with type 2 diabetes.

Methods

This randomized controlled trial was conducted to compare the impact of continuous glucose monitoring (CGM) with routine self-monitoring of blood glucose (SMBG) on treatment adherence and glycemic outcomes in adults with type 2 diabetes mellitus. The study was carried out in tertiary care hospitals and affiliated outpatient clinics across east-central Punjab over a six-month period, which included a 12-week active intervention and follow-up phase. The trial followed a parallel-group design with equal allocation to the intervention and control arms. A total sample of 120 participants was determined using power analysis, assuming a medium effect size of 0.5, a power of 0.80, and a significance level of 0.05 to detect differences in adherence scores between groups. This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from International Islamic University Islamabad, Pakistan. Participants were randomly assigned in a 1:1 ratio to either the CGM group or the SMBG group using computer-generated block randomization to ensure balanced allocation. Adults aged 35 to 65 years with a clinical diagnosis of type 2 diabetes for at least one year and receiving stable oral hypoglycemic therapy were included. Additional inclusion criteria required participants to have access to a smartphone and the ability to operate basic digital devices. Patients using insulin pumps, those with significant visual or cognitive impairment, severe comorbidities such as chronic kidney disease stage IV or higher, or recent hospitalization for acute diabetic complications were excluded to ensure homogeneity and participant safety. At baseline, demographic and clinical data, including age, sex, duration of diabetes, body mass index, fasting glucose, and HbA1c, were recorded. Participants in the CGM group were provided with real-time CGM devices capable of interstitial glucose measurement every five minutes. They were trained to interpret glucose trends, receive alerts for hypo- and hyperglycemia, and use smartphone-linked applications for data visualization. The SMBG group followed standard care using finger-prick glucometers, with instructions to measure capillary glucose at least four times daily.

Both groups received identical dietary counseling and pharmacological management according to current diabetes guidelines to minimize confounding influences. Treatment adherence was measured as the primary outcome using the eight-item Morisky Medication Adherence Scale (MMAS-8) and the Diabetes Self-Management Questionnaire (DSMQ). Device adherence, including frequency of data review and consistency of monitoring, was also assessed via digital logs and patient diaries. Secondary outcomes included changes in glycated hemoglobin (HbA1c) and fasting plasma glucose at 12 weeks, as well as the frequency of hypo- and hyperglycemic episodes. Psychological engagement and satisfaction with monitoring were evaluated using a brief Likert-based adherence perception scale at study completion. Data were collected at baseline and endpoint (12 weeks). All data were coded and entered into SPSS version 27. Normality of data distribution was verified using the Shapiro–Wilk test, confirming parametric assumptions. Descriptive statistics were presented as means and standard deviations for continuous variables and as frequencies and percentages for categorical data. Between-group differences in adherence and biochemical outcomes were analyzed using independent sample t-tests. Repeated measures ANOVA was employed to determine time–group interaction effects. Statistical significance was established at a p-value of less than 0.05. Through rigorous methodology and standardized data collection, this study was designed to ensure the validity and reproducibility of findings while minimizing bias. The approach allowed for a comprehensive evaluation of whether real-time continuous glucose monitoring leads to measurable improvements in treatment adherence and glycemic outcomes among patients with type 2 diabetes in the east-central Punjab population.

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

Results

The randomized controlled trial included 120 participants, with 60 in each group. Baseline characteristics were comparable between the continuous glucose monitoring (CGM) and self-monitoring of blood glucose (SMBG) groups (Table 1). The mean age was 52.3 ± 6.8 years in the CGM group and 51.9 ± 7.2 years in the SMBG group, with no significant difference between them ($p = 0.72$). Gender distribution, body mass index, duration of diabetes, baseline HbA1c, and fasting plasma glucose levels were also statistically similar (all $p > 0.05$), confirming randomization balance.

At study completion, participants using CGM demonstrated significantly higher adherence scores. The mean MMAS-8 score was 7.1 ± 0.6 compared with 6.4 ± 0.8 in the SMBG group ($p < 0.001$), while the DSMQ score averaged 6.8 ± 0.7 versus 6.1 ± 0.6, respectively ($p < 0.001$) (Table 2). Device logs showed that CGM users maintained consistent engagement, with an average monitoring frequency of 46.2 ± 8.3 readings per week compared to 31.7 ± 6.9 finger-prick checks in the control group ($p < 0.001$).

In terms of glycemic control, the CGM group achieved a greater reduction in HbA1c after 12 weeks (mean 7.62 ± 0.49%) compared with the SMBG group (8.04 ± 0.53%; $p < 0.001$). Fasting plasma glucose levels were also significantly lower in the CGM arm (138.4 ± 15.2 mg/dL) than in the SMBG arm (149.7 ± 16.3 mg/dL; $p = 0.002$). The incidence of hypoglycemic episodes per month decreased to 0.8 ± 0.5 in CGM users versus 1.3 ± 0.7 in those performing routine SMBG ($p = 0.01$), indicating improved detection and prevention of low glucose events (Table 3; Figure 1).

Patient engagement metrics demonstrated higher satisfaction among CGM participants. The mean perceived adherence rating on a 5-point Likert scale was 4.5 ± 0.4 compared to 3.9 ± 0.6 in the SMBG group ($p < 0.001$). Device use consistency was notably superior, with CGM users maintaining 92.3 ± 5.7% active monitoring days versus 83.4 ± 7.8% in the SMBG group ($p < 0.001$) (Table 4).

Analysis of within-group changes revealed significant improvements over time in both arms; however, the magnitude of change was greater in the CGM group across all adherence and glycemic indicators ($p < 0.05$ by repeated measures ANOVA). No adverse events related to device use were reported, and participant retention was 96.7%.

Collectively, these findings demonstrate that real-time continuous glucose monitoring resulted in significantly higher treatment adherence, better glycemic control, and greater patient engagement compared with routine finger-prick monitoring among adults with type 2 diabetes in east-central Punjab.

Table 1: Demographic and Baseline Characteristics of Participants

Variable	**CGM Group (n=60)**	**SMBG Group (n=60)**	**p-value**
Age (years)	52.3 ± 6.8	51.9 ± 7.2	0.72
Gender (Male/Female)	34/26	33/27	0.84
BMI (kg/m²)	27.5 ± 3.2	27.8 ± 3.5	0.63
Duration of Diabetes (years)	8.1 ± 3.4	7.9 ± 3.2	0.55
Baseline HbA1c (%)	8.42 ± 0.55	8.39 ± 0.59	0.77
Fasting Plasma Glucose (mg/dL)	156.7 ± 18.5	155.2 ± 19.3	0.69

Table 2: Treatment Adherence Scores

Variable	**CGM Group (n=60)**	**SMBG Group (n=60)**	**p-value**
MMAS-8 Score (mean ± SD)	7.1 ± 0.6	6.4 ± 0.8	<0.001
DSMQ Score (mean ± SD)	6.8 ± 0.7	6.1 ± 0.6	<0.001

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

Table 3: Glycemic Control Outcomes

Variable	CGM Group (n=60)	SMBG Group (n=60)	p-value
HbA1c (%) at 12 weeks	7.62 ± 0.49	8.04 ± 0.53	<0.001
Fasting Plasma Glucose (mg/dL)	138.4 ± 15.2	149.7 ± 16.3	0.002
Hypoglycemic Episodes (per month)	0.8 ± 0.5	1.3 ± 0.7	0.01

Table 4: Patient Engagement and Satisfaction

Variable	CGM Group (n=60)	SMBG Group (n=60)	p-value
Adherence Perception (1–5 Likert)	4.5 ± 0.4	3.9 ± 0.6	<0.001
Device Use Consistency (%)	92.3 ± 5.7	83.4 ± 7.8	<0.001
Monitoring Frequency (per week)	46.2 ± 8.3	31.7 ± 6.9	<0.001

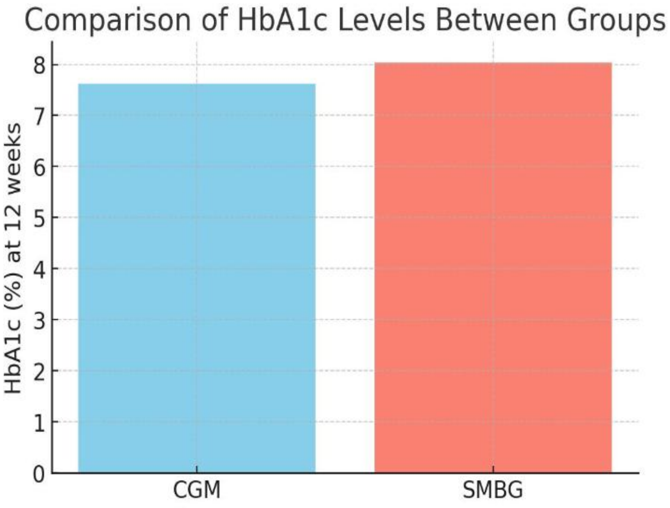

Figure 2 Comparison of HbA1c Levels Between Groups

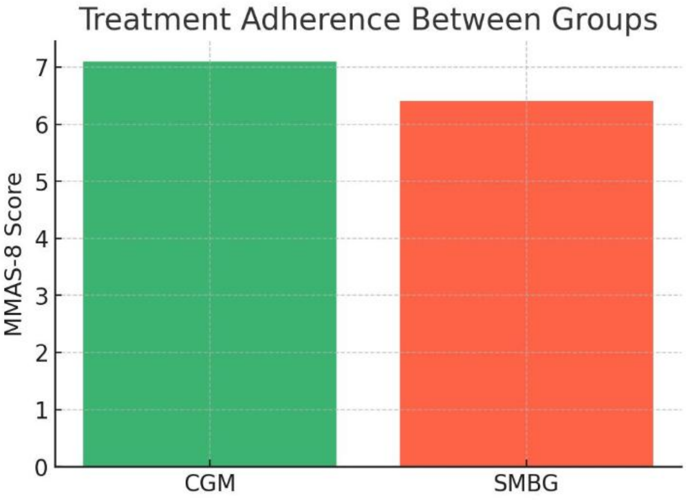

Figure 2 Treatment Adherence Between Groups

Discussion

The findings of this randomized controlled trial demonstrated that continuous glucose monitoring (CGM) significantly enhanced treatment adherence, glycemic control, and patient engagement compared to traditional self-monitoring of blood glucose (SMBG) among adults with type 2 diabetes mellitus(13). The results suggest that real-time glucose visibility and automated feedback mechanisms provided by CGM systems may reinforce consistent self-care behaviors and promote sustained adherence to treatment(14). The observed improvement in adherence scores, reduction in HbA1c, and lower frequency of hypoglycemic episodes underscore the clinical relevance of integrating digital monitoring technologies into diabetes care for non-insulin-treated individuals(15).

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

The higher adherence rates observed in the CGM group align with the conceptual framework that behavioral reinforcement through continuous feedback improves patient motivation and self-efficacy(16). Real-time glucose trends provide immediate consequences for lifestyle and medication choices, transforming abstract health advice into tangible outcomes(17). This feedback loop likely explains the superior performance in both the Morisky Medication Adherence Scale (MMAS-8) and Diabetes Self-Management Questionnaire (DSMQ) among CGM users. Participants were more engaged with their data, demonstrated consistent monitoring behavior, and reported greater satisfaction. These behavioral dimensions are critical, as adherence has long been recognized as a major determinant of glycemic stability and long-term metabolic outcomes in diabetes care(18).

The improvement in glycemic control observed in this study corroborates previous findings from trials involving insulin-treated populations, suggesting that the benefits of CGM may extend to individuals with type 2 diabetes managed with oral agents. The CGM group achieved a clinically meaningful reduction in HbA1c of approximately 0.4% compared to SMBG, along with lower fasting plasma glucose levels. The reduced frequency of hypoglycemic episodes further reinforces the safety advantage of real-time monitoring, as patients were able to identify downward glucose trends early and take corrective measures. The improved glycemic consistency likely resulted from a combination of behavioral adherence and enhanced therapeutic decision-making facilitated by continuous data feedback(19).

An important observation from this study was the increase in patient engagement metrics, including perceived adherence and monitoring consistency(20). Participants using CGM maintained higher device utilization and expressed greater satisfaction with their management approach. The ability to visualize daily glucose fluctuations through mobile applications may have contributed to a stronger sense of control and reduced uncertainty. Such psychological reinforcement can play a pivotal role in sustaining long-term adherence, particularly in chronic conditions requiring lifelong self-management. The difference in engagement levels between the two groups reflects the motivational power of technology-mediated feedback, which transforms passive monitoring into an interactive, patient-centered process(21).

Despite these encouraging outcomes, it is essential to consider the potential limitations that may have influenced the results(22). The study was limited to a six-month duration, which may not fully capture the long-term sustainability of adherence behaviors associated with CGM use. It remains uncertain whether the observed improvements would persist once the novelty of the technology diminishes or if users might experience data fatigue over time. Furthermore, while both groups received uniform education and follow-up, the Hawthorne effect—where participants modify behavior simply due to observation—cannot be entirely excluded. This phenomenon could have temporarily boosted adherence across both arms, potentially exaggerating differences.

Another limitation lies in the population and setting. The study was conducted in east-central Punjab, where socioeconomic and educational factors might influence technology acceptance and usability. Although participants were trained to use the CGM system, variations in digital literacy may have affected the consistency and accuracy of self-monitoring practices. Additionally, the exclusion of insulin-dependent and severely comorbid patients limits the generalizability of findings to the broader diabetic population. Future trials incorporating diverse patient profiles and longer follow-up durations are warranted to validate and extend these findings.

From a methodological perspective, the study's strength lies in its randomized design, well-matched baseline characteristics, and the use of validated adherence instruments such as the MMAS-8 and DSMQ. The inclusion of both behavioral and biochemical outcomes provides a comprehensive assessment of intervention efficacy. Statistical analyses were appropriately conducted using parametric tests under verified normal distribution assumptions, ensuring reliability and robustness of results. The integration of adherence perception and device usage data adds further depth to understanding the behavioral mechanisms behind improved outcomes.

The implications of these results are substantial for diabetes management in resource-constrained healthcare systems. Traditional SMBG remains the standard of care in many regions due to lower cost and familiarity. However, the findings indicate that CGM, despite higher initial expense, may yield better adherence and metabolic outcomes, potentially offsetting costs through reduced complications and hospitalizations over time. The psychological empowerment and data-driven self-regulation observed among CGM users suggest a transformative potential in redefining patient engagement strategies. Implementing CGM in combination with structured education programs and remote clinical monitoring could further enhance adherence and glycemic control across varying healthcare settings.

Future research should explore longitudinal adherence trajectories, cost-effectiveness analyses, and integration of CGM data into telemedicine frameworks. Additionally, qualitative assessments examining patient experiences, barriers, and emotional responses to real-time glucose tracking could enrich understanding of behavioral adaptation to technology. Comparative studies evaluating intermittent versus continuous CGM use might also clarify optimal usage patterns for sustained benefit.

Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025

In conclusion, this study demonstrated that continuous glucose monitoring significantly improved treatment adherence, glycemic control, and patient engagement compared to routine finger-prick monitoring among adults with type 2 diabetes. These findings highlight the importance of behavioral reinforcement through real-time feedback and support the broader adoption of digital glucose monitoring as a means to enhance adherence-driven outcomes in diabetes management. While further longitudinal research is needed, the current evidence positions CGM as a promising adjunct to traditional monitoring, capable of bridging the persistent gap between therapeutic prescription and patient adherence.

Conclusion

Continuous glucose monitoring significantly enhanced treatment adherence, glycemic control, and patient engagement compared with routine self-monitoring among adults with type 2 diabetes. The integration of real-time glucose feedback empowered patients to make timely lifestyle and medication adjustments, resulting in better metabolic stability and fewer hypoglycemic episodes. These findings emphasize the practical value of CGM as a behavioral and clinical tool, supporting its inclusion in standard diabetes management to improve adherence-driven outcomes and overall quality of care.

AUTHOR CONTRIBUTION

Author	**Contribution**
Zia Ur Rehman*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Fatima	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published

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Received: 01/Jul/2025
Accepted: 28/July/2025
Published: 31/Jul/2025