

Comparative Effectiveness of Continuous Versus Conventional Glucose Monitoring for Early Diabetes Risk Detection in Children with Acanthosis Nigricans

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ABSTRACT

INTRODUCTION: The rising incidence of pediatric diabetes underscores the need for accurate glucose monitoring tools to facilitate early detection. Although both Blood Glucose Meters (BGM) and Continuous Glucose Monitoring (CGM) are widely used, their comparative effectiveness in predicting diabetes onset in children remains contested. This study evaluated and compared the predictive utility of BGM and CGM in high-risk pediatric populations.

METHODS: A nine-month prospective observational study (January–September 2024) was conducted at the Health Polytechnic of the Ministry of Health, Sorong, involving 76 children aged 10–18 years diagnosed with Acanthosis Nigricans and positive FINDRISC scores. Participants were allocated to either BGM (every 3 days) or CGM (15-minute intervals). Key outcome measures included Time in Range (TIR), mean glucose levels, frequencies of hypo- and hyperglycaemic episodes, adherence rates, and Mean Absolute Relative Difference (MARD).

RESULTS: CGM significantly outperformed BGM across all parameters: higher TIR (78.9% vs. 63.4%, $p < 0.001$), lower average glucose levels (145.3 vs. 162.7 mg/dL, $p = 0.003$), fewer hypoglycaemic (1.1 vs. 2.8, $p = 0.015$) and hyperglycaemic events (2.6 vs. 4.5, $p = 0.002$), and superior adherence (88.7% vs. 71.3%, $p < 0.001$). CGM also showed a lower MARD (7.2% vs. 10.8%, $p = 0.004$), indicating greater accuracy.

CONCLUSIONS: CGM offers more reliable and comprehensive glucose monitoring than BGM for predicting diabetes onset in children at risk, supported by better glycaemic control, higher adherence, and improved accuracy. These findings endorse CGM as the preferred approach for early diabetes detection in pediatric populations.

Keywords: Continuous Glucose Monitoring, Blood Glucose Meters, Pediatric Diabetes, Early Diagnosis, Acanthosis Nigricans

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INTRODUCTION

The growing prevalence of type 2 diabetes mellitus (T2DM) among children and adolescents has become a pressing global health issue, largely driven by rising obesity rates and increasingly sedentary lifestyles [1,2]. Early detection of glucose dysregulation is critical in preventing the progression from prediabetes to overt diabetes. Effective glucose monitoring not only facilitates timely intervention but also helps mitigate long-term complications such as neuropathy, cardiovascular disease, and retinopathy [3–7].

Blood Glucose Meters (BGM) and Continuous Glucose Monitoring (CGM) represent two commonly used approaches for monitoring glucose levels. BGMs rely on intermittent fingerstick testing and provide point-in-time data, which may miss critical glycaemic fluctuations—especially in paediatric patients with irregular eating and activity patterns [8–10]. In contrast, CGM systems offer real-time, continuous tracking of glucose levels and deliver insights into glycaemic variability, time-in-range (TIR), and episodes of dysglycaemia. While CGM has demonstrated clinical advantages in adult populations with diabetes, its predictive utility in at-risk children remains underexplored [11–15]. Most existing research focuses on CGM's role in glycaemic management rather than its value in early diabetes prediction. Additionally, prior studies often suffer from limited sample sizes and insufficient longitudinal follow-up.

Moreover, practical challenges such as device cost, sensor calibration, and patient compliance complicate the implementation of CGM, particularly in resource-constrained settings [16–21]. While BGM remains more accessible and affordable, its intermittent data may lead to missed transient dysglycaemic events, undermining early diagnosis and treatment decisions.

To address this gap, our study compares the predictive performance of BGM and CGM in detecting early signs of diabetes in children aged 10–18 years with clinical risk factors, including acanthosis nigricans and a positive FINDRISC score. The hypothesis is that CGM will provide greater predictive accuracy due to its ability to capture real-time glycaemic trends and subtle variations often missed by BGM.

This research was conducted through a nine-month

observational study involving 76 participants at the Health Polytechnic of the Ministry of Health Sorong, Indonesia. Both CGM and BGM data were analysed for TIR, mean glucose levels, and occurrences of hypo- and hyperglycaemia. By evaluating both clinical accuracy and user adherence, this study contributes to identifying an optimal monitoring strategy for early diabetes detection in high-risk paediatric groups. The findings of this research aim to inform evidence-based recommendations for paediatric glucose monitoring strategies and may help guide updates to clinical screening protocols for childhood diabetes.

METHODS

Study Design

This study applied a prospective observational approach to assess the predictive effectiveness of Blood Glucose Meters (BGM) and Continuous Glucose Monitoring (CGM) systems in identifying the onset of diabetes mellitus among paediatric subjects. The design was structured to observe outcomes without intervention, ensuring naturalistic data collection.

Study Setting

The research was conducted at the Health Polytechnic of the Ministry of Health Sorong, Indonesia, over a nine-month period from January to September 2024. The study was formally registered under ClinicalTrials.gov (ID: NCT03240432).

Study Population

A total of 76 children aged between 10 and 18 years were recruited based on predefined inclusion and exclusion criteria. Eligible participants displayed visible signs of acanthosis nigricans in the neck, axillae, or groin regions, had no prior HbA1c testing, and scored positively on a modified Finnish Diabetes Risk Score (FINDRISC) adapted for paediatric use. Exclusion criteria included a prior diabetes diagnosis, recent use of medications that affect glucose metabolism, acute illnesses during the study period, or intake of vitamin C or salicylate-based medications.

Sampling and Sample Size

Sample size was determined through power analysis to ensure sufficient statistical power for comparative analysis. Participants were randomly assigned to either the BGM or CGM monitoring group following the screening and baseline assessment phase.

Data Collection Tools and Procedures

Initial assessments included physical examinations to confirm acanthosis nigricans and collection of anthropometric data (height, weight, BMI, and waist circumference).

BGM group: Participants performed self-monitoring of glucose levels using standard glucometers every three days, preferably in the morning before meals. Devices were calibrated regularly, and data were recorded by trained healthcare personnel under quality-controlled conditions.

CGM group: Participants were monitored using the FreeStyle Libre 14-Day system, which captured glucose readings every 15 minutes. Sensors were applied to the upper arm, replaced biweekly, and monitored following manufacturer instructions. Data collected included Time in Range (TIR), mean glucose levels, hypoglycaemia and hyperglycaemia episodes, adherence rates, and potential device-related issues.

Data Management and Statistical Analysis

All data were anonymised and securely stored in compliance with data protection protocols. Analysis was conducted using Jamovi software. Missing values were imputed using multiple imputation techniques, and outliers were examined using boxplots. Descriptive statistics summarised participant characteristics, and independent t-tests compared outcomes between BGM and CGM groups. Correlations between key glycaemic indicators were assessed using Pearson or Spearman coefficients. Logistic regression modelling evaluated the predictive performance of both monitoring systems for diabetes onset. Statistical significance was set at $p < 0.05$. Device accuracy was validated using the Clarke Error Grid and quantified via the Mean Absolute Relative Difference (MARD). Additional quality control measures included routine device calibration, staff training, and adherence to standard operating procedures. Ethical approval was granted by the Ethics Committee of the Health Polytechnic

of the Ministry of Health Sorong (Approval No. DM.03.01/4.3/1001/2024, dated 5 January 2024). Written informed consent was obtained from parents or legal guardians, while assent was secured from participants aged over 12. All procedures adhered strictly to ethical standards and data confidentiality regulations. A CONSORT-compliant flowchart guided participant progression through each study phase—from screening and randomisation to monitoring and final analysis.

RESULTS

Respondents' Characteristics

Table 1 presents the distribution of participants based on age, sex, body mass index (BMI), waist circumference, and FINDRISC score. Most participants were female (54%), with a mean age of 13.8 years (SD ± 2.4). The average BMI corresponded to the overweight category, and all participants exhibited clinical signs of acanthosis nigricans. Furthermore, FINDRISC assessments indicated that the entire cohort was at elevated risk for developing type 2 diabetes mellitus. The findings revealed that Continuous Glucose Monitoring (CGM) outperformed Blood Glucose Meter (BGM) in predicting the onset of diabetes among paediatric participants.

Table 1: Demographic and Clinical Characteristics of Participants

| Variable | Mean (SD) / n (%) |
|--------------------------|---------------------|
| Age (years) | 13.8 (± 2.4) |
| Gender (Male/Female) | 35 (46%) / 41 (54%) |
| BMI (kg/m ²) | 24.5 (± 4.3) |
| Waist Circumference (cm) | 82.1 (± 10.7) |
| Acanthosis Nigricans | 76 (100%) |
| FINDRISC Score | 12.4 (± 3.2) |

BMI: Body mass index; FINDRISC: Finnish Diabetes Risk Score. Those monitored with CGM demonstrated a

Table 2: Comparison the efficacy of Glycaemic Metrics between BGM and CGM

| Metric | BGM (Mean \pm SD) | CGM (Mean \pm SD) | P-value |
|-------------------------------------|----------------------|----------------------|---------|
| Time in Range (TIR, %) | 63.4 (± 12.7) | 78.9 (± 10.3) | <0.001 |
| Mean Glucose Level (mg/dL) | 162.7 (± 20.4) | 145.3 (± 18.6) | 0.003 |
| Hypoglycaemia Episodes (frequency) | 2.8 (± 1.2) | 1.1 (± 0.7) | 0.015 |
| Hyperglycaemia Episodes (frequency) | 4.5 (± 1.7) | 2.6 (± 1.1) | 0.002 |

p-value < 0.005: Statistically significant

significantly greater Time in Range (TIR) (78.9% vs. 63.4%, $p < 0.001$) and lower average glucose levels (145.3 mg/dL vs. 162.7 mg/dL, $p = 0.003$). Additionally, the CGM group experienced markedly fewer episodes of both hypoglycaemia and hyperglycaemia compared to the BGM group (Table 2).

Adherence and Accuracy Analysis

As shown in Table 3, adherence rates were significantly higher among participants using CGM compared to those using BGM (88.7% vs. 71.3%, $p < 0.001$). The CGM system also exhibited superior accuracy, reflected by a lower Mean Absolute Relative Difference (MARD) (7.2% vs. 10.8%, $p = 0.004$). Additionally, device-related technical failures were more commonly observed in the BGM group than in the CGM group

Evaluation of Glycaemic Episodes and Time in Range (TIR)

The study also examined glycaemic events to provide deeper insights into glucose fluctuation patterns among participants. As outlined in Table 4, participants in the younger age group (10–12 years) experienced a greater incidence of glycaemic episodes—both hypoglycaemic and hyperglycaemic—particularly when monitored using BGM. In contrast, CGM consistently recorded fewer such events across all age categories, indicating more stable glycaemic control irrespective of age

DISCUSSION

This study offers valuable insight into the comparative performance of Blood Glucose Meters

(BGM) and Continuous Glucose Monitoring (CGM) in identifying early diabetes risk among children. The results strongly indicate that CGM provides superior outcomes across several key parameters, including reduced glycaemic variability, improved time-in-range (TIR), and fewer episodes of both hyperglycaemia and hypoglycaemia. These findings confirm the initial hypothesis that CGM, through its continuous data capture, enables earlier and more accurate detection of glucose irregularities compared to the intermittent readings provided by BGM.

Importantly, children using CGM experienced greater glycaemic stability and fewer fluctuations, suggesting better overall glucose control. This aligns with previous literature highlighting CGM's effectiveness in paediatric diabetes management and supports its role in early intervention strategies [22–30].

An unexpected but significant finding was the higher adherence observed in the CGM group, despite the system's more complex setup. This may be attributed to CGM's less invasive nature and its ability to provide real-time feedback, which potentially motivates users to monitor consistently. Interestingly, older children demonstrated higher compliance rates, possibly due to a better understanding of the benefits of continuous monitoring—highlighting the importance of age-specific behavioural factors in device adoption. Theoretically, CGM's ability to continuously track glucose levels allows for timely dietary and lifestyle adjustments, thus enabling proactive rather than reactive care. These advantages are consistent with recent research showing that CGM leads to better long-term glucose control outcomes in children at risk of diabetes [28,31–34]. On the other hand,

Table 3: Adherence and Accuracy between BGM and CGM

| Parameter | BGM | CGM | P-value |
|---|--------------|--------------|---------|
| Adherence (%) | 71.3 (±15.4) | 88.7 (±10.2) | <0.001 |
| Mean Absolute Relative Difference (MARD, %) | 10.8 (±2.6) | 7.2 (±1.9) | 0.004 |
| Technical Failures (frequency) | 5 (13.2%) | 2 (5.3%) | 0.046 |

Table 4: Distribution of Glycaemic Episodes by Age Category

| Age (years) | Hypoglycaemic Episodes (BGM vs CGM) | Hyperglycaemic Episodes (BGM vs CGM) |
|-------------|-------------------------------------|--------------------------------------|
| 10-12 | 3.2 (±1.4) vs 1.5 (±0.8) | 5.1 (±1.9) vs 3.0 (±1.2) |
| 13-15 | 2.7 (±1.1) vs 0.9 (±0.6) | 4.3 (±1.5) vs 2.4 (±1.0) |
| 16-18 | 2.3 (±1.0) vs 0.8 (±0.5) | 4.0 (±1.3) vs 2.1 (±0.9) |

some studies have raised concerns over CGM's higher costs and learning curve, especially in low-resource settings [35,36]. However, the present findings suggest that the clinical benefits and improved adherence may outweigh these initial barriers.

Moreover, the study reinforces the value of CGM as a strategic tool in diabetes prevention among high-risk paediatric populations. The data indicate that continuous monitoring allows for the detection of subtle glucose changes that BGM might miss, underscoring the role of CGM in comprehensive risk assessment. Prior studies, such as those by Podwojniak et al., support these conclusions by showing that CGM leads to fewer adverse events and better long-term control in paediatric patients [37].

Nonetheless, the study has several limitations. Being single-centre and relatively small in scale, the generalisability of the findings may be restricted. Additionally, adherence data relied partly on self-reporting, which may introduce bias. The study also did not explore socioeconomic factors that could affect access to CGM technology and influence its adoption.

CONCLUSION

This study concludes that Continuous Glucose Monitoring (CGM) is significantly more effective than Blood Glucose Meters (BGM) in predicting diabetes onset in at-risk children. CGM not only improved glycaemic outcomes but also promoted better adherence among participants. These findings underscore the potential for CGM to be integrated into standard paediatric diabetes screening and prevention programs. Future research should expand on this work through multicentre trials with larger, more diverse samples and should examine the role of socioeconomic and psychological factors in CGM use.

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