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Research Article

Long-term Impact of Continuous Glucose Monitoring Assistance on Glycemic Control in Children and Adolescents with Type 1 Diabetes Following the 2023 Kahramanmaraş Earthquake

Tarçın G et al. Effect of Post-earthquake CGM Aid in T1D

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What is already known on this topic?

- Natural disasters, like earthquakes, can negatively impact glycemic control in people with diabetes.
- Continuous glucose monitoring (CGM) aids individuals with diabetes in maintaining improved glycemic control.

What this study adds?

- This study reports the impact of CGM support on glycemic control in children and adolescents with diabetes following the 2023 Kahramanmaraş earthquake.
- Despite the negative impacts of the earthquake, there was no change in HbA1c levels among those who did not benefit from CGM support, while a decrease in HbA1c was observed in those who did, and this reduction was sustained over a 9-month follow-up period.
- In children and adolescents benefiting from CGM support, an increase in active CGM use and a decrease in the frequency of hypoglycemia were observed in follow-up.

Abstract

Objective: This study aimed to evaluate the impact of continuous glucose monitoring (CGM) assistance on glycemic control in children with type 1 diabetes (T1D) in earthquake-affected regions, comparing those who benefited from CGM with those who did not. Additionally, the study assessed changes in CGM metrics over nine months of CGM use.
Methods: A multicenter, cross-sectional study was conducted across 11 centers in Türkiye. Children with T1D were divided into two groups: those who received CGM support (CGM+) and those who continued with finger-stick glucose monitoring (CGM-). HbA1c levels were measured at four intervals: pre-earthquake, 3-6 months, 6-9 months, and 9-12 months post-earthquake. In the second phase, CGM metrics were analyzed over 90-day intervals in the CGM+ group with at least 85% sensor usage.
Results: A total of 532 children were included. Median HbA1c levels decreased from 9.1% pre-earthquake to 8.8% 3-6 months post-earthquake ($p=0.027$). In the CGM+ group, HbA1c levels significantly decreased from 8.8% to 8.3% ($p<0.001$), while no significant change was observed in the CGM- group. Of the 412 subjects with access to CGM reports, 105 (25.4%) had less than 85% sensor usage and were excluded. In the remaining 307 patients, there was a significant increase in active sensor time and daily glucose measurements, along with a reduction in hypoglycemia frequency over the 90-day intervals ($p<0.001$ for all three).
Conclusion: CGM assistance improved glycemic control in children with T1D, even under the challenging conditions of the earthquake. These findings highlight the need for broader access to CGM devices to enhance diabetes management.
Keywords: Continuous glucose monitoring, diabetes, earthquake, glucose sensor

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Introduction

On February 6, 2023, Kahramanmaraş, Türkiye, was struck by two major earthquakes with magnitudes of 7.7 Mw and 7.6 Mw, occurring nine hours apart. Just two weeks later, a significant aftershock measuring 6.4 Mw hit Hatay on February 20, 2023. Official reports indicate that at least 50,000 people died, and 9.1 million people, one-tenth of Türkiye's population, were affected. In the disaster area, approximately 300,000 homes were destroyed. The World Health Organization (WHO) declared a Level 3 emergency, and a state of emergency was declared in the ten affected provinces (1,2). Following the earthquakes, 94 hospitals sustained light damage, while 42 hospitals were moderately to severely damaged. To mitigate the impact on the healthcare system, volunteer healthcare personnel were deployed, pharmaceuticals and medical supplies were delivered, and 35 field hospitals were established (3).
It is well known that social stressors, including natural disasters, can negatively impact glycemic control in individuals with diabetes (4). Children and adolescents with diabetes were among the groups most significantly impacted by this disaster. Those living closer to the epicenter, where homes were destroyed or severely damaged, faced substantial disruptions in their care. In contrast, those in regions further from the epicenter, which were less affected, experienced disruptions in their daily routines and dietary habits due to challenges such as fear of entering homes and relocation, particularly in the early post-earthquake period. In response, the Turkish Society for Pediatric Endocrinology and Diabetes coordinated the deployment of volunteer pediatric endocrinologists, as well as the distribution of insulin pens,

fingerstick blood glucose meters, and blood glucose test strips to the affected regions. They also organized a network of voluntary pediatric endocrinology specialists from across Türkiye to provide daily consultations for doctors in the disaster areas, sharing their contact information with local medical teams. Additionally, medical device companies and pharmaceutical companies independently made donations. During this period, in order to facilitate access to medication, patients with Type 1 diabetes were allowed to obtain their insulin directly from the pharmacy without a prescription. Finally, and most notably, one month after the earthquake, in March 2023, the government took a significant step by distributing free continuous glucose monitoring (CGM) devices and compatible mobile phones to all children and adolescents with diabetes under the age of 22 (5). All who applied during the announced application period received these devices for a two-year period.

We previously reported a study conducted in the Adana province, where we compared HbA1c levels before and after the earthquake and demonstrated a significant decrease in HbA1c levels among patients who benefited from CGM support (6). Building on these findings, we sought to replicate the study on a larger, multicenter scale while also incorporating longitudinal follow-up data. The primary aim of this study is to evaluate the impact of this intervention on glycemic control in patients living in earthquake-affected regions by assessing changes in HbA1c levels before and after the earthquakes and analyzing CGM parameters over time in those who benefited from CGM device support.

Materials and Methods

Study Design

This study was conducted as a multicenter, cross-sectional analysis involving 11 centers across 7 provinces significantly affected by the earthquake (Figure 1). The study population consisted of children and adolescents under the age of 18 diagnosed with type 1 diabetes. Exclusion criteria included patients in the honeymoon phase, those using insulin pumps, those already using CGM before the earthquake.

Study Population and Data Collection

The study protocol was shared with all centers, and data on eligible patients, including demographic information and HbA1c levels, were requested to be entered into a standardized data form. Patients who did not initially use CGM but later received CGM support (Freestyle Libre 2, Abbott Diabetes Care Inc, California, USA) were classified as the CGM (+) group, while those who either missed the opportunity for CGM support or chose not to apply, thereby continuing with finger-stick glucose measurements, were categorized as the CGM (-) group.

In the first phase of the study, HbA1c levels were evaluated at four specific time intervals: the three months preceding the earthquake (November 2022 - February 2023), three to six months post-earthquake (June - August 2023) (to reflect at least three months of sensor use for those who benefited from CGM support), six to nine months post-earthquake (September - November 2023), and nine to twelve months post-earthquake (December 2023 - February 2024). Only patients who regularly attended follow-ups every three months and had complete HbA1c data across all four time intervals were included in this analysis. Patients whose initial HbA1c measurement was taken at the time of diagnosis of diabetes were excluded.

The second phase of the study focused on CGM usage metrics in patients who received CGM support. Sensor parameters (percentage of days with sensor data, active sensor time, number of low glucose events, average daily scan frequency, coefficient of variation, glucose management indicator, and percentage of time spent in different glucose ranges) were accessed through the Libreview.com remote access system. To standardize the evaluation, patients with less than 85% active sensor use during any 90-day period were excluded. CGM metrics were assessed in 90-day intervals starting from May 2023 to evaluate trends in sensor use and its impact on glycemic control.

Ethical Considerations

This study was approved by the Adana City Training and Research Hospital Scientific Research Ethics Committee with approval dated May 30, 2024, and decision number 35.

Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Sciences version 27 (Ilionis, USA). To assess whether the data followed a parametric distribution, histogram curves were examined, and the Kolmogorov-Smirnov test was applied. Parametric data were presented as mean ± standard deviation (SD), while non-parametric data were expressed as median (min-max). Comparisons between two independent variables were made using the T-test for parametric data and the Mann-Whitney U test for non-parametric data. For comparisons involving more than two dependent variables, repeated measures analysis of variance (ANOVA) was used for parametric data, with Tukey's test applied for post-hoc pairwise comparisons if significance was found. For nonparametric data, the Friedman test was used, and post-hoc comparisons were conducted using the Wilcoxon test with Bonferroni correction. A two-way repeated measures ANOVA was conducted to analyze the interaction effect between the earthquake and CGM usage on the change in HbA1c levels, as well as to analyze the interaction effect between the earthquake and age groups on the change in HbA1c levels only in the CGM (+) group. Since both pre- and post-earthquake HbA1c levels exhibited a nonparametric distribution, logarithmic transformation was applied to achieve a Gaussian distribution, and the transformed data were used in the ANOVA analysis. A p-value below 0.05 was considered statistically significant.

Results

HbA1c Levels Before and After the Earthquake

In the analysis examining HbA1c trends, data from 532 patients (M/F: 256/276) were included. The average age was 12.4 ± 3.5 years (2.5-18). The baseline HbA1c levels prior to the earthquake were significantly higher in the CGM(-) group compared to the CGM(+) group ($p=0.019$). Across the entire cohort, the median HbA1c level decreased from 9.1% pre-earthquake to 8.8% three to six months post-earthquake, showing a statistically significant improvement ($p=0.027$). In the CGM (+) group, the median HbA1c decreased from 8.8% to 8.3% ($p<0.001$), while no statistically significant change in HbA1c was observed in the CGM (-) group. This trend was consistent across both the primarily and secondarily affected provinces (Table 1). Additionally, as shown in Figure 2, when analyzing HbA1c trends in the CGM (+) and CGM (-) groups, it was found that in the CGM (+) group, median HbA1c level significantly decreased after the earthquake and then remained stable in subsequent measurements.

In the two-way repeated measures ANOVA analysis for the change in HbA1c levels between the two time points (before and after the earthquake), a significant effect of CGM usage on changes in HbA1c levels ($F=11{,}063$, $p<0.001$), indicating that the change in HbA1c levels between the two time points varied significantly based on whether participants were using CGM.

When the CGM (+) group was divided into two subgroups according to age: <12 years (n=130) and ≥12 years (n=133), the two-way repeated measures ANOVA analysis showed that there was no significant interaction effect between the earthquake and age group ($F=0.370$, $p=0.544$), indicating that the impact of the earthquake on HbA1c levels did not differ based on the age groups within the CGM (+) group.

CGM Usage and Glycemic Control Trends

In the analysis of sensor parameters in children and adolescents who benefited from CGM support, data from a total of 412 individuals were collected from all centers. However, 105 were excluded due to less than 85% sensor data capture during any 90-day period, resulting in a final analysis of 307 children and adolescents (M/F: 166/141). The average age in this group was 11.5 ± 3.5 years (2-18). Over the nine-month follow-up period, active sensor use steadily increased, hypoglycemia events decreased, and the average number of daily glucose measurements rose (Table 2). Also, as seen in Figure 3, the hypoglycemic portion consistently decreased across the three time intervals.

Discussion

In this study, the impact of the earthquake and glucose sensor assistance on glycemic control in children and adolescents with diabetes was investigated across a broad region, including the provinces affected by the earthquake. The main finding of this study is that CGM support after the earthquake significantly improved glycemic control in children with diabetes, whereas those who did not receive this support did not exhibit any notable changes in their glycemic control. Previous research on the impact of earthquakes on glycemic control in individuals with diabetes has largely been conducted in Japan (7–9). These studies have generally reported an increase in HbA1c levels post-earthquake, with peaks observed around the 3rd and 5th months, followed by a decrease in the months thereafter. Almost all studies have been conducted in adults, except for a study examining the effects of the 1999 Marmara earthquake, which included adolescents over the age of 14 and demonstrated a similar rise in HbA1c at the third month post-earthquake, followed by a subsequent decline (10). Only in the 2016 Kumamoto earthquake, HbA1c levels remained stable after the earthquake, which was attributed to the effective management strategies implemented by patients, who used social network platforms to exchange information on insulin dosing, carbohydrate counting, and dietary management in the post-earthquake period (9). The present study, the first to examine this issue in the pediatric population, found no significant increase in HbA1c levels after the earthquake among those who did not benefit from CGM support, regardless of whether they were in the primarily or less affected regions. This contrasts with findings in adult studies and may be due to the successful efforts of both the association and the government to ensure easy access to essential diabetes supplies. Additionally, considering that insulin therapy in children is often closely monitored by parents, it is possible that stricter adherence to glycemic control contributed to maintaining stable HbA1c levels.

Disasters like earthquakes or hurricanes can disrupt access to medications and healthcare services, as pharmacies and clinics may be forced to close. Furthermore, medications might become damaged or inaccessible, leaving individuals without sufficient supplies, even temporarily. The lack of access to healthy food options and the interruption of regular physical activity routines can also create significant challenges, particularly for those managing diabetes (4). Although this was largely true for the regions most affected by the earthquake, in the areas that were less severely impacted, the primary challenges stemmed from people relocating to different homes, either due to ongoing damage assessments or out of fear. These disruptions in living arrangements led to significant disturbances in daily routines. Our study reveals a significant reduction in HbA1c levels among patients who received CGM assistance, which aligns with existing literature that highlights the considerable enhancement in glycemic control facilitated by CGM utilization (11,12). What sets our study apart is the ability of CGM to improve even severe conditions and reverse negative trends in glycemic control, achieving positive outcomes even in challenging circumstances, both in regions severely impacted by the earthquake and in those less affected.

In our study, after demonstrating that CGM usage effectively reduced HbA1c levels, we sought to determine whether this benefit varied between different age groups or was specific to a particular age group. To explore this, we divided the participants into two categories: children under 12 years and adolescents aged 12 and above. Our previous study in the Adana region showed that CGM use significantly improved glycemic control, particularly in adolescents (6). However, in this larger-scale study, we observed comparable benefits in both age groups. Notably, there is a lack of studies that have examined the effectiveness of CGM by categorizing children based on age (12). The improvement in glycemic control associated with CGM use in the pediatric population has been attributed to age-specific factors: younger children often resist finger-stick glucose monitoring, while adolescents may face challenges in maintaining consistent monitoring as they begin to take over diabetes management (13,14). Despite the negative effects of the earthquake, CGM use in this study showed consistent benefits by helping both groups overcome these age-related challenges.

In the second phase of the study, an analysis of sensor parameters over the 9-month follow-up period revealed a gradual increase in active sensor usage and the frequency of blood glucose measurements, accompanied by a decrease in the frequency of hypoglycemic events. When examining trends within specific glucose ranges, a similar reduction in the hypoglycemic area was observed over time. Despite a statistically significant decrease in time in range and an increase in both the hyperglycemic range and the glucose management indicator, these changes were minor and not clinically significant, whereas the decrease in hypoglycemia was considered clinically valuable. Studies conducted on patients using CGM have also highlighted that the reduction in HbA1c levels and hypoglycemic events observed after the initial transition to CGM is sustained over the long term (15,16). The decrease in hypoglycemia frequency can be largely attributed to the ability to monitor blood glucose more comfortably and to the alerts from the hypoglycemia alarm. Furthermore, in our patients, the observed increase over time in the frequency of blood glucose measurements and active sensor usage may be related to the fact that, although technical aspects such as sensor placement were taught during the initial distribution, these patients had not been seen by a clinician at that time. As time progressed, regular hospital follow-ups likely provided additional information on sensor usage and further encouragement from doctors or nurses, contributing to this increase.

This study has some limitations. As a retrospective study, it lacked data on the frequency of blood glucose measurements before the earthquake for patients using CGM. Consequently, we could not establish a link between the observed HbA1c improvement and potential changes in blood glucose monitoring frequency following CGM use. Additionally, we were unable to assess changes in patients' dietary habits and carbohydrate intake before and after the earthquake, factors that may have directly impacted glycemic control.

Conclusion

This study provides a comprehensive overview of the impact of the Kahramanmaraş earthquake on children with diabetes, emphasizing the effectiveness of CGM in improving glycemic control despite the challenging circumstances caused by the disaster. Importantly, this improvement was not transient; it persisted throughout long-term follow-up, underscoring the sustained benefits of CGM. These findings strongly support the argument for making CGM devices freely accessible to all individuals with diabetes.

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Authorship Contribution

Surgical and medical practices, concept, design, data collection, analysis and interpretation, literature search, writing: G.T.; data collection: N.A., M.Y., K.C.Ş., G.Tr., İ.D., D.Ç., H.G.B., H.M., A.B., C.C., S.Ö.D., S.K., D.D.K., A.A., E.Ç., E.M., M.K., B.Y., S.A.U.

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Table 1. Changes in HbA1c Levels Before and After the Earthquake.

	n	**HbA1c level before earthquake (%)**	**HbA1c levels after earthquake (%)**	***p***
All subjects	532	9.1 (4.9-16.6)	8.8 (5.1-16.4)	**0.027**
CGM (+)	263	8.8 (4.9-15.6)	8.3 (5.1-15.0)	**<0.001**
CGM (-)	269	9.3 (5.6-16.6)	9.5 (5.7-16.4)	0.203
Primary affected region				
CGM (+)	124	8.7 (4.9-15.6)	8.4 (6.0-15.0)	**0.006**
CGM (-)	103	9.7 (5.6-16.6)	9.4 (5.7-15.5)	0.588
Secondary affected region				
CGM (+)	139	8.8 (5.4-14.7)	8.5 (5.1-12.9)	**<0.001**
CGM (-)	166	9.3 (5.8-16.0)	9.5 (6.0-16.4)	0.211

CGM: continuous glucose monitoring

Table 2. Comparison of sensor parameters over three-month intervals

	First three months	**Second three months**	**Third three months**	***p***
Active sensor time (%)	89 (31-100)	92 (38-100)	94 (57-100)	**<0.001***
Number of hypoglycemia events	40 (0-203)	35 (0-192)	34 (0-165)	**<0.001***
Average daily scan frequency	10 (2-56)	12 (2-92)	23 (3-163)	**<0.001***
Coefficient of variation (%)	43.6 ± 6.8	42.7 ± 6.6	42.5 ± 7	**<0.001****
Glucose management indicator (%)	8 (6-12.8)	8.1 (6.2-13.1)	8.1 (6.2-12.8)	**<0.001****

* Statistically significant among all three pairwise comparisons
** Statistically significant between the first and second, and the first and third three-month intervals

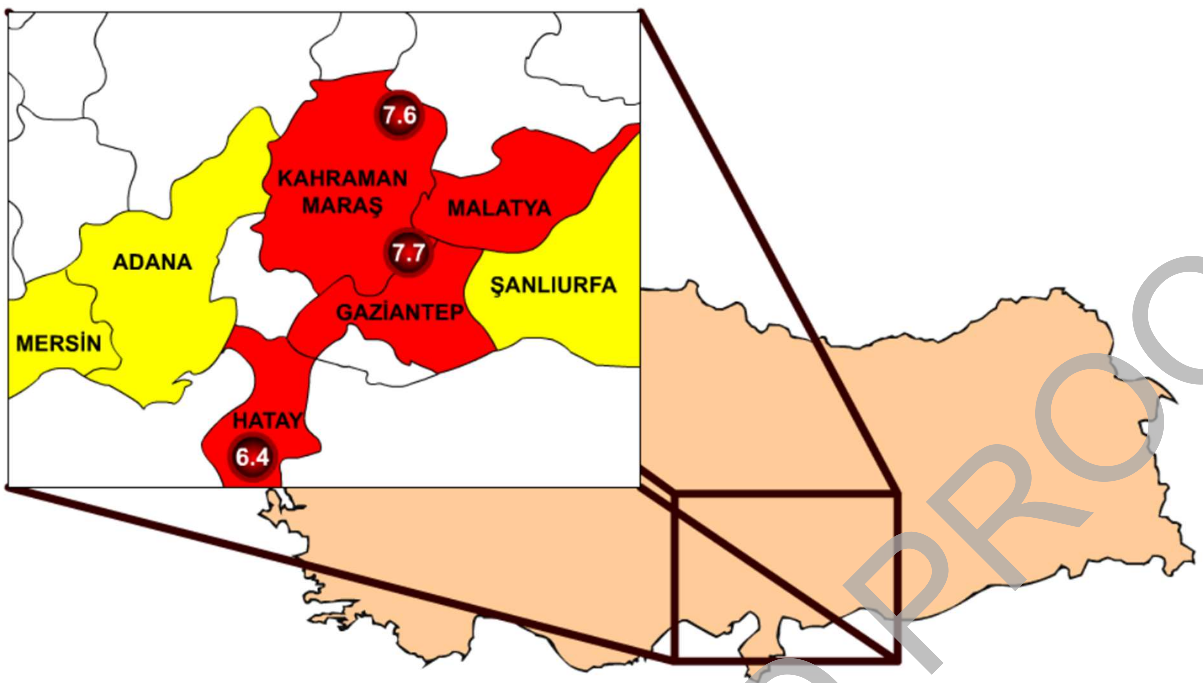

Figure 1. Map of the Earthquake-Affected Region and Epicenters.
The colored areas are the provinces with participating centers. Provinces shown in red are severely affected by the earthquakes, while those in yellow are relatively less affected.

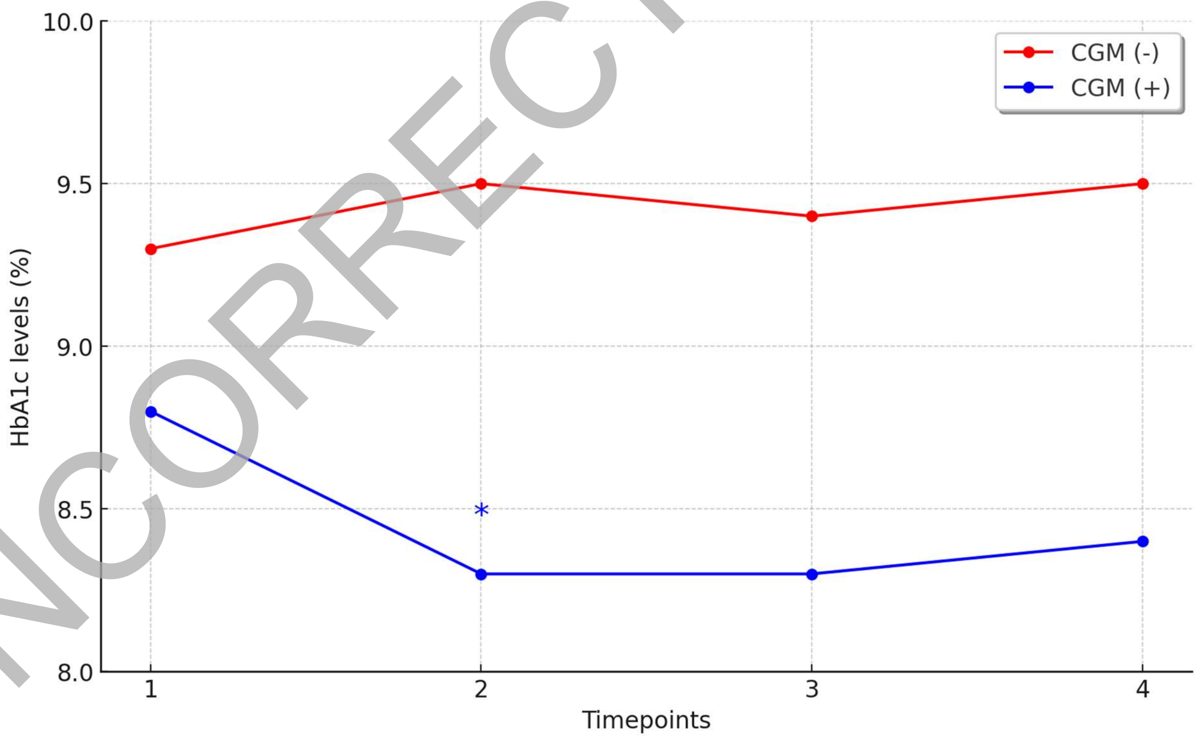

Figure 2. Trends in the median HbA1c levels in the CGM (+) and CGM (-) groups
* Statistically significant with the prior median HbA1c level after Bonferroni correction

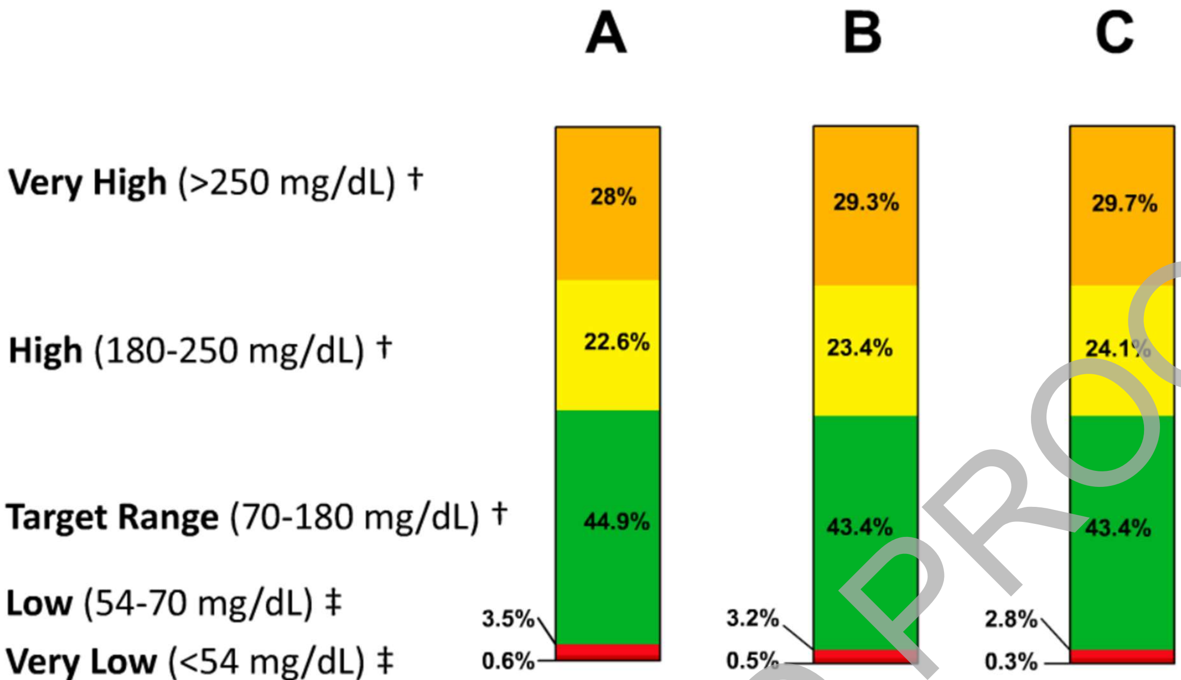

Figure 3. Comparison of the percentage of time spent in different glucose ranges across three time intervals.
† Indicates a significant difference between A-B and A-C after Bonferroni correction.
‡ Indicates a significant difference among A-B, B-C, and A-C after Bonferroni correction.