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Quantification of the relation between continuous glucose monitoring observation period and the estimation error in assessing long-term glucose regulation

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ABSTRACT

Introduction The integration of continuous glucose monitoring (CGM) into clinical practice has rapidly emerged in the last decade, changing the evaluation of long-term glucose regulation in patients with diabetes. When using CGM-derived metrics to evaluate long-term glucose regulation, it is essential to determine the minimal observation period necessary for a reliable estimate. The approach of this study was to calculate mean absolute errors (MAEs) for varying window lengths, with the goal of demonstrating how the CGM observation period influences the accuracy of the estimation of 90-day glycemic control.

Research design and methods CGM data were collected from the DIABASE cohort (ZGT hospital, The Netherlands). Trailing aggregates (TAs) were calculated for four CGM-derived metrics: time in range (TIR), time below range (TBR), glucose management indicator (GMI) and glycemic variability (GV). Arbitrary MAEs for each patient were compared between the TAs of window lengths from 1 to 89 days and a reference TA of 90 days, which is assumed to reflect long-term glycemic regulation.

Results Using 14 days of CGM data resulted in 65% of subjects having their TIR estimation being below a MAE threshold of 5%. In order to have 90% of the subjects below a TIR MAE threshold of 5%, the observation period needs to be 29 days.

Conclusions Although there is currently no consensus on what is an acceptable MAE, this study provides insight into how MAEs of CGM-derived metrics change according to the used observation period within a population and may thus be helpful for clinical decision-making.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Several studies have investigated the optimal continuous glucose monitoring (CGM) observation period, with 14 days commonly used in practice.

⇒ However, the minimal observation period has not yet been evaluated using mean absolute error (MAE), which provides a more direct interpretation of changes in metrics derived from CGM.

WHAT THIS STUDY ADDS

⇒ This study demonstrates that a 14-day CGM observation period provides a time in range estimate below a MAE threshold of 5% for 65% of patients, while 29 days is needed for 90% of patients to meet an MAE threshold of 5%.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study provides insights into how the accuracy of long-term CGM-derived metric estimations varies with different observation periods, offering valuable guidance for clinical decision-making.

INTRODUCTION

The integration of continuous glucose monitoring (CGM) into clinical practice has rapidly emerged in the last decade, changing the management and care of patients with diabetes. Glycated hemoglobin (HbA1c) is the gold standard for assessing average long-term blood glucose over 2–3 months.[1] CGM can estimate HbA1c values using the glucose management indicator (GMI) but also provides more detailed information, for example, on time in range (TIR), time below range (TBR) and glycemic variability (GV).[2] These metrics can be used by patients and clinicians to substantiate their treatment decisions.

In this respect, it is relevant to understand how varying lengths of CGM duration reflect long-term glucose regulation in order to determine what is the minimum length of CGM measurements to gain a reliable estimation. One has to take into account that, for practical limitations such as data collection and resource use, it is desirable to opt for the shortest time interval that reliably enough reflects long-term glucose regulation.[3 4]

Several studies have previously addressed this issue, and the current recommendation from the 2019 Advanced Technologies & Treatments for Diabetes (ATTD) states that the CGM measurement duration should be at least 14 days with CGM data available for at least 70% of the time.[5] Previous studies have demonstrated a high correlation (R^2) between CGM-derived metrics calculated within this period and those calculated over a 3-month period.[3 6] However, correlation-based methods are somewhat difficult to translate into clinical applicability. Later studies showed that 15 days of data are required for an absolute SD of 5% around TIR,[7] or that 18 days of data needs to be used to ensure a CI of 5% around TIR.[8] More recently, the mean absolute percentage error (MAPE) has been applied for this issue, and it was shown that the mean glucose after 2 weeks reaches the threshold of 5% MAPE,[9] meaning that the percentage average deviation between the estimated value and actual values was 5%. MAPE is related to the mean absolute error (MAE). Whereas MAPE provides the percentage error, the MAE reflects the average absolute magnitude of errors associated with long-term estimations. Thus, MAE may offer an easier way to interpret the reliability of changes in CGM-derived metrics by considering the MAE-based determination of accuracy, with the general rule of thumb that the MAE value should be smaller than the changes in CGM-derived metrics that one aims to reliably detect.

So far, a limitation of most studies is that they determine a single average optimal CGM duration for the entire population, while it would be worthwhile to provide insight for individual patients.[10] Therefore, the approach of the current study was to calculate MAEs for varying window lengths for each individual patient, with the goal to demonstrate how the CGM observation period influences the accuracy of the estimation of 90-day glycemic control. Because there is currently no consensus on the MAE that would be desirable, calculations were performed for several error thresholds. Also, similar calculations with MAPE were performed to enable comparison of the results with existing literature.

MATERIALS AND METHODS

Data collection

Data for this research were obtained from the DIABASE cohort (trial register code: NCT05584293) of the Ziekenhuisgroep Twente (ZGT) in Almelo and Hengelo, The Netherlands. The database of the DIABASE cohort consists of CGM data from patients with diabetes mellitus of different subtypes (ie, type 1 diabetes and type 2 diabetes) together with clinical data from the hospital's electronic health record. Data from the electronic health records were extracted using a Visual Studio script, which queried a copy database of the electronic health records using SQL statements. All patients with diabetes mellitus who use CGM were eligible for inclusion in this cohort. The only exclusion criterion is the inability to provide informed consent before participation in the cohort, for example, because of a mental disorder. Data from patients included until February 16, 2024, were used for this research. The CGM recordings consisted of data from June 11, 2016, to February 16, 2024. All glucose sensors generally used in clinical practice were represented, that is, the sensors Abbott FreeStyle Libre 1 and 2, Medtronic Guardian 3 and 4, and Dexcom G5 and G6. Clinical data used in this research were age, sex, type of diabetes mellitus diagnosis and average HbA1c, body mass index (BMI) and treatment modality during the measurement period. Treatments were categorized as "insulin-independent," "multiple daily injections," "insulin pump, not connected to a sensor," and "hybrid closed-loop system." Regardless of the presence of missing data for a subject, all time points with existing data were concatenated, while still assuming the original sample frequency. Subjects with at least 180 days of concatenated CGM data were selected for analysis.

Definition of CGM-derived metrics

TIR is defined as the percentage of time (%) that glucose values are ≥3.9 mmol/L and ≤10.0 mmol/L. TBR is defined as the percentage of time (%) that glucose values are <3.9 mmol/L. GMI is calculated by 12.71+4.70587 · "mean glucose" and expressed in mmol/mol, which can be converted to % using (0.0915 mmol/mol) + 2.15.[11] The GV is defined by the coefficient of variation, which is calculated by "SD glucose"/"mean glucose" · 100 and expressed in %.

Calculation of trailing aggregates

To ensure that each period in the data contributed equally, trailing aggregates (TAs) were calculated. The CGM data per patient were split in days, with 96 or 288 samples per day depending on the sampling frequency of the specific sensor that was worn. For each day, the CGM-derived metrics TIR, TBR, GMI and GV were calculated as defined in the "Definitions of CGM-derived metrics" section. After calculation of the CGM-derived metrics, the glucose data for consecutive days were grouped and trailing aggregates for the selected CGM-derived metrics were calculated for increasing window lengths from 1 to 90 days (Equation 1; for more information on TA see online supplemental table S1). The TAs were determined until the last day (N) of the available data. The period of 90 days was chosen because it coincides with the regular intervals between outpatient visits. Although this is also the window for HbA1c, there was no intention to evaluate CGM metrics as a replacement for the latter.

Equation 1: TA of window length (WL) at day t:

$$TA_{WL}(t) = f(x_{t-n+1}, x_{t-n+2}, \ldots, x_t)$$

with $WL \in \{1,2,\ldots,90\}$ days and $t \in \{WL, WL+1, WL+2, \ldots, N\}$. In this equation, f is the aggregate function that describes the CGM-derived metric (eg, TIR, TBR, GMI or GV) that is assessed over data points of days x_{t-n+1} to x_t.

Calculation of MAE and MAPE

The MAEs between TAs were calculated to quantify the differences between estimated and actual metric values over time, providing insights into the accuracy of the estimates. The MAEs were calculated between $TA_1\ (t)$ to $TA_{89}\ (t)$ and $TA_{90}\ (t)$ until the last day (N) of the available data of a subject (Equation 2; for more information on MAE, see online supplemental table S1). After calculating the MAE for each WL for each subject separately, the distributions of the MAEs per CGM WL within the population were assessed.

Equation 2: MAE between TAs of different WLs of one subject:

$$MAE_{WL} = \frac{1}{N-89}\sum_{t=90}^{N}\left|TA_{90}\ (t) - TA_{WL}\ (t)\right|$$

with WL ∈ {1,2,…,89} days and t ∈ {90,91,…,N}. The unit of MAE_{WL} depends on the units of the CGM-derived metric under consideration.

The MAPEs were also calculated for TIR, again between $TA_1\ (t)$ to $TA_{89}\ (t)$ and $TA_{90}\ (t)$ across the total data length (N) of a subject (Equation 3; for more information on MAPE, see online supplemental table S1).

Equation 3: MAPE between TAs of different WLs of one subject:

$$MAPE_{WL} = \frac{1}{N-89}\sum_{t=90}^{N}\frac{\left|TA_{90}\ (t) - TA_{WL}\ (t)\right|}{TA_{90}\ (t)}\cdot 100\ \%$$

with WL ∈ {1,2,…,89} days and t ∈ {90,91,…,N}. $MAPE_{WL}$ is expressed in %.

Different arbitrary thresholds for MAEs were applied to evaluate the optimal CGM duration for the selected CGM-derived metrics. The respective arbitrary thresholds were 1%, 2%, 5% and 10% for TIR; 0.2%, 0.5%, 1% and 2% for TBR; 0.05% (0.5 mmol/mol), 0.1% (1 mmol/mol), 0.2% (2 mmol/mol) and 0.5% (5 mmol/mol) for GMI; and 0.5%, 1%, 2% and 5% for GV. Although arbitrary, it is not uncommon that the MAE is required to be below the clinically meaningful change for the outcome variable (in this case a CGM-derived metric). The fraction of patients who will fall below a MAE threshold at a given CGM duration provides an estimate for the probability that a patient will fall below the MAE threshold. In other words, if 75% of subjects are below a certain MAE threshold at a given CGM duration, then the probability of a random subject being below that MAE threshold is assumed to be 75%.

Data and resource availability

An anonymized version of the dataset is available from the corresponding author on reasonable request.

RESULTS

A total of 200 subjects from the DIABASE cohort were included (age 49.9 (15.6) years (mean (SD)), 55.5% male). A majority of 87.0% had a confirmed diagnosis of type 1 diabetes, and 13.0% had a confirmed diagnosis of type 2 diabetes. 73.0% wore an intermittently scanned CGM (isCGM) sensor, while 27.0% wore a real-time CGM (rtCGM) sensor. All patients were on insulin therapy, with 8.5% using multiple daily injections, 73.0% using an insulin pump (not connected to a sensor), and 18.5% using an insulin pump in a hybrid-closed loop system. The consecutive data length was 499 (350–825) days (median (IQR)), with a minimum of 185 days and a maximum of 2300 days. All characteristics are summarized in table 1. The characteristics for subgroups based on diabetes type and treatment modality are summarized in online supplemental table S2.

Table 1 Overview of the patient characteristics

Characteristics		All subjects (N=200)
General		
Age (years)	Mean (SD)	49.9 (15.6)
Male	N (%)	111 (55.5%)
Diagnosis: Type 1 diabetes	N (%)	174 (87.0%)
Diagnosis: Type 2 diabetes	N (%)	26 (13.0%)
Treatment modality		
Multiple daily injections	N (%)	17 (8.5%)
Insulin pump	N (%)	146 (73.0%)
Hybrid closed-loop system	N (%)	37 (18.5%)
Sensor information		
Measurement period (days)	Median (IQR)	654 (458–1166)
	Min–max	190–2417
Consecutive data length (days)	Median (IQR)	499 (350–825)
	Min–max	185–2300
Available data (%)	Median (IQR)	87.4 (74.4–94.7)
	Min–max	18.3–99.4
Periods of missing data per 100 days <1 hour	Mean (SD)	102 (56)
Periods of missing data per 100 days >1 hour and <24 hours	Mean (SD)	65 (44)
Periods of missing data per 100 days >24 hours	Mean (SD)	3 (7)
isCGM (sample frequency: 96/day) (–)	N (%)	146 (73.0%)
rtCGM (sample frequency: 288/day) (–)	N (%)	54 (27.0%)
Clinical parameters		
Mean blood glucose (mmol/L)	Mean (SD)	9.36 (1.48)
HbA1c (% (mmol/mol))	Mean (SD)	7.8 (0.8) (61.2 (8.7))
BMI (kg/m^2)	Mean (SD)	26.9 (4.6)
Mean TIR (%)	Mean (SD)	60.7 (15.0)
Mean TBR (%)	Mean (SD)	3.3 (3.1)
Mean GMI (% (mmol/mol))	Mean (SD)	7.3 (0.6) (56.8 (7.0))
Mean GV (%)	Mean (SD)	36.5 (6.3)

BMI, body mass index; GMI, glucose management indicator; GV, glycemic variability; HbA1c, glycated hemoglobin; isCGM, intermittently scanned CGM; rtCGM, real-time CGM; TBR, time below range; TIR, time in range.

Table 2 Descriptive statistics of TIR MAEs and TIR MAPEs between TA_1TA_7, TA_{14} and TA_{28} compared with TA_{90}

	TA_1 compared with TA_{90}	TA_7 compared with TA_{90}	TA_{14} compared with TA_{90}	TA_{28} compared with TA_{90}
Mean MAE (%)	13.3	6.4	4.8	3.4
Median MAE (%)	13.4	6.2	4.6	3.2
Minimal MAE (%)	4.4	2.2	1.6	1.1
Maximal MAE (%)	23.1	16.0	13.5	10.6
Mean MAPE (%)	24.8	12.0	9.1	6.3
Median MAPE (%)	22.3	10.2	7.7	5.2
Minimal MAPE (%)	4.7	2.4	1.7	1.2
Maximal MAPE (%)	63.7	40.1	33.0	23.5

MAE, mean absolute error; MAPE, mean absolute percentage error.

Table 2 shows how the TIR MAEs and TIR MAPEs change according to a chosen WL for the TA. Both the mean TIR MAE and the other TIR MAE-related descriptive statistics became lower with progressive increase of CGM duration. An estimation based on CGM data of 1 day resulted in a mean MAE_1 of 13.3% with a maximum MAE_1 of 23.1%. An estimation based on CGM data of 2 weeks resulted in a mean MAE_{14} of 4.8% with a maximum MAE_{14} of 13.5%. In line with MAE, all the descriptive statistics of the MAPE for each estimation also decreased with progressive increase of CGM duration. An estimation based on CGM data of 1 day resulted in a mean $MAPE_1$ of 24.8% with a maximum $MAPE_1$ of 63.7%. An estimation based on CGM data of 2 weeks resulted in a mean $MAPE_{14}$ of 9.1% with a maximum $MAPE_{14}$ of 33.0%.

Figure 1 shows the distribution of MAEs of CGM-derived metrics for WLs of 1–89 days within the population. For example, a measurement duration of 14 days resulted in 65% of subjects being below a hypothetical TIR MAE threshold of 5% and 1% of subjects being below a TIR MAE threshold of 2% (figure 1A). No subjects were below a TIR MAE threshold of 1% with a measurement duration of 14 days. Also, when it is hypothetically desired that 50% of the population are below a TIR MAE threshold of 5%, 11 days of measurement would be required, and when it is desired that 90% of the patients are below a TIR MAE threshold of 5%, 29 days of measurement would be required.

A measurement duration of 14 days resulted in 89% of subjects being below a hypothetical TBR MAE threshold of 2% and 56% of subjects being below a TBR MAE threshold of 1% (figure 1B). When 50% of the population needed to be below the TBR MAE threshold of 0.5%, 39 days of measurement would be required, and to be below the TBR MAE threshold of 1%, 11 days of measurement would be required. When 90% of subjects must be below the hypothetical TBR MAE threshold of 1%, 51 days of measurement would be required.

A measurement duration of 14 days resulted in 51% of subjects being below a hypothetical GMI MAE threshold of 0.2% (2 mmol/mol) and 3% of subjects being below a GMI MAE threshold of 0.1% (1 mmol/mol) (figure 1C). A measurement duration of 22 days results in all subjects being below the GMI MAE threshold of 0.5% (5 mmol/mol). When it is hypothetically desired that 50% of the population needed to be below the GMI MAE threshold of 0.2% (2 mmol/mol), 13 days of measurement would be required. When 90% of subjects must be below the GMI MAE threshold of 0.2% (2 mmol/mol), 40 days of measurement would be required.

A measurement duration of 14 days resulted in 36% of subjects being below a hypothetical GV MAE threshold of 2% and 100% of subjects being below a GV MAE threshold of 5% (figure 1D). No subjects were below a GV MAE threshold of 1% with a measurement duration of 14 days. When it is hypothetically desired that 50% of the population needed to be below the GV MAE threshold of 2%, 17 days of measurement would be required. When 90% of subjects must be below the GV MAE threshold of 2%, 33 days of measurement would be required.

Table 3 summarizes the results shown in figure 1A–D.

The results presented in table 3 stratified by diabetes type (ie, type 1 diabetes and type 2 diabetes) and treatment modality (ie, multiple daily injections, insulin pump, and hybrid closed-loop system) are provided as a summary in online supplemental table S3.

A TIR MAE of 5% for 90% of the patients was achieved after 27 days for patients with type 1 diabetes and after 40 days for patients with type 2 diabetes. The same TIR MAE threshold of 5% for 90% of the patients was achieved for those under treatment with multiple daily injections at 40 days, for insulin pump users at 31 days, and with 9 days for hybrid closed-loop system users. A TBR MAE of 1% for 90% of the patients was achieved after 48 days for patients with type 1 diabetes and after 45 days for patients with type 2. The same TBR MAE threshold of 1% for 90% of the patients was achieved for those under treatment with multiple daily injections at 56 days, for insulin pump users at 53 days, and with 17 days for hybrid closed-loop system users.

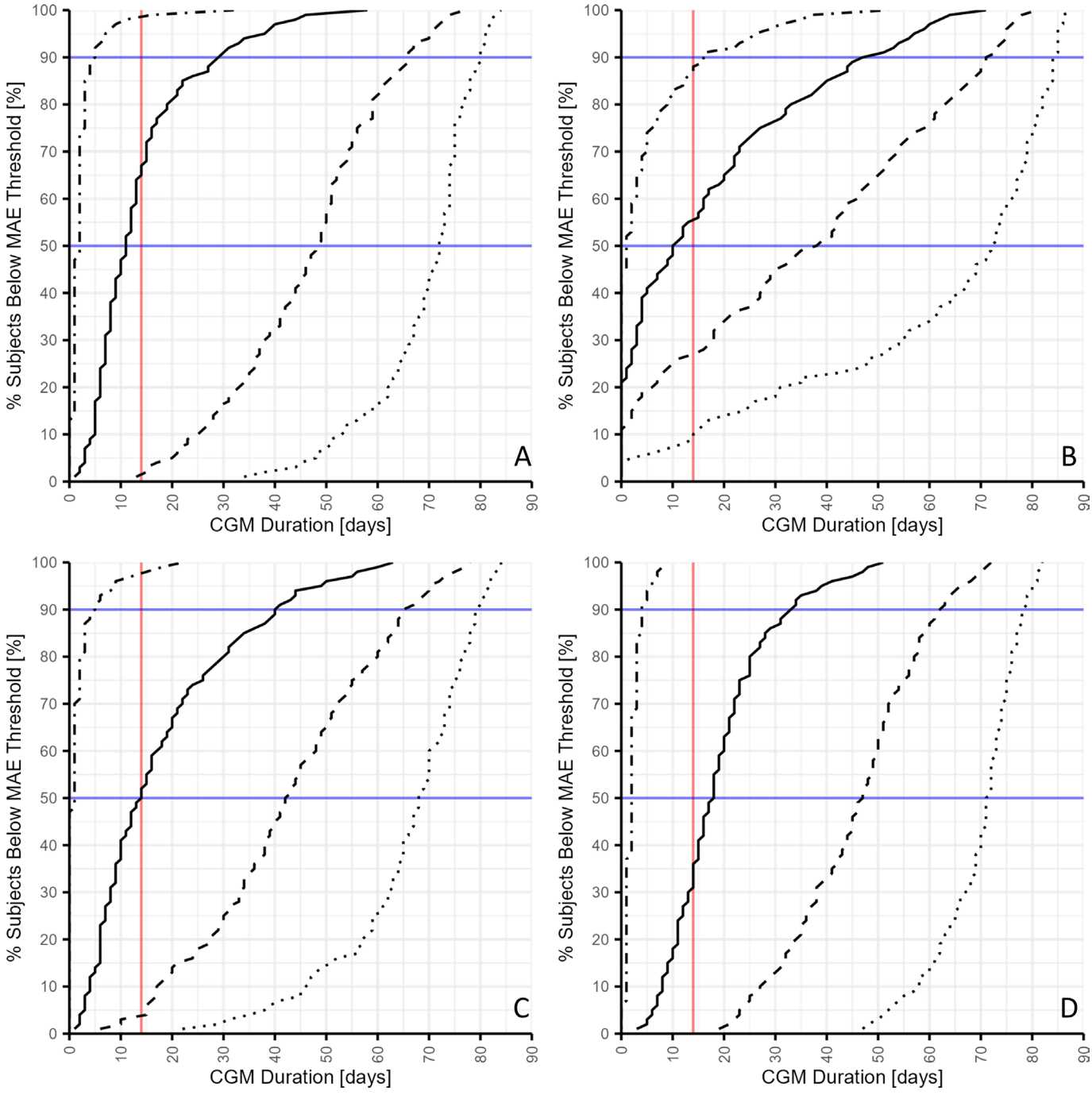

Figure 1 Required CGM durations for fractions of subjects to be below arbitrary CGM-derived metric MAE thresholds. (A) TIR. Dotted: TIR MAE=1%; dashed: TIR MAE=2%; solid: TIR MAE=5%; dot-dashed: MAE=10%. (B) TBR. Dotted: TBR MAE=0.2%; dashed: TBR MAE=0.5%; solid: TBR MAE=1%; dot-dashed: TBR MAE=2%. (C) GMI. Dotted: GMI MAE=0.05% (0.5 mmol/mol); dashed: GMI MAE=0.1% (1 mmol/mol); solid: GMI MAE=0.2% (2 mmol/mol); dot-dashed: GMI MAE=0.5% (5 mmol/mol). (D) GV. Dotted: GV MAE=0.5%; dashed: GV MAE=1%; solid: GV MAE=2%; dot-dashed: GV MAE=5%. The red vertical line at 14 days in each subfigure represents the current recommended time interval for evaluation of CGM-derived metrics. The two blue horizontal lines at 50% and 90% in each figure represent the median of the population and the point where 90% of the population is below the MAE threshold, that is, the 50th and the 90th percentile. CGM, continuous glucose monitoring; GMI, glucose management indicator; GV, glycemic variability; MAE, mean absolute error; TBR, time below range; TIR, time in range.

DISCUSSION

This study provides the necessary analyses and specific information to guide decisions on the required measurement duration when estimating CGM-derived metrics. In contrast to some previous studies,[3 6 7 12] the calculations were performed on individual patient data. That individual calculations can lead to different conclusions and decisions for individual patients, for example, within the currently recommended 14-day time window, is underscored by the finding that there was a notable difference

Table 3 Required number of days of CGM duration for fractions of subjects to be below arbitrary CGM-derived metric MAE thresholds

	50% of subjects below threshold	60% of subjects below threshold	70% of subjects below threshold	80% of subjects below threshold	90% of subjects below threshold	100% of subjects below threshold
TIR MAE <1%	72 days	74 days	75 days	77 days	80 days	84 days
TIR MAE <2%	48 days	51 days	54 days	59 days	66 days	77 days
TIR MAE <5%	11 days	13 days	15 days	19 days	29 days	58 days
TIR MAE <10%	2 days	2 days	2 days	3 days	5 days	32 days
TBR MAE <0.2%	73 days	77 days	79 days	82 days	85 days	88 days
TBR MAE <0.5%	39 days	46 days	54 days	64 days	73 days	81 days
TBR MAE <1%	11 days	17 days	23 days	35 days	51 days	71 days
TBR MAE <2%	1 day	3 days	5 days	9 days	16 days	52 days
GMI MAE <0.05% (0.5 mmol/mol)	68 days	70 days	74 days	77 days	79 days	84 days
GMI MAE <0.1% (1 mmol/mol)	42 days	48 days	52 days	60 days	65 days	78 days
GMI MAE <0.2% (2 mmol/mol)	14 days	17 days	22 days	30 days	40 days	63 days
GMI MAE <0.5% (5 mmol/mol)	1 day	1 day	1 day	2 days	5 days	22 days
GV MAE <0.5%	71 days	73 days	74 days	76 days	78 days	82 days
GV MAE <1%	47 days	50 days	52 days	57 days	62 days	72 days
GV MAE <2%	18 days	20 days	22 days	25 days	33 days	51 days
GV MAE<5%	2 days	2 days	3 days	3 days	4 days	8 days

GV, glycemic variability ; MAE, mean absolute error; TBR, time below range; TIR, time in range.

between the study population's mean MAE for TIR estimation versus the population's maximum MAE, namely, 4.8% vs 13.5%.

When considering the different arbitrary MAE thresholds, it is relevant to focus on the most commonly applied and evaluated CGM-derived metric, that is, the TIR. It is currently accepted that changes in TIR of at least 5% are considered as clinically significant.[5 13] Likewise, a change of 0.5% (5 mmol/mol) for GMI HbA1c can be considered as clinically relevant.[14] Then, proceeding with the notion that the MAE of the estimate should not exceed the clinically relevant 5% change in TIR, one could propose the TIR MAE must stay below this 5% threshold. When one assumes that the accuracy of an estimate of long-term glucose regulation must be better than a clinically significant change in TIR for at least 90% of cases, the conclusion from our findings based on the data of all subjects would be that 29 days of measurement are required.

Also, with 29 days of measurement, the CGM duration is sufficient to ensure that 100% of subjects fall below a GMI MAE threshold of 0.5% (5 mmol/mol) and that between 70% and 80% of subjects fall below a TBR MAE threshold of 1%. Although one could argue that every moment of hypoglycemia—and therefore every percentage in TBR—should ideally be detectable, there is no clearly defined clinically relevant change for TBR that the MAE should be below. However, to keep the TBR MAE below 2% for 90% of subjects, a measurement duration of 16 days is already required. If a maximum TBR MAE of 1% is desired, an even longer measurement period is necessary, namely, 51 days. For GV, similar conclusions can be drawn about the influence of CGM duration on the fraction of patients being below MAE thresholds.

When analyzing subgroups, it can be concluded that a CGM duration of more than 14 days is necessary for all but one group for 90% of subjects to be below a TIR MAE of 5%. The exception is the group of hybrid closed-loop system users who needed 9 days to be below the MAE threshold.

All in all, at least in the population currently investigated, we argue that CGM duration longer than the currently recommended 14 days is necessary to ensure an accuracy sufficient for detecting clinically relevant changes in long-term glucose control. However, using the full 90 days is not necessary to secure that more than 90% of the population is within a relevant TIR MAE. When estimating based on shorter CGM durations than the recommended minimum required CGM duration, deviations of the true value may exist and should be considered. On the other hand, when an estimate needs to be made for a shorter time period than 90 days, fewer days will likely be required for a reliable assessment.

Not all findings of this work can be directly compared with existing literature. Herrero *et al* used MAPE instead of MAE and found a median MAPE of ~19% over 1 day of data.[9] Given the fact that the mean TIR for the two datasets used by Herrero *et al* is ~62%, this would translate to a median MAE of ~11.8%, while a median MAE of 13.4% and a median MAPE of 22.3% were found in our work.

For minimum and maximum MAE and longer observation periods, similar deviations can be observed. These small differences could be explained by differences in mean TIR and other characteristics of the datasets.

The strengths of this study are the use of TAs, the number of included patients and the insight into distributions of MAEs within the population. A total of 200 patients with diabetes were included in this study, meaning that the resolution in the fraction of patients below thresholds is 0.5% and therefore individual patients do not have major impact on the outcomes. This work demonstrates that achieving MAE thresholds for every subject requires significantly more time compared with targeting for half of the subjects to be below the thresholds.

Another strength of this study is the use of real-world data. This ensures that sensor usage, therapy, and therefore glucose patterns in the patients resemble those in real-world scenarios. Subjects had various diagnoses, therapies, and sensors. This reasonable reflection of a cross-section of patients with diabetes allows for, if desired, identification of a single minimum required duration of CGM measurement that might be applicable to the entire population. However, as suggested by the results, there are differences between subgroups. Some groups, such as the group with type 2 diabetes and the multiple daily injections group, were relatively small, making the results more sensitive to the influence of individual patients. Moreover, different sensors were used, and sensor placement was not standardized, which may have caused deviations in calculated CGM-derived metrics and might be a limitation of this study. However, sensor placement could also be an unknown factor in scenarios where the results of this study are applied.

A potential limitation of this study is that it does not address the presence of missing data. All CGM data points are concatenated per patient, meaning that a measurement period was reduced to a consecutive data based on the percentage of available data. When applying the results of this study to real-world data, a strategy for addressing this limitation is to concatenate the available data points. For estimation of the minimum required CGM duration, the amount of missing data could be estimated to determine the length of non-concatenated data that is needed to meet the desired MAE. When data are not concatenated and high percentages of data loss or long periods of data loss exist, this could affect the minimum required measurement duration.[15 16]

The generalizability of the findings needs to be addressed in future research, although both patients with type 1 and type 2 diabetes were represented in the current study, and the population was heterogeneous with respect to age, sensor types, treatment modalities and HbA1c values. Still, the optimal measurement duration may differ, dependent on the characteristics of the population under study. Furthermore, the characteristics of subgroups regarding the relationship between CGM duration and the MAE of CGM-derived metrics should be investigated. It is plausible that comparable MAEs can be achieved with different CGM durations depending on the characteristics of the selected subgroup, for example, the mean TIR, sex or different BMI categories.[14 17]

Healthcare professionals and researchers using CGM data can take the results of this study into consideration when assessing CGM-derived metrics. When more than 14 days of data are accessible, using them will decrease the MAE of the estimation. The results of this research can be used to give an indication of the fraction of patients being below a MAE for a given CGM duration.

CONCLUSIONS

Although there is currently no consensus on what is an acceptable MAE, and the acceptable threshold may vary depending on the CGM-derived metric of primary concern, this study provides insight into how MAEs of CGM-derived metrics change in comparison to those over a long-term period of 90 days according to the used observation period. It can be helpful for decision-making in the clinical setting and might be taken into account in future consensus meetings.

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Contributors SZ was involved in the design of the study and the analysis and interpretation of the results, contributed to discussion, and wrote the first draft of the manuscript. TU was involved in the design of the study, collected data, contributed to discussion, and reviewed and edited the manuscript. AV collected and processed data. B-JvB and GDL were involved in the design of the study and contributed to discussion and reviewed and edited the manuscript. All authors approved the final version of the manuscript. SZ is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests None declared.

Patient consent for publication Not applicable.

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