# Abstract

1. Diametrics is a web application designed for the analysis of Continuous Glucose Monitoring (CGM) data. The application provides functionalities for data overview and editing, allowing users to verify and adjust the analyzed period. Users can customize analysis options, including filling data gaps, defining day/night time settings, and setting time in range thresholds. Diametrics calculates standard metrics based on ADA recommendations, presenting them in a sortable and filterable table. Visualizations, powered by Plotly, facilitate the exploration of metric results and distributions. The application also offers advanced analysis capabilities, enabling users to focus on specific periods of interest and explore associated metrics. Overall, Diametrics provides an accessible and comprehensive tool for assessing glycemic control using CGM data.

# Introduction

The aim of this project was to make a simple, flexible tool to calculate the metrics of glycemic control from continuous glucose monitoring (CGM) data.

Continuous glucose monitors are an exciting new development in the management of type 1 diabetes (T1D). These devices give glucose readings every 5 to 15 minutes, providing large amounts of data and providing potential for unprecedented insight into glucose dynamics throughout the day. NICE has recently announced that all people with type 1 diabetes will receive a CGM. This dramatic increase in data will provide opportunity for significant advances in diabetes health research, but will naturally result in an increased demand for effective data analysis tools for non-technical researchers and clinicians.

The international consensus on the use of continuous glucose monitors (CGMs) has identified several metrics of glycemic control that are important for assessing and optimizing diabetes management. However, the current platforms on which CGM data analysis can be performed are proprietary, closed source and limited in terms of functionality. The glucose data can be analysed with some basic metrics but cannot be explored in any more flexible or complex ways. Consequently, researchers are exporting the data and calculating the relevant metrics manually, which is extremely time consuming and prone to error.

The idea of this project began when Cat was approached to try to solve this problem and the idea of a no-code WebApp for calculating the metrics of glycemic control was was born. The WebApp allows researchers to easily calculate the metrics of glycemic control whilst also providing unprecedented freedom to explore the data further. Diametrics can be used to calculate the commonly used metrics of glycaemic control, explore your data through interactive visualisations and break your data down into specific periods of interest.

Whilst there are plenty of tools available to calculate the metrics of glycemic control using a variety of different packages there are a few important ways Diametrics adds to the literature. Firstly, there are only a few that require no coding or data preprocessing and secondly (most importantly) there are none available that can be used to calculate the metrics of glycemic control for short periods within a CGM file, such as exercise, mealtimes and stages of pregnancy.

# Methods

All code was written in Python 3.9. Go our [GitHub](https://github.com/cafoala/diametrics-webapp-dash) where you can also find all the open source code.

# Functionality

Here I think I should talk about the different things the webapp can do, e.g. upload data from different devices,

## Easy-to-use Web Application

The Diametrics dashboard is navigated using the tabs at the top of the page. The first 4 tabs must be run consecutively, and you won’t be able to open the next one before the previous one is completed. The final 2 tabs can be accessed once the standard metrics in tab 4 have been calculated. For a more detailed description of each tab see the description below.

## Uploading data

To utilize Diametrics, users begin by uploading CGM data to the first tab of the application, which supports CSV, Excel, and text file formats. The application currently supports devices such as Abbot (FreeStyle Libre), Dexcom, and Medtronic. Users can upload multiple files for analysis, as long as they are of the same type in terms of device, units, and date-time format. There are no limitations on the size or number of files that can be uploaded. Once the upload process is completed, users can verify the correctness of the uploaded files by checking the list of files displayed in the application.

## Data overview

Once data is uploaded, an overview of the processed CGM files is available to view in an editable table. If the data is not usable due to errors in the file, this will be visible in the ***“Usable”***column and the row is highlighted red. If the row is highlighted red, the analysis with this file cannot go any further and the file will need to be edited in some way.

This tool also gives users the opportunity to edit the period of data they wish to analyse. This can be done by editing the *“****Start DateTime”*** and *“****End DateTime”*** columns with the period of their interest. ~~The format for this will need to be either “yyyy-mm-dd hh:mm” or “yyyy/mm/dd hh:mm”, with hours and minutes being optional.~~ If edited, the *“Days”* and *“Data Sufficiency (%)”* columns will be updated automatically to the new period. If the entries are invalid, you’ll see ***N/A*** appear and the row will be highlighted red to show that it is no longer usable.

The International consensus specifies that there should be a minimum of 2 weeks of data with 70-80% data sufficiency. If either the number of days or the data sufficiency are below this recommendation, they will be highlighted orange to inform users of this, however they can still proceed with their analysis.

## Analysis options

This section gives users more freedom to adjust the metrics to suit their needs but is not necessary to proceed with calculating the standard metrics. If you’d like to have a bit more control over how your metrics are calculated, there are three different ways you can do that here.

**Filling gaps**

Add this bro

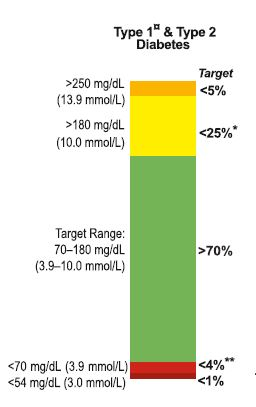
Cite interp paper!

**Day/night time**

ADA recommends calculating metrics for all the glucose data as well as periods broken down into day and night.

You can edit the day/night settings by clicking on the first drop-down bar. Here you can enter the times for the start and end of the day and night-time. The default times are set to 6am-12am for the day and 12am-6am for the night, as defined in the International Consensus.

The times you set don’t need to be the same for day and night, for example you can finish the day at 10pm and start the night at 2am (or vice versa). However, the times you set will remain the same across all files, at this stage you can’t tailor them to individuals. If you’re interested in more in-depth periodic analysis, then see the advanced analysis section.

**Time in range thresholds**

The ADA provides 5 ranges of interest, which can be seen in figure X. Diametrics automatically adds a further split of normal range into tight range and less tight range, as proposed by this paper.

In addition to this, Diametrics allows users to add percentage of time spent in a range that’s outside of the standard ranges. This is done using range sliders in the Analysis Options tab where users can add all the ranges they’re interested in. These will then appear **alongside the** standard metrics with the header “***Time in range (lower threshold)-(upper threshold)”****.*

**Glycemic events**

The International consensus defines a glycemic event as 15 minutes or more below the level 1 threshold (3.9 mmol/L/70 mg/dL) for hypoglycemia and above the level 1 threshold (10.0 mmol/L/200 mg/dL) for hyperglycemia. The episode is over when 15 mins are spent back under/over the threshold respectively. A level 2 event is reached when the glucose level drops below/above the level 2 threshold (3.0 and 13.9 mmol/L for hypo- and hyper-glycemia respectively) for 15 minutes. A prolonged episode is 120 mins consecutively spent in level 2 hypo/hyper-glycemia.

Diametrics provides the option to change these defaults. Sliders can be used adjust the thresholds for level 1 and level 2 episodes for both hypoglycemia and hyperglycemia. The duration of glycemia considered an episode can also be edited from the default of 15 minutes for regular and 120 minutes for prolonged events.

## Standard metrics

The ADA released the international consensus detailing the important metrics. These metrics are all calculated by Diametrics plus a few other commonly used ones, all can be seen in figure X.

The metrics are displayed in a table with the metrics as the column headings and the ID as the index. The rows of the table can be sorted or filtered by specific columns. The columns can also be toggled to remove any unwanted metrics.

The units of the metrics can be displayed in either mmol/L to mg/dL, regardless of the units displayed in the original CGM files. The metrics can also be displayed as breakdowns of the metrics for day and night times selected in the analysis options.

Once adjusted, the table can be downloaded. The table will be download the table exactly as it looks on the screen so all of the filtering, sorting and column toggling will be maintained in the final file.

## Visualisations

The figures displayed on the Diametrics are all created using Plotly, an interactive Python plotting library. All figures can be downloaded and manipulated using the toolbar available in all of Plotly’s plots.

Below the metrics table are two overview data visualisations. The first is a bar graph that shows the result of each metric for each individual. The default is set to time in range, broken down into the different ranges recommended by the International Consensus. The second visualisation in a boxplot to show the distribution of the metric between individuals in the data uploaded. Both of these visualisations are controlled with the drop-down selection to the right of the page. These figures reflect the data in the table, so will change when units or time period is changed with the buttons at the top.

The visualisations tab contains three figures that explore each CGM file uploaded. The ID can be changed with the drop-down bar at the top. The first figure is the ambulatory glucose profile. The yellow central line shows the median glucose, the blue shows the interquartile range (25th and 75th percentiles) and the green dashed lines show the 10th and 90th percentiles. The second figure is a pie chart with the breakdown of the standard percentage time in ranges. The final figure is a line graph of the entire glucose trace.

## Advanced analysis

This section is the most exciting since it allows users to get a breakdown of the metrics of glycemic control for specific periods within the data, something that’s not available for non-coders until now.

For this analysis, users must create an external file documenting the time periods of interest to them which they will then upload to the app. This file must include the ID of the participant, the start and end times of the period of interest and optional label(s). The format for the date-times are flexible to allow for maximum ease when inputting data from other sources. A combination of start and end date (YYYY-MM-DD), start and end time (HH:MM(:SS)), start and end date-time (YYYY-MM-DD HH:MM(:SS), and duration (minutes). Labels can can used by users to distinguish the periods of interest. There is no limit to the number of labels and they can be named whatever the user wants.

As well as getting metrics for the period specified in the external file, Diametrics also allows users to look at the windows around the event. This feature is particularly useful for those establishing glycemic control during set events throughout that are generally less than a day in length. For example, exercise and the 4 hours after exercise or mealtimes and the hour before and after.

The range sliders give the users the chance to customise the window they are interested in around the periods in the file. The first slider is set to the default window of the start of the period to the end of the period. Users can only add windows up to 4 hours before and after the event. The time before is measured from the start of the event and the time after is measured from the end.

There is also the option to produce the standard metrics for the whole 24 hours after the period of interest and the night after the event. The night-time is taken from the analysis options in tab 3 (default 12am-6am).

The table produced will show all of the metrics of glycemic control for each period specified. Any changes made in the analysis options will also be reflected in these metrics. The data sufficiency column shows how much data is available for the period of interest, if there is no data available the row will be filled with N/A values. The metrics table can be manipulated in the same manner as the standard metrics table.

# Validation with external dataset