ISSN: 2640-4133

Research Article

Advances in Bioengineering & Biomedical Science Research

Comparison of High Range and Low Range of Sensor eAG and 24-Hour Daily GF Using 3+ years of Continuous Glucose Monitoring Sensor Device Collected Data Based on GH-Method: Math-Physical Medicine (No. 458)

Gerald C Hsu

EclaireMD Foundation, USA

*Corresponding author

Gerald C Hsu, EclaireMD Foundation, USA

Submitted: 11 Sep 2021; **Accepted:** 15 Sep 2021; **Published:** 25 Sep 2021

Citation: *Gerald C Hsu (2021) Comparison of High Range and Low Range of Sensor eAG and 24-Hour Daily GF Using 3+ years of Continuous Glucose Monitoring Sensor Device Collected Data Based on GH-Method: Math-Physical Medicine (No. 458). Adv Bioeng Biomed Sci Res 4(3): 22-.25.*

Abstract

Since 5/5/2018, the author utilized a continuous glucose monitoring (CGM) sensor device to collect his glucoses 96 times each day. He then calculates his average daily sensor glucoses (eAG) and sensor glucose fluctuation (GF) within a 24-hour period each. His GF is defined as the maximum glucose value minus the minimum glucose value within a day. The definition of "eAG" is the mean value of glucose data that is similar to HbA1C which is useful in diabetes control. Moreover, the glucose excursion or GF has noticeable influences on various diabetes complications. During the period of 1,218 days from 5/5/2018 through 5/31/2021, he has collected a total of 116,928 glucose data. With this big data accumulated for over 3+ years and stored on a cloud server, it is easily for him to study and observe the overall glucose changes from day to day along with the phenomenon of his daily GF changes.

During the past decade, the medical community has used the term "glycemic variability (GV)" to describe the glucose excursion which involves some questionable definitions of mathematical equations with less-quantitative and somewhat inconclusive findings. It is the author's belief that the word "variability" could mean many things to different people; therefore, he decides to apply the basic concept of glucose excursion (fluctuation) without using the defined GV equation. This will allow him to have a better understanding and achieve a deeper appreciation for the important biophysical phenomenon of "glucose fluctuation".

Many research publications have covered the importance and impact of GV or GF on diabetic macro-vascular and micro-vascular complications (References 16 and 17). In those publications, it has defined and "qualitatively proven" that GF does impact the macro-vascular system, including the heart and brain, as well as the micro-vascular system such as kidneys, feet, eyes, nerves, etc. This particular report adopts the author's developed GH-Method: math-physical medicine to seek more quantitatively described results. Hopefully, it can provide a different but still accurate enough description to complement those using biochemical medicine interpretations of glucose and glucose fluctuations.

In this study, two important glucose values serve as the dividing line in medicine today. The two dividing lines from above are "unhealthy" while the following two dividing lines are "healthy":

(1) eAG at 140 mg/dL
(2) GF at 96 mg/dL

From the ~3-year period from 5/5/2018 through 5/31/2021, his identified key data are listed:

Average eAG = 124 mg/dL
High eAG = 148 mg/dL (14%)
Low eAG = 120 mg/dL (86%)
Average GF = 96 mg/dL
High GF = 122 mg/dL (43%)
Low GF = 76 mg/dL (57%)

In summary, the control of his eAG, which is below the medically accepted baseline of 140 mg/dL, is better than the control of his GF that is equal to the medically accepted baseline of 96 mg/dL.

Introduction

Since 5/5/2018, the author utilized a continuous glucose monitoring (CGM) sensor device to collect his glucoses 96 times each day. He then calculates his average daily sensor glucoses (eAG) and sensor glucose fluctuation (GF) within a 24-hour period each. His GF is defined as the maximum glucose value minus the minimum glucose value within a day. The definition of "eAG" is the mean value of glucose data that is similar to HbA1C which is useful in diabetes control. Moreover, the glucose excursion or GF has noticeable influences on various diabetes complications. During the period of 1,218 days from 5/5/2018 through 5/31/2021, he has collected a total of 116,928 glucose data. With this big data accumulated for over 3+ years and stored on a cloud server, it is easily for him to study and observe the overall glucose changes from day to day along with the phenomenon of his daily GF changes.

During the past decade, the medical community has used the term "glycemic variability (GV)" to describe the glucose excursion which involves some questionable definitions of mathematical equations with less-quantitative and somewhat inconclusive findings. It is the author's belief that the word "variability" could mean many things to different people; therefore, he decides to apply the basic concept of glucose excursion (fluctuation) without using the defined GV equation. This will allow him to have a better understanding and achieve a deeper appreciation for the important biophysical phenomenon of "glucose fluctuation".

Method

Glucose and HbA1C

Using signal processing techniques, the author identified approximately 20 influential factors of physical behaviors for glucose. From these 20 factors, he further outlined the following six most prominent conclusions for his glucose and HbA1C values:

1. The CGM sensor based A1C variances have the following contributions: 29% from fasting plasma glucose (FPG), 38% from postprandial plasma glucose (PPG), and 33% from between-meals and pre-bedtime periods. Therefore, ***all three segments contributed to HbA1C value almost equally.***
2. FPG variance due to weight change with ~77% contribution.
3. Colder weather impact on FPG with a decrease of each Fahrenheit degree caused 0.3 mg/dL decrease of FPG.
4. PPG variance due to carbs/sugar intake with ~39% weighted contribution on PPG.
5. PPG variance due to post-meal walking with ~41% weighted contribution on PPG.
6. Warm weather impact on PPG with an increase of each Fahrenheit degree caused 0.9 mg/dL increase of PPG.

It is common knowledge that *HbA1C is closely connected to the average glucose for the past 90 days*. Actually, the average human red blood cells (RBC), after differentiating from erythroblasts in the bone marrow, are released into the blood and survive in circulation for approximately 115 days. Although the author has adopted a 120-days model in his previous sensor HbA1C studies, he uses the 90-days model in this particular study. It should also be pointed out that he utilized the CGM collected sensor glucose and calculated HbA1C to compare against his collected nine lab-tested HbA1C data, while the lab A1C data actually contained a large margin of error due to various reasons.

GF and Diabetic Complications

The following are excerpts from References 16 and 17:

From Reference 16: "Diabetes mellitus is a world-wide health issue with potential for significant negative health outcomes, including microvascular and macrovascular complications. The relationship of hemoglobin HbA1c and other glycosylation end products (AGEs) to these complications, particularly microvascular disease, is well understood. More recent evidence suggests that glycemic variability may be associated with diabetes macrovascular complications. As HbA1c is better representative of average glucose levels and does not account as well for glycemic variability, hence new methods to assess and treat this variability is needed to reduce incidence of complications."

From Reference 17: "Few physicians recognized that only 6.6% of the variation in risk of retinopathy for the entire study cohort was explained by the difference in the treatment groups, although it was widely appreciated that nearly all of this treatment group effect was explained by differences in the mean level of HbA1C over time. The trial results also considered the instantaneous risk of retinopathy (i.e., whether a patient would develop retinopathy at a particular point in time during the study) rather than eventual risk of retinopathy (whether a patient would develop retinopathy over his or her entire life). However, this latter outcome is not feasible to study because it would require lifetime follow-up of patients.

Similarly, HbA1C and duration of diabetes (glycemic exposure) explained only about 11% of the variation in retinopathy risk for the entire study population, suggesting that the remaining 89% of the variation in risk is presumably explained by other factors independent of HbA1C. Given the magnitude of the effect of unmeasured elements in the Diabetes Control and Complications Trial, identification of these elements is critically important for designing more effective therapy for type 1 diabetes.

What factors not captured by HbA1C measurements might explain the remaining 89% of microvascular complications risk? Possible factors unrelated to blood glucose levels include genetics, environmental toxins, and metabolic consequences of abnormal insulinization such as increased free fatty acid levels. Possible factors related to blood glucose levels most likely reflect the fact that ***since HbA1c represents the time-averaged mean level of glycemia, it provides no information about how closely the fluctuations of blood glucose levels around that mean mimic the normal narrow range of blood glucose excursion. In addition, patients with identical HbA1C values differ significantly in amplitude and duration of glycemic spikes."***

Glucose Fluctuation (GF)

Another excerpt regarding glucose and glucose fluctuation from Reference 19 is listed below:

"A variety of stimulations and mechanisms tightly regulates blood sugar levels. This is important for metabolic homeostasis. Levels may fluctuate after fasting for long periods of time or an hour or two after food consumption. Despite this, the fluctuations are minor. Normal human blood glucose levels remain within a remarkably narrow range.

Blood Sugar Fluctuations

In most humans, this varies from about 82 mg/dl to 110 mg/dl (4.4 to 6.1 mmol/l) and the author takes the average glucose fluctuation from the mid-point value of 96 mg/dL. *The blood sugar levels rise to nearly 140 mg/dl (7.8 mmol/l) or a bit more in normal humans after a full meal. In humans, normal blood glucose levels are around 90 mg/dl, equivalent to 5mM (mmol/l). Since the molecular weight of glucose, C6H12O6, is about 180 g/mol, when calculated, the total amount of glucose normally in circulating human blood is around 3.3 to 7g (assuming an ordinary adult blood volume of 5 liters).”*

GF-Influenced eAG Study

In this study, he applied the following procedures to calculate and analyze both eAG and GF:

1. He collects his daily average CGM sensor glucose and calculates where he uses the abbreviation eAG and average glucose fluctuation (maximum glucose minus minimum glucose) with the abbreviation ***GF.***
2. He defines the high eAG for the glucose levels within the range of 140-210 mg/dL and the low eAG for the glucose readings within the range of ***70-140 mg/dL.***
3. He defines the high GF within the range of 96-223 mg/dL and low GF within the range of ***0-96 mg/dL.***
4. He calculate the average value for both high and low eAG and GF. He also calculate the percentages of contribution of high data dates and low data dates versus the total data dates.

Results

Figure 1 shows the analysis results of daily average glucose values or eAG with the following data table:

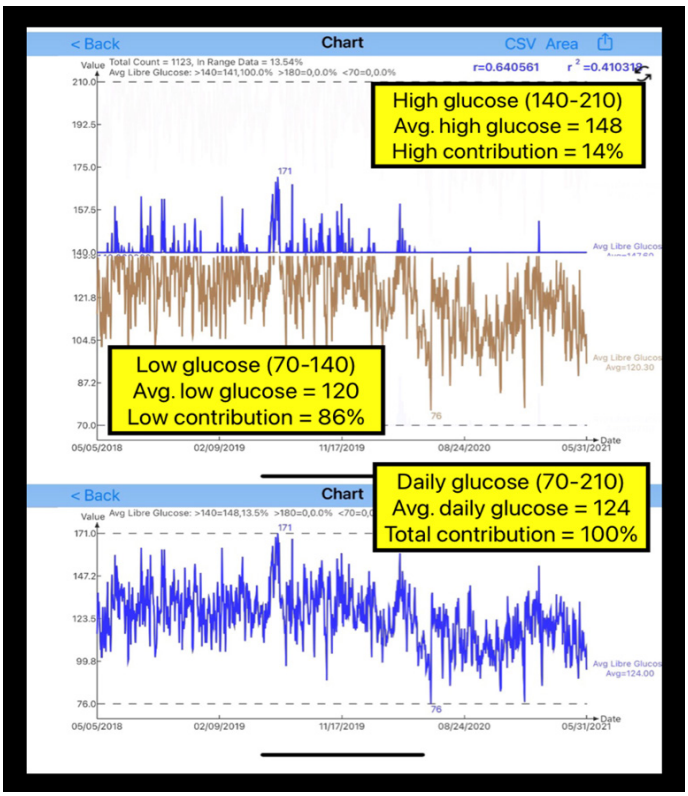

Figure 1: Daily eAG with high eAG and low eAG

Average eAG	***= 124 mg/dL***
Average high eAG	***= 148 mg/dL***
Average low eAG	***= 120 mg/dL***
High eAG share	***= 14%***
Low eAG share	***= 86%***

Figure 2 depicts the analysis results of daily glucose fluctuations or GF with the following data table:

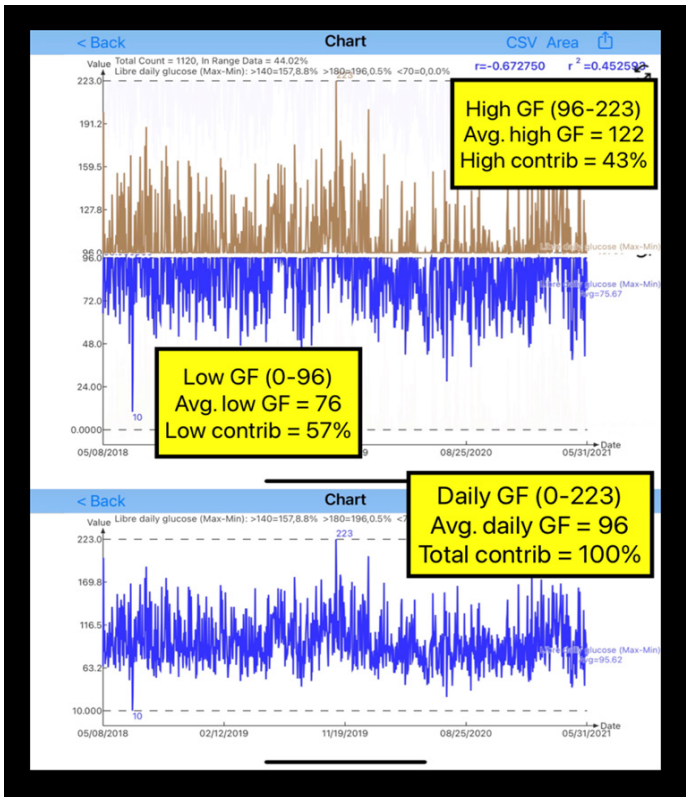

Figure 2: Daily GF with high GF and low GF

Average eAG	***= 96 mg/dL***
Average high eAG	***= 122 mg/dL***
Average low eAG	***= 76 mg/dL***
High eAG share	***= 43%***
Low eAG share	***= 57%***

Conclusion

Many research publications have covered the importance and impact of GV or GF on diabetic macro-vascular and micro-vascular complications (References 16 and 17). In those publications, it has defined and “***qualitatively*** proven” that GF does impact the macro-vascular system, including the heart and brain, as well as the micro-vascular system such as kidneys, feet, eyes, nerves, etc. This particular report adopts the author’s developed GH-Method: ***math-physical medicine*** to seek more quantitatively described results. Hopefully, it can provide a different but still accurate enough description to complement those using ***biochemical medicine*** interpretations of glucose and glucose fluctuations.

In this study, two important glucose values serve as the dividing line in medicine today. The two dividing lines from above are “unhealthy” while the following two dividing lines are “healthy”:

(1) eAG at 140 mg/dL
(2) GF at 96 mg/dL

From the ~3-year period from 5/5/2018 through 5/31/2021, his identified key data are listed:

Average eAG = 124 mg/dL
High eAG = 148 mg/dL (14%)
Low eAG = 120 mg/dL (86%)
Average GF = 96 mg/dL
High GF = 122 mg/dL (43%)
Low GF = 76 mg/dL (57%)

In summary, the control of his eAG, which is below the medically accepted baseline of 140 mg/dL, is better than the control of his GF that is equal to the medically accepted baseline of 96 mg/dL [1-21].

References

1. Hsu Gerald C (2020) Biomedical research methodology based on GH-Method: math-physical medicine (No. 310). GHMethod: Math-Physical Medicine 2020: 22-34.
2. Hsu Gerald C (2020) A Case Study on the Prediction of A1C Variances over Seven Periods with guidelines Using GH-Method: math-physical medicine (No. 262). OSP J Health Car Med 1. HCM-1-107.
3. Hsu Gerald C (2020) A Case Study on the Investigation and Prediction of A1C Variances Over Six Periods Using GH-Method: math-physical medicine (No. 116). International Journal of Research Studies in Medical and Health Sciences 5: 36-37.
4. Hsu Gerald C (2020) A Case Study of Investigation and Prediction of A1C Variances Over 5 Periods Using GH-Method: math-physical medicine (No. 65).
5. Hsu Gerald C (2020) Segmentation and pattern analyses for three meals of postprandial plasma glucose values and associated carbs/sugar amounts using GH-Method: math-physical medicine (No. 326). J App Mat Sci & Engg Res 4: 142-146.
6. Hsu Gerald C (2020) Using GH-Method: math-physical medicine to Conduct Segmentation Analysis to Investigate the Impact of both Weight and Weather Temperatures on Fasting Plasma Glucose (FPG) (No. 68). International Journal of Research Studies in Medical and Health Sciences 5: 3-5.
7. Hsu Gerald C (2020) Investigation of linear elastic glucose behavior with GH-modulus linking carbohydrates/sugar intake and incremental PPG via an analogy of Young's modulus from theory of elasticity and engineering strength of materials using GH-Method: math-physical medicine, Parts 1, 2, and 3 (No. 352). J App Mat Sci & Engg Res 4: 8-18.
8. Hsu Gerald C (2020) Applying linear elastic glucose behavior theory and AI auto-correction to predict A1C Variances over the ninth period using GH-Method: math-physical medicine (No. 354). Gynecol Women's Health 20: 556032.
9. Hsu Gerald C (2021) Building up a formula for estimated HbA1C value using averaged daily glucose, daily glucose fluctuation, and A1C conversion factor and comparing against lab-tested HbA1C for 10 period within past 3 years based on GH-Method: math-physical medicine (No. 441).
10. Hsu Gerald C (2021) Investigating the HbA1C changes between adjacent periods for two clinical cases based on GH-Method: math-physical medicine (No. 442).
11. Hsu Gerald C (2021) Investigating glucose changes of a type 2 diabetes patient's clinical data for three selected periods based on GH-Method: math-physical medicine (No. 443).
12. Hsu Gerald C (2021) Predicted HbA1C values using a continuous glucose monitor sensor for a type 2 diabetes patient's clinical data over six long periods and two short periods based on GH-Method: math-physical medicine (No. 444).
13. Hsu Gerald C (2021) Predicted HbA1C values using an eAG/A1C conversion factor from continuous glucose monitor (CGM) sensor data over three years based on GH-Method: math-physical medicine (No. 448).
14. Hsu Gerald C (2021) Predicted HbA1C values using a combination of weighted glucose and glucose fluctuation with an eAG/A1C conversion factor from continuous glucose monitor (CGM) sensor data over three years based on GH-Method: math-physical medicine (No. 449).
15. Hsu Gerald C (2021) Predicted HbA1C comparison between lab-tested A1C and three models, simple conversion factor equation, weighted eAG and glucose fluctuation equation, and ADA defined HbA1C equation using three-years continuous glucose monitor (CGM) sensor data based on GH-Method: math-physical medicine (No. 450).
16. Johnson Eric L (2012) Glycemic variability in type 2 diabetes mellitus: oxidative stress and macrovascular complications. Adv Exp Med Biol 771:139-154.
17. Michael Brownlee, Irl B Hirsch (2006) Glycemic variability: a hemoglobin A1c-independent risk factor for diabetic complications. JAMA 295: 1707-1708.
18. Hsu Gerald C (2021) The contribution of Glycemic Variability or Glucose Fluctuation in risk probability for various diabetic complications using three years of continuous glucose monitor sensor data based on GH-Method: math-physical medicine (No. 451).
19. Ananya Mandal (2021) Normal Blood Sugar Values, Molarity and Fluctuations. https://www.news-medical.net/health/Blood-Sugar-Normal-Values.aspx
20. Hsu Gerald C (2021) Quantification of the CVD/stroke risk probability due to the extra input of an adjustment factor of Glycemic Variability (GV) or Glucose Fluctuation (GF) using three years of CGM sensor device collected data based on GH-Method: math-physical medicine (No. 456).
21. Hsu, Gerald C (2021) Comparison of waves and energies between the 3-hours versus 24-hours of glucose fluctuation using 3+ years of continuous glucose monitoring sensor device collected data based on GH-Method: math-physical medicine (No. 457).