The GH-Method

Predicted HbA1C Values Using a Combination of Weighted Glucose and Glucose Fluctuation with an eAG/A1C Conversion Factor from Continuous Glucose Monitor Sensor Data Over Three Years Based on GH-Method: Math-Physical Medicine (No. 449)

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Abstract

The author utilized his collected data of finger pierced glucose (4x per day), carbs-sugar intake amount, and post-meal walking steps for each meal over a period of 4 years, from 2017 to 2020, to calculate his predicted HbA1C values. His previously predicted A1C was conducted 9x for 9 different 5-month periods. In comparison to another set of 9 lab-tested HbA1C data, he achieved a near 100% prediction accuracy. Starting from 5/5/2018, along with the finger glucose, he also collected 96 glucose data per day for 1,095 days using a continuous glucose monitoring (CGM) sensor device for a total of ~105,120 glucose data. He noticed that from 5/5/2018 through 5/4/2019, his average daily sensor glucose (124.4 mg/dL) is 12% higher than his average daily finger glucose (110.9 mg/dL); therefore, if he uses the same formula for predicting HbA1C, it will result in a 12% higher sensor A1C (7.4%) than his finger A1C (6.6%). In this article, he uses the 90-days moving average daily glucose data (eAG) as his calculation base, which applies the following simple definition and equation of his predicted HbA1C formula with a conversion factor of CF: Predicted HbA1C = (67% eAG +33% GF) / CF, where the used CF values are 15.486 as the upper bound of the eAG/A1C CF value and 17.4 as the best-fitted CF value via a trial-and-error approach. In summary, comparing his predicted HbA1C values using an equation with a combination of 67% from eAG and 33% from GF with two different CF values against the lab-tested HbA1C values, he has drawn the following four key observations: (1) Using the same equation and CF value, the average sensor glucose and A1C are 12 % higher than his average finger glucose and A1C. However, his finger A1C is very close to the lab-tested A1C with a 99% of prediction accuracy. This observation explains his 9 published A1C variance papers using finger glucose, carbs/sugar, and post-meal walking steps. (2) In terms of time-scale based on 9 lab-tested dates, applying the equation of "Predicted HbA1C = (67% eAG +33% GF) / CF", his predicted sensor A1C would be 7.6 (13% higher than lab A1C with 86% accuracy) if using 15.486 as the CF value; and 6.7 (same as lab A1C with 99% accuracy) if using 17.4 as the CF value. (3) The case of CF=15.486 and predicted sensor A1C=7.6 has a correlation of 62% in comparison with 9 lab-tested A1C data curve. In the case of CF=18.9 and predicted sensor A1C=6.7 has a slightly higher correlation of 65% in comparison with 9 lab-tested A1C data curve. (4) The conclusion from the HbA1C equation with weighted eAG and GF is that using CF=17.4 would generate the best predicted sensor HbA1C with 99% prediction accuracy and 65% correlation with lab-tested A1C data and curve.

Keywords: HbA1C; Glucose; Continuous glucose monitoring; Finger glucose; Diabetes

Abbreviations: CGM: continuous glucose monitoring; FPG: fasting plasma glucose; PPG: postprandial plasma glucose; HbA1C: glycated hemoglobin; GF: glucose fluctuation

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1. INTRODUCTION

The author utilized his collected data of finger pierced glucose (4x per day), carbs-sugar intake amount, and post-meal walking steps for each meal over a period of 4 years, from 2017 to 2020, to calculate his predicted HbA1C values. His previously predicted A1C was conducted 9x for 9 different 5-month periods. In comparison to another set of 9 lab-tested HbA1C data, he achieved a near 100% prediction accuracy(1,2).

Starting from 5/5/2018, along with the finger glucose, he also collected 96 glucose data per day for 1,095 days using a continuous glucose monitoring (CGM) sensor device for a total of ~105,120 glucose data. He noticed that from 5/5/2018 through 5/4/2019, his average daily sensor glucose (124.4 mg/dL) is 12% higher than his average daily finger glucose (110.9 mg/dL); therefore, if he uses the same formula for predicting HbA1C, it will result in a 12% higher sensor A1C (7.4%) than his finger A1C (6.6%)(3,4).

In this article, he uses the 90-days moving average daily glucose data (eAG) as his calculation base, which applies the following simple definition and equation of his predicted HbA1C formula with a conversion factor of CF:

Predicted HbA1C = (67% eAG +33% GF) / CF

Where the used CF values are 15.486 as the upper bound of the eAG/A1C CF value and 17.4 as the best-fitted CF value via a trial-and-error approach.

2. METHODS

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 of the 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. He has adopted the 120-days model in his previous sensor HbA1C studies, but he uses the 90-days model in this particular study. It should also be pointed out that, he has used the CGM collected sensor glucose and calculated HbA1C to compare against his collected nine lab-tested HbA1C data, while the lab A1C data contained a large margin of error due to various reasons(5,6).

In this study, he applied the following procedures to calculate and analyze his predicted HbA1C:

(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) as GF. The role and influence of GF on HbA1C will be further discussed in his comparison against American Diabetes Association defined HbA1C formula in his next article No. 450.

(2) As a reference, he also accumulates his customized software calculated finger A1C based on finger-pierced glucose and sensor A1C based on CGM collected glucose.

(3) He then defines the following equation for his predicted HbA1C with different weight factors (WF) and A1C conversion factors. Predicted A1C = (eAG * WF1 + GF * WF2) / (A1C conversion factor CF) where WF1=67% and WF2=33%; A1C conversion factors are a lower CF=15.486 to generate higher A1C values and a preferred CF=17.4 to generate an almost identical value as the lab-tested A1C of 6.7.

(4) Finally, he calculates the HbA1C prediction accuracy and correlation coefficients (R) of the two predicted HbA1C values using two different CF values to compare against the lab-tested HbA1C dataset[7-9].

3. RESULTS

Figure 1 shows the comparison of sensor glucose vs. finger glucose (both daily and 90-days moving average) with sensor A1C vs. finger A1C (red cross points are the lab-tested A1C in figure 1). During the 3-year period from 5/5/2018 through 5/4/2019, his average daily sensor glucose (124.4 mg/dL) is 12% higher than his average daily finger glucose (110.9 mg/dL). Therefore, if he uses the same formula for predicting the HbA1C formula, it will provide the same result of 12% higher sensor A1C (7.4%) than his finger A1C (6.6%). This figure depicts the high accuracy of his finger A1C. However, sensor glucose monitoring has become increasingly popular for outpatients with diabetes. While the CGM can provide valuable information, the author would like to develop a simple yet highly accurate sensor A1C prediction equation for patients. This is the purpose of this article and article No. 450.

Figure 2 illustrates the HbA1C comparison between the lab-tested A1C vs. his predicted sensor A1C using the equation

Predicted HbA1C = (67% eAG +33% GF) / CF

Where he used CF values of 15.486 as the upper bound of the eAG/A1C CF value and 17.4 as the preferred CF value via a trial-and-error approach.

He has obtained an upper bound of A1C (7.6%) using a lower CF value of 15.486 (accuracy 86%) and a much more accurately predicted A1C (6.7%) using a higher CF value of 17.4 (accuracy 99%). In this diagram, the curve shape results using two different CF values are quite similar to each other, R=62% with CF=15.486 and R=65% with CF=17.4. Therefore, the model of CF=17.4 with 67% contribution from eAG and 33% contribution from GF not only provides a near 100% prediction accuracy but also has a 3% correlation improvement on A1C shape similarity with a correlation of 65%.

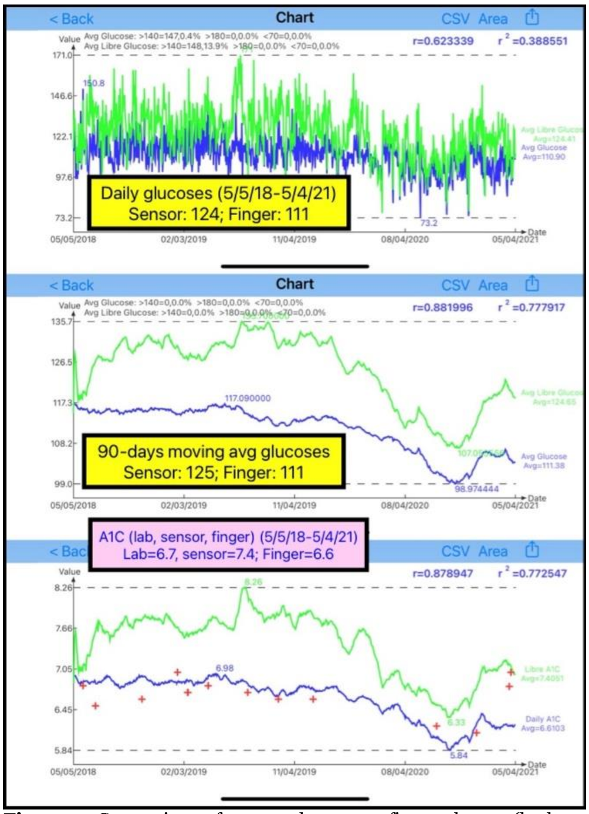
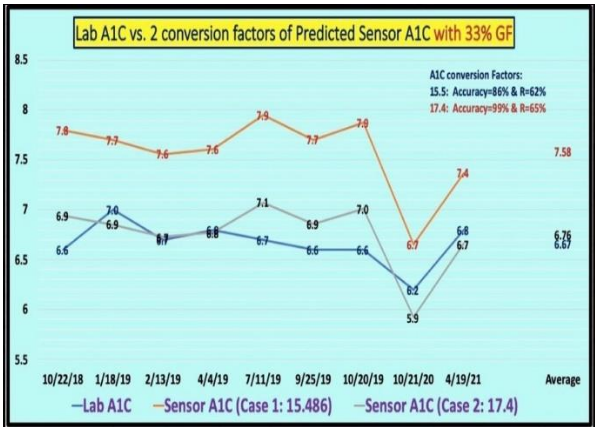


Figure 1: Comparison of sensor glucose vs. finger glucose (both daily and 90-days moving average) with sensor A1C vs. finger A1C (red cross points are lab-tested A1C).



Weight (GF 33% eAG 67%)	10/22/18	1/18/19	2/13/19	4/4/19	7/11/19	9/25/19	10/20/19	10/21/20	4/19/21	Average	Accuracy
Lab A1C	6.6	7.0	6.7	6.8	6.7	6.6	6.6	6.2	6.8	6.67	
Sensor A1C (Case 1: 15.486)	7.8	7.7	7.6	7.6	7.9	7.7	7.9	6.7	7.4	7.58	
Sensor A1C (Case 2: 17.4)	6.9	6.9	6.7	6.8	7.1	6.9	7.0	5.9	6.7	6.76	
Correlation (Lab vs. Case 1)										62%	86%
Correlation (Lab vs. Case 2)										65%	99%

Figure 2: Three HbA1C curves (CF=15.486, CF=17.4, and lab A1C) with weighted eAG and GF and input data table with results of prediction accuracy and correlation coefficients.

4. CONCLUSION

In summary, comparing his predicted HbA1C values using an equation with a combination of 67% from eAG and 33% from GF with two different CF values against the lab-tested HbA1C values, he has drawn the following four key observations:

(1) Using the same equation and CF value, the average sensor glucose and A1C are 12 % higher than his average finger glucose and A1C. However, his finger A1C is very close to the lab-tested A1C with a 99% of prediction accuracy. This observation explains his 9 published A1C variance papers using finger glucose, carbs/sugar, and post-meal walking steps.

(2) In terms of time-scale based on 9 lab-tested dates, applying the equation of "Predicted HbA1C = (67% eAG +33% GF) / CF", his predicted sensor A1C would be 7.6 (13% higher than lab A1C with 86% accuracy) if using 15.486 as the CF value; and 6.7 (same as lab A1C with 99% accuracy) if using 17.4 as the CF value.

(3) The case of CF=15.486 and predicted sensor A1C=7.6 has a correlation of 62% in comparison with 9 lab-tested A1C data curve. In the case of CF=18.9 and predicted sensor A1C=6.7 has a slightly higher correlation of 65% in comparison with 9 lab-tested A1C data curve.

(4) The conclusion from the HbA1C equation with weighted eAG and GF is that using CF=17.4 would generate the best predicted sensor HbA1C with 99% prediction accuracy and 65% correlation with lab-tested A1C data and curve[10-13].

5. REFERENCES

1) Hsu GC. Biomedical research methodology based on GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 310.

2) Hsu GC. A case study on the prediction of A1C variances over seven periods with guidelines using GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 262.

3) Hsu GC. A case study on the investigation and prediction of A1C variances over six periods using GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 116.

4) Hsu GC. A case study of investigation and prediction of A1C variances over 5 periods using GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 65.

5) Hsu GC. Segmentation and pattern analyses for three meals of postprandial plasma glucose values and associated carbs/sugar amounts using GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 326.

6) Hsu GC. 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). eclaireMD Foundation, USA. No. 68.

7) Hsu GC. 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. eclaireMD Foundation, USA. No. 352.

8) Hsu GC. Applying linear elastic glucose behavior theory and AI auto-correction to predict A1C variances over the ninth period using GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 354.

9) Hsu GC. 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. eclaireMD Foundation, USA. No. 441.

10) Hsu GC. Investigating the HbA1C changes between adjacent periods for two clinical cases based on GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 442.

11) Hsu GC. Investigating glucose changes of a type 2 diabetes patient's clinical data for three selected periods based on GH-Method: Math-Physical Medicine. eclaireMD Foundation, USA. No. 443.

12) Hsu GC. 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. eclaireMD Foundation, USA. No. 444.

13) Hsu GC. 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. eclaireMD Foundation, USA. No. 448.

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