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The GH-Method

Predicted HbA1C Comparison Among Lab-Tested A1C, Simple Conversion Factor Equation, Weighted eAG and Glucose Fluctuation Equation, along with the ADA Defined HbA1C Equation Using Three-Years of Continuous Glucose Monitor Sensor Data Based on GH-Method: Math-Physical Medicine (No. 450)

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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 (eAG) data and his glucose fluctuation (GF), defined as maximum glucose minus minimum glucose, as his calculation base. He also applies the following three equations to calculate his predicted HbA1C values: (1) Predicted HbA1C = eAG / CF1, (2) Predicted HbA1C = (67% eAG +33% GF) / CF2, (3) ADA defined A1C = (eAG + 46.7) / 28.7, where the CF1 is 18.9, CF2 is 17.4. Both the conversion factors yield near 100% accuracy on predicted A1C values. The two CF values were obtained via a trial-and-error approach. In summary, comparing his predicted HbA1C values using three different equations against the lab-tested HbA1C results, he has drawn the following five key observations: (1) Both Equation 1 using simple CF=18.9 and Equation 2 using weighted 67% eAG, 33% GF with CF=17.4 have resulted near 100% prediction accuracies (Equation 1 is 101% and Equation 2 is 99%). However, the American Diabetes Association (ADA) defined equation only yields a 91% prediction accuracy. (2) The biggest predicted A1C differences occur on the first lab-test day of 10/22/2018 and the most recent lab-test day of 4/19/2021. However, the average A1C values, 6.6 from Equation 1 (lower bound) and 6.8 from Equation 2 (upper bound), are extremely close to the average lab-tested A1C of 6.7. (3) In terms of shape similarity of HbA1C curves through the calculation of correlation coefficients, all three equation results are within the range of 62% to 65%. This means that the three curves are moving compatibly. (4) The conclusion is that both equations from using a simple conversion factor (Equation 1) and using weighted eAG and GF (Equation 2) are quite accurate in predicting the HbA1C value. However, the ADA equation model provides a less satisfactory result for this clinical case. (5) It seems that GF plays a hidden role in the formation of HbA1C.

Keywords: HbA1C; Lab-tested A1C; Glucose fluctuation; Continuous glucose monitoring; Finger glucose

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

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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 (eAG) data and his glucose fluctuation (GF), defined as maximum glucose minus minimum glucose, as his calculation base. He also applies the following three equations to calculate his predicted HbA1C values:

Predicted HbA1C = eAG / CF1

Predicted HbA1C = (67% eAG +33% GF) / CF2

ADA defined A1C = (eAG + 46.7) / 28.7

Where the CF1 is 18.9, CF2 is 17.4. Both the conversion factors yield near 100% accuracy on predicted A1C values. The two CF values were obtained 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 is identified in this article.

(2) As a reference, he also accumulates his customized software calculated finger A1C

based on finger-pierced glucose and sensor A1C based on CGM sensor collected glucose.

(3) He then uses the following three predicted HbA1C equations:

Predicted HbA1C = eAG / CF1

Predicted HbA1C = (67% eAG +33% GF) / CF2

ADA defined A1C = (eAG + 46.7) / 28

Where CF1=18.9, CF2=17.4

(4) Finally, he calculates the HbA1C prediction accuracy and correlation coefficients (R) of these 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.

Figure 2 illustrates the comparison among lab-tested HbA1C, 90-days moving average eAG, and predicted HbA1C using the ADA defined equation. It should be pointed out that the ADA HbA1C curve and 90-days moving average eAG curve are identical since the ADA equation is based on eAG solely and linearly.

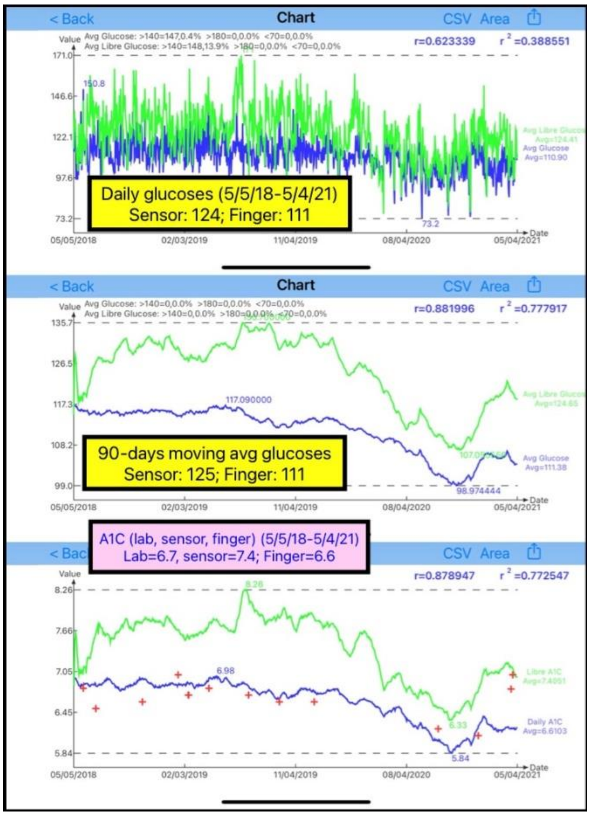


Figure 1: Comparison of sensor glucose vs. finger glucose (both daily and 90-days moving average) with sensor A1C vs. finger A1C (red cross points are lab-tested A1C).

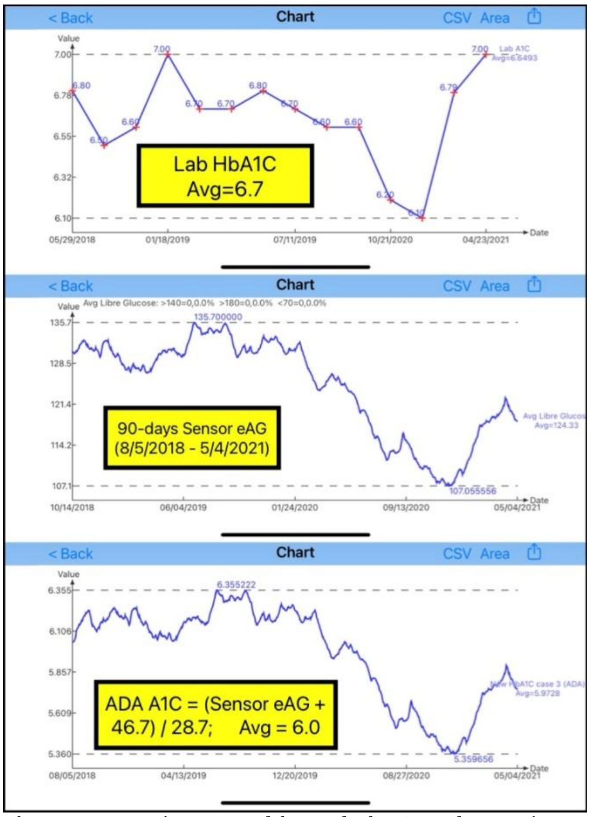


Figure 2: Comparison among lab-tested HbA1C, 90-days moving averaged eAG, and predicted HbA1C using ADA defined equation.

Figure 3 depicts the HbA1C comparison between the lab-tested A1C vs. the following three equations on nine lab-test dates:

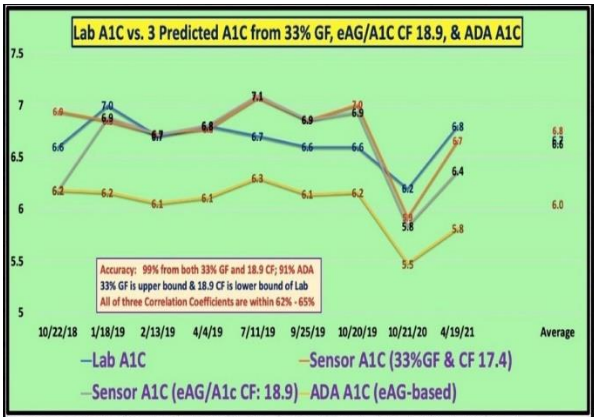
Predicted HbA1C = eAG / 18.9

Predicted HbA1C = (67% eAG +33% GF) / 17.4

ADA defined A1C = (eAG + 46.7) / 28

Equation 1 uses a simple CF=18.9 and Equation 2 applies a weighted 67% eAG and 33% GF with CF=17.4, which resulted in close to 100% prediction accuracies (Equation 1 is 101% and Equation 2 is 99%). However, the ADA defined equation has only yielded a 91% prediction accuracy.

In terms of shape similarity of HbA1C curves through the calculation of correlation coefficients, all three equation results are within the range of 62% to 65%. This means that the three curves are moving compatibly.



ADA A1C = (eAG + 46.7) / 28.7	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		6.7	100%
Sensor A1C (33%GF & CF 17.4)	6.9	6.9	6.7	6.8	7.1	6.9	7.0	5.9	6.7		6.8	99%
Sensor A1C (eAG/A1c CF: 18.9)	6.2	6.9	6.7	6.8	7.1	6.9	6.9	5.8	6.4		6.6	101%
ADA A1C (eAG-based)	6.2	6.2	6.1	6.1	6.3	6.1	6.2	5.5	5.8		6.0	109%
Sensor eAG	131	130	127	129	134	130	130	111	120		127	
Correlation (Lab vs.33%GF)											65%	
Correlation (Lab vs.CF 18.9)											63%	
Correlation (Lab vs. ADA A1C)											62%	

Figure 3: Four HbA1C curves of (1) lab-tested A1C, (2) eAG/A1C with CF=18.9, (3) weighted 67% of eAG and 33% of GF with CF=17.4, and (4) ADA defined equation of (eAG+46.7)/28.7.

The conclusion is that both equations from using a simple conversion factor (Equation 1) and using weighted eAG and GF (Equation 2) are quite accurate in predicting the HbA1C value. However, the ADA equation model provides a less satisfactory result for this clinical case. In addition, it seems that GF plays a hidden role in the formation of HbA1C.

4. CONCLUSION

In summary, comparing his predicted HbA1C values using three different equations against the lab-tested HbA1C results, he has drawn the following five key observations:

(1) Both Equation 1 using simple CF=18.9 and Equation 2 using weighted 67% eAG, 33% GF with CF=17.4 have resulted near 100% prediction accuracies (Equation 1 is 101% and Equation 2 is 99%). However, ADA defined equation has only yielded a 91% prediction accuracy[10].

(2) The biggest predicted A1C differences occur on the first lab-test day of 10/22/2018 and the most recent lab-test day of 4/19/2021. But their averaged A1C values, 6.6 from equation 1 (lower bound) and 6.8 from equation 2 (upper bound), are extremely close to the averaged lab-tested A1C of 6.7[11].

(3) In terms of shape similarity of HbA1C curves through calculation of correlation coefficients, all of these three equation results are within the range of 62% to 65%. This means that all three curves are moving compatibly[12].

(4) The conclusion is that both equations from using a simple conversion factor (Equation 1) and using weighted eAG and GF (Equation 2) are quite accurate in predicting the HbA1C value. However, the ADA equation model provides a less satisfactory result for this clinical case[13].

(5) It seems that GF indeed plays some hidden role in the formation of HbA1C[14].

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