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Research Article

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Accuracy of Three HbA1C Equations and their Predicted Results in Comparison with the Lab-Tested A1C on 7/22/2021 Based on GH-Method: Math-Physical Medicine (No. 485)

Gerald C Hsu

EclaireMD Foundation, USA

*Corresponding author

Gerald C Hsu, EclaireMD Foundation, USA

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Abstract

Since 7/1/2015, the author has utilized his collected data of finger pierced glucose readings 4 times daily, carbs/sugar intake amount, and post-meal walking steps for each meal to calculate the predicted daily HbA1C values (the "daily finger A1C"). Over the past 5.5 years, the predicted HbA1C values were calculated 12 times within the same timeframe of the12 different lab-tested dates. During the 12 continuous 5-month time periods, he achieved a 100% prediction accuracy using his daily finger A1C model.

Starting from 5/5/2018, along with finger glucose levels, he has been collecting 96 glucose data each day using a continuous glucose monitoring (CGM) sensor device until present day. Based on the collected CGM sensor glucoses, he further developed two extra HbA1C prediction models, the "sensor-1" A1C model using the combination of both average sensor glucoses and daily glucose fluctuations, and the "sensor-2" A1C model using the average sensor glucoses (eAG).

On 7/22/2021, he performed his HbA1C test at a medical laboratory and received its latest quarterly HbA1C result of 6.3%.

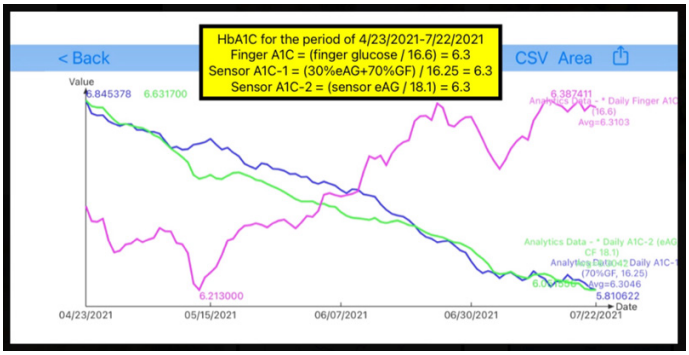
In conclusion, all three HbA1C prediction models (finger, sensor-1, and sensor-2) have yielded the same predicted HbA1C values of 6.3% which is identical to his lab-tested HbA1C value on 7/22/2021.

His objective is to provide some simple yet useful A1C prediction tool to other diabetes patients for their diabetes control efforts. If we can predict the future outcomes of A1C on a daily basis, then diabetes control will not be a difficult task.

Both glucose and HbA1C involve many influential factors. Although the medical community lacks a precise definition for the term HbA1C (mathematically), it loosely defines HbA1C as being the 90-days average glucose value. However, the actual life-span of red blood cells (RBC) range between 90 to 120 days, where some documents even stated as 115 days. In reality, a lab-tested HbA1C is also affected by many other non-biomedical influential factors, including but not limited to its operational procedures, possible human errors, testing environment differences (even the altitude of the laboratory), etc.

The author spends his time and efforts on developing several highly accurate HbA1C prediction models in order to provide an "early and preventive warning" to diabetes patients on a daily basis. Therefore, they do not have to wait until the actual lab-test day to find out their HbA1C value. Usually, by that time, it would be too late to do anything or to make any modifications for their past behaviors in order to control their diabetes.

The author strongly believes that an accurate prediction offers a better chance in preventing the disease, which is always superior to treating it, including medications, injections, surgeries, chemotherapy, or radiation.



Introduction

Since 7/1/2015, the author has utilized his collected data of finger pierced glucose readings 4 times daily, carbs/sugar intake amount, and post-meal walking steps for each meal to calculate the predicted daily HbA1C values (the "daily finger A1C"). Over the past 5.5 years, the predicted HbA1C values were calculated 12 times within the same timeframe of the12 different lab-tested dates. During the 12 continuous 5-month time periods, he achieved a 100% prediction accuracy using his daily finger A1C model.

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Method

Using signal processing techniques, the author identified more than 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 the HbA1C value almost equally (approximately one-third each).***
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 RBCs, after differentiating from erythroblasts in the bone marrow, are released into the blood and survive in circulation for approximately 115 days. The author has adopted the 120-days finger glucose model with different weight-factor for each month. In addition, he uses the CGM collected average sensor glucose (eAG) data with the daily glucose fluctuation data for this HbA1C study. It should be reemphasized that the lab-tested HbA1C value should not be considered as the "golden standard" since it contains a large margin of error due to various possible causes.

Here, he is listing his three arithmetic equations to be used for the predicted HbA1C for the end of the most-recent quarter (4/22/2021-7/22/2021). These three predicted HbA1C formulas with three associated conversion factors (CF) are as follows:

(a) Daily A1C = (finger eAG) / 16.6
(b) New A1C-1 = (30% * sensor eAG +70% * GF) / 16.25
(c) New A1C-2 = (sensor eAG) / 18.1

The CF values of 16.6 for finger, 16.25 for sensor-1, and 18.1 for sensor-2 are selected for achieving high accuracy and could vary from patient to patient or from one time period to another time period. This CF value is dependent on significant changes occurring in certain time period or for a particular patient with some special health conditions. However, for a general case, they do not vary too much from the author's case.

It should be noted that the Sensor-1 A1C model includes the influences from the daily glucose fluctuation (GF) factor. GF can influence the outcomes of diabetes complications such as stroke, atherosclerosis, cardiovascular disease, chronical kidney disease, diabetic retinopathy, and Neuropathy, etc. Furthermore, by choosing a high weighting-factor of 70% for GF, it would modify the basic characteristics of the traditionally defined HbA1C.

To summarize the above methodology into a step-by-step description, the author has 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 of eAG, and his average glucose fluctuation (defined as the maximum glucose minus the minimum glucose) where he uses the abbreviation of ***GF***. The role and influence of ***GF*** on HbA1C will be further discussed in his comparison study against the American Diabetes Association defined HbA1C formula in paper No. 450.
2. As a reference, he also accumulates his customized software calculated Finger A1C based on finger-pierced glucoses with a CF value of 16.6 and Sensor-2 A1C based on CGM sensor collected glucose with a CF value of 18.1.
3. He then defines another more complicated Sensor-1 A1C equation for his predicted HbA1C with different weight factors for eAG and GF. ***Predicted A1C = (eAG * 30% + GF * 70%) / (conversion factor CF = 16.25).***
4. Finally, he calculates the HbA1C prediction accuracy between his predicted A1C versus the lab-tested A1C. It should be noted that his predicted HbA1C values for Comparison against the lab-tested HbA1C value are the 90-days moving average value of his three predicted A1C curves.

Results

This paper is a simple demonstration of his 3 predicted A1C models that achieved 100% prediction accuracy with his lab-tested

results on 7/22/2021.

Figure 1 shows the construction of the daily finger eAG from FPG and PPG along with PPG from carbs/sugar & walking k-steps.

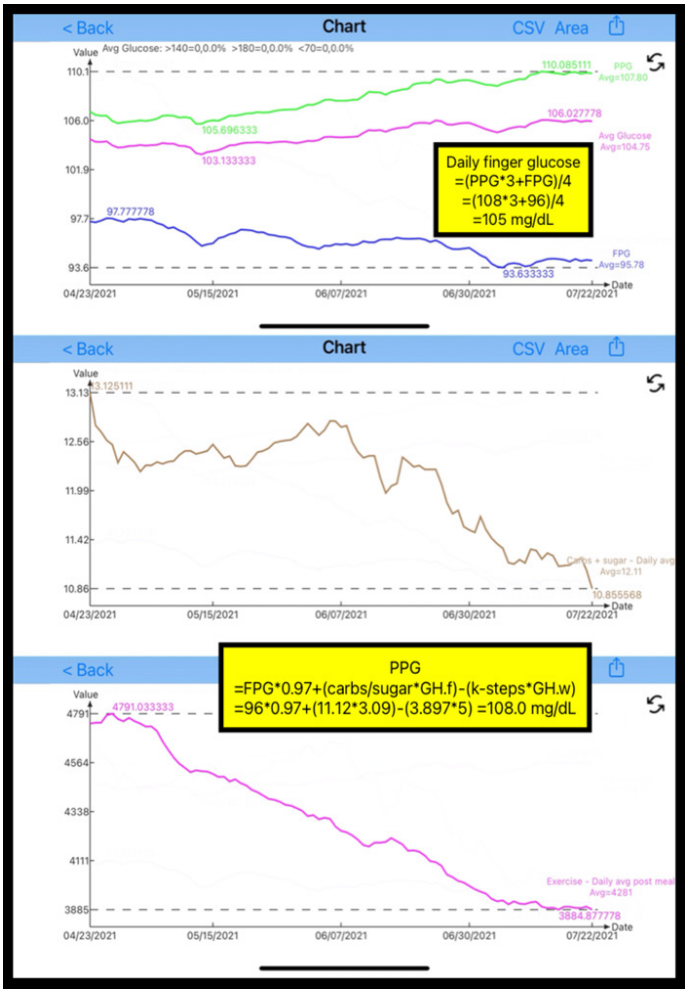

Figure 1: Comparison of finger and sensor glucose and three predicted A1C using three different equations

The following two equations are used in this Figure 1.

Predicted Finger eAG
= (PPG*3 + FPG)/4
= (108*3 + 96)/4
= 105

Predicted Finger PPG
= FPG*0.97 + (carbs/sugar * GH.p + k-steps * GH.w)
= 96*0.97 + (11.12*3.09) + (3.897*(-5.0))
= 108

Where his GH.p coefficient is 3.09 and GH.w coefficient is -5.0.

The second equation for the predicted PPG is based on his developed linear elastic glucose theory (***LEGT***). If readers are interested in learning more about this subject, they can visit the author's website at: www.eclairemd.com

Figure 2 illustrates the comparison of his glucose curves among finger FPG, finger PPG, finger eAG, and sensor eAG along with the three predicted A1C curves using three different equations.

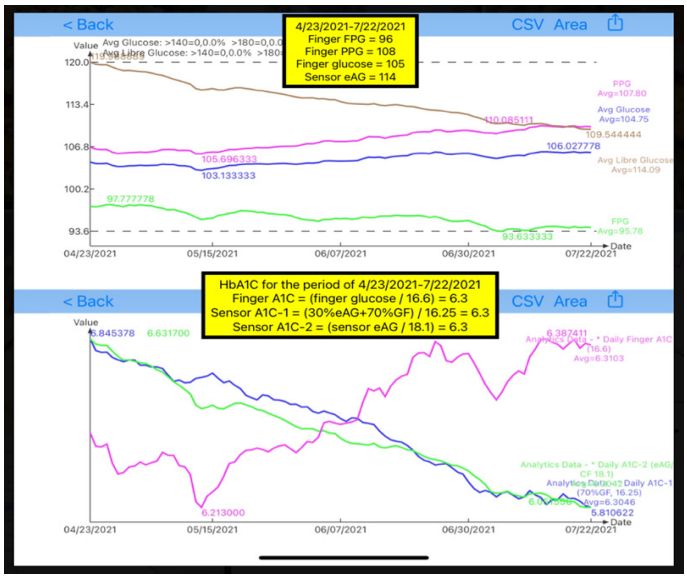

Figure 2: Comparison of finger FPG, PPG, and eAG with sensor eAG, and a combined chart of 3 HbA1C curves

The 90-days moving average glucose values are:

Finger FPG = 96 mg/dL
Finger PPG = 108 mg/dL
Finger eAG = 105 mg/dL
Sensor eAG = 114 mg/dL

The lab-tested A1C and the three predicted A1C have an identical value of 6.3%, as shown below:

Lab A1C: ***6.3%***
Finger A1C: ***6.3%***
Sensor-1 A1C: ***6.3%***
Sensor-2 A1C: ***6.3%***

In the bottom diagram of Figure 2, the difference between Sensor-1 curve & Sensor-2 curve may indicate the Glucose Fluctuation's impact on our internal organs. For another Comparison between the Finger A1C and sensor A1C, they have quite different waveform shapes from each other due to the finger glucoses are collected at 120-minutes after first-bite of meals which usually are the lowest value in the entire 3-hours PPG time-span. The sensor eAG is the average of 96 collected sensor glucoses over the day which usually is higher than the finger eAG.

Figure 3 depicts three separates predicted HbA1C charts and one combined HbA1C chart in one single diagram.

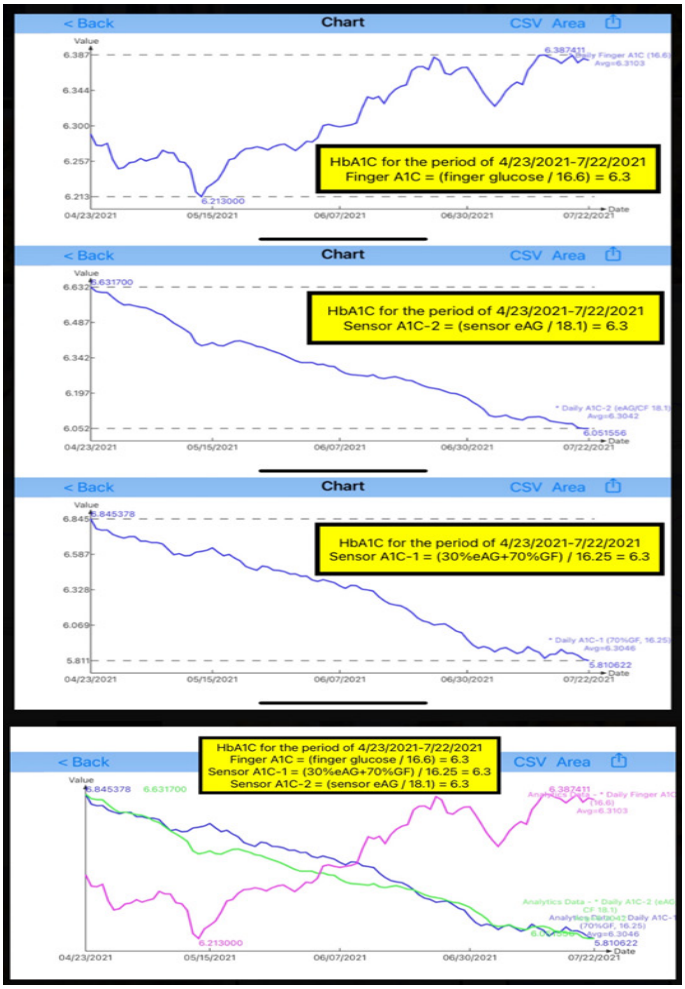

Figure 3: Three separate predicted HbA1C charts and one combined HbA1C chart

In conclusion, these three predicted HbA1C models offer 100% prediction accuracy in comparison against the lab-tested A1C of 6.3% on 7/22/2021.

Conclusion

In conclusion, all three HbA1C prediction models (finger, sensor-1, and sensor-2) have yielded the same predicted HbA1C values of 6.3% which is identical to his lab-tested HbA1C value on 7/22/2021.

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