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Research Article

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Three Predicted HbA1C Equations and Results in Comparison with Lab-Tested A1C from 12 Discrete Lab-Tested Dates over a 3-Year Period Based on GH-Method: Math-Physical Medicine (No. 467)

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Abstract

The author has utilized his collected data of finger pierced glucose readings 4x daily, carbs-sugar intake amount and post-meal walking steps for each meal over a 4-year period, from 2017 to 2020, to calculate the predicted HbA1C values (daily finger A1C). His previously predicted A1C values were conducted 10x close to 10 different lab-tested dates over 5 months for each period. During the 10 continuous 5-month periods, he achieved a 100% prediction accuracy using the daily finger A1C model.

Starting from 5/5/2018, along with the finger glucoses, he collected 96 glucose data per day for 1,127 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 6/5/2019, his average daily sensor glucose (123.96 mg/dL) is 12% higher than his average daily finger glucose (110.72 mg/dL); therefore, if he uses the same formula for predicting HbA1C, it will result in a 12% higher Sensor A1C (7.39%) than his finger A1C (6.60%). In order to match his predicted sensor A1C with the lab A1C, he must multiply the average sensor glucose with a conversion factor to obtain the HbA1C value. In this article, he uses the 90-days moving average daily glucose data, eAG as his calculation base, which applies to the following three different equations as his predicted HbA1C formula with a conversion factor (CF):

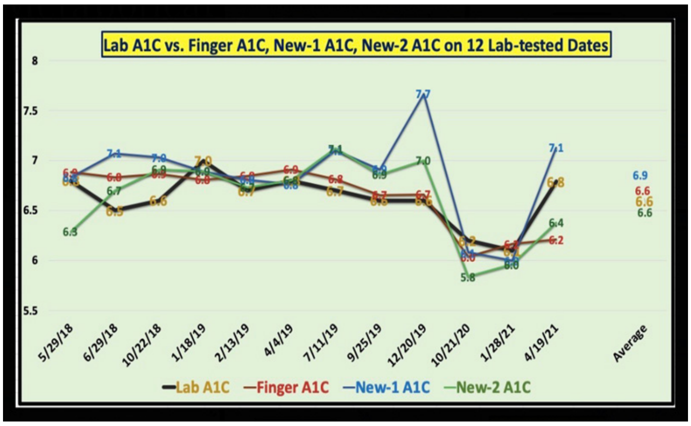
(a) Daily A1C = (finger eAG) / 16.84
(b) New A1C-1 = (29% * sensor eAG +71% * GF) / 15.75
(c) New A1C-2 = (sensor eAG) / 18.86

The 3 conversion factors, 16.84, 15,75, 18.86, are the best-fitted CF values via a trial-and-error approach in order to make his predicted-A1C as close to the lab-A1C as possible. It should be noted that the New A1C-1 includes the influences from the glucose fluctuation (GF) factor. The GF influenced the outcomes of diabetes complications such as Stroke, Atherosclerosis, and cardiovascular disease. Furthermore, by choosing a high weighting factor of 71% for GF, it would modify the basic characteristics of the traditionally defined HbA1C. For example, the New A1C-1 has a different waveform shape from the daily finger A1C and New A1C-2 (daily sensor A1C) under the influences of eAG only.

In summary, all 3 predicted HbA1C values have a near 100% prediction accuracy and >60% correlation coefficients in comparison with the Lab test A1C results on the 12 discrete testing dates over the past 3 years from 5/29/2018 to 4/19/2021.

Both glucose and HbA1C involve many influential factors. Besides, in the medical community, it lacks a precise definition for the term HbA1C (mathematically). The medical community 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 state 115 days. In reality, a lab-tested HbA1C is impacted by many other non-biomedical influential factors, including but not limited to its operational procedures, possible human errors, testing environments (even the altitude of a 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 diabetes.



Introduction

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Starting from 5/5/2018, along with the finger glucoses, he collected 96 glucose data per day for 1,127 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 6/5/2019, *his average daily sensor glucose (123.96 mg/dL) is 12% higher than his average daily finger glucose (110.72 mg/dL);* therefore, if he uses the same formula for predicting HbA1C, it will result in a *12% higher Sensor A1C (7.39%) than his finger A1C (6.60%).* In order to match his predicted sensor A1C with the lab A1C, he must multiply the average sensor glucose with a conversion factor to obtain the HbA1C value. In this article, he uses the 90-days moving average daily glucose data, eAG as his calculation base, which applies to the following three different equations as his predicted HbA1C formula with a conversion factor (CF):

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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 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 with daily glucose fluctuation and calculated HbA1C to compare against his collected 12 lab-tested HbA1C data, while the lab A1C data contained a large margin of error due to various reasons.

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 the American Diabetes Association defined HbA1C formula in article 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 16.84 and Sensor A1C based on CGM sensor collected glucose with a CF value of 18.86.
3. He then defines the following equation for his predicted HbA1C with different weight factors (WF) and A1C CF.

Predicted A1C = (eAG * WF1 + GF * WF2) / (A1C conversion factor CF)

where WF1=29% and WF2=71%; A1C conversion factors are a lower CF=15.75 to generate a slightly higher New A1C-1 value of 6.9% in comparison against the Lab-tested A1C of 6.6%.
(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.

In summary, the following three equations are used as his predicted HbA1C formula:

(a) Daily A1C = (finger eAG) / 16.84
(b) New A1C-1 = (29% * sensor eAG +71% * GF) / 15.75
(c) New A1C-2 = (sensor eAG) / 18.86

Results

Figure 1 shows the comparison of Daily finger A1C, New sensor A1C-2, New sensor A1C-1 (eAG+GHF) with the lab-tested A1C. These ***daily continuous*** A1C model results are listed below in the format of average A1C, correlation vs. Lab A1C:

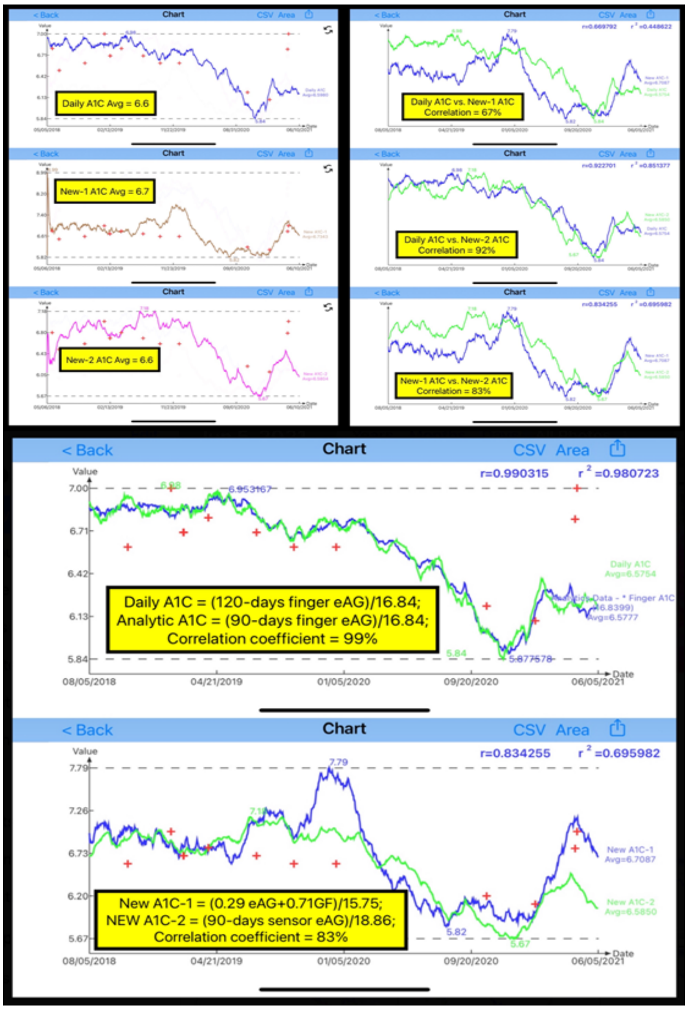


Figure 1: Comparison of three Predicted A1C and Analytic finger A1C results (~6.6) versus Lab A1C of 6.6% during 3-year period (Red Cross points are lab-tested A1C)

Lab A1C: 6.6%, 100%
Daily finger A1C: 6.6%, 66%
New sensor A1C-1: 6.7%, 62%
New sensor A1C-2: 6.6%, 63%
Analytic finger A1C:6.6%, 66%

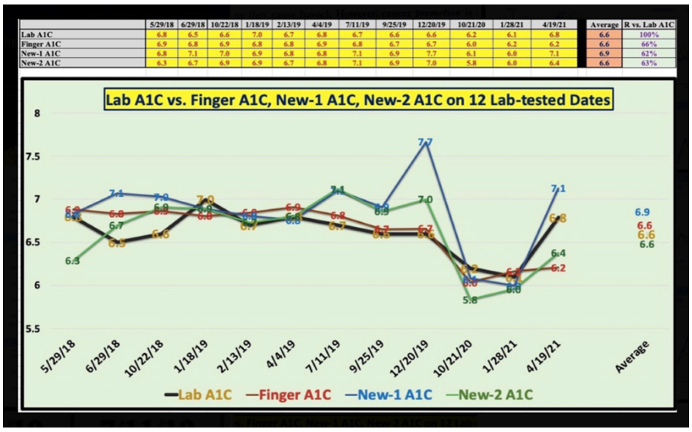
It should be noted that the daily finger A1C is based on a 120-days moving average finger eAG, while the Analytic finger A1C is based on a 90-days moving average finger eAG. The correlation coefficient between the daily finger A1C and analytic finger A1C is extremely high with 99% since they are based on the same eAG dataset but with two different moving average days.

Furthermore, the correlations between the two different predicted HbA1C models are listed below:

Daily finger vs. New-1: 67%
Daily finger vs. New-2: 92%
New-1 vs. New-2: 83%
Daily finger vs. Analytic: 99%

The waveform shapes of the daily finger A1C and New A1C-2 have a 92% similarity which proves that the glucose shapes of finger and sensor are highly comparable.

Figure 2 illustrates these 3 predicted HbA1C comparison against the lab-tested A1C on the 12 discrete lab-testing dates using the following three equations:



	5/29/18	6/29/18	10/22/18	1/18/19	2/13/19	4/4/19	7/11/19	9/25/19	12/20/19	10/21/20	1/28/21	4/19/21	Average	R vs. Lab A1C
Lab A1C	6.8	6.5	6.6	7.0	6.7	6.8	6.7	6.6	6.6	6.2	6.1	6.8	6.6	100%
Finger A1C	6.9	6.8	6.9	6.8	6.8	6.9	6.8	6.7	6.7	6.0	6.2	6.2	6.6	66%
New-1 A1C	6.8	7.1	7.0	6.9	6.8	6.8	7.1	6.9	7.7	6.1	6.0	7.1	6.9	62%
New-2 A1C	6.3	6.7	6.9	6.9	6.7	6.8	7.1	6.9	7.0	5.8	6.0	6.4	6.6	63%

Figure 2: Three predicted HbA1C curves (daily finger, new-1, and new-2) along with input data table with results of prediction accuracy and correlation coefficients

(a) Daily A1C = (finger eAG) / 16.84
(b) New A1C-1 = (29% * sensor eAG +71% * GF) / 15.75
(c) New A1C-2 = (sensor eAG) / 18.86

The Comparison of the 3 predicted A1C versus lab-A1C are expressed in the format of average HbA1C values, correlation vs. Lab-A1C:

Lab A1C: 6.6%, 100%
Daily finger A1C: 6.6%, 66%
New sensor A1C-1: 6.9%, 62%
New sensor A1C-2: 6.6%, 63%

In conclusion, these three predicted HbA1C models offer a near 100% prediction accuracy except for the New A1C-1 due to its high weight contribution by GF. In addition, all of the three predicted A1C models provide highly similar curve shapes as the lab-tested A1C curve over the 12 discrete lab-testing dates.

Conclusion

In summary, all 3 predicted HbA1C values have a near 100% prediction accuracy and >60% correlation coefficients in comparison with the Lab test A1C results on the 12 discrete testing dates over the past 3 years from 5/29/2018 to 4/19/2021.

Both glucose and HbA1C involve many influential factors. Besides, in the medical community, it lacks a precise definition for the term HbA1C (mathematically). The medical community 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 state 115 days. In reality, a lab-tested HbA1C is impacted by many other non-biomedical influential factors, including but not limited to its operational procedures, possible human errors, testing environments (even the altitude of a laboratory), etc.

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