The GH-Method

Comparison of Lab A1C against Three Predicted A1C and Two American Diabetes Association Defined A1C Using Three-Years of Continuous Glucose Monitor Sensor Data Based on GH-Method: Math-Physical Medicine (No. 455)

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Abstract

The author uses his measured data of finger pierced glucose values 4x per day over a period of 3+ years, from 5/5/2018 to 5/25/2021, and a conversion factor (CF) of 16.84 to calculate his predicted daily HbA1C values, which he terms daily A1C. He also collected and displayed his lab-tested HbA1C from 12 different testing dates at the same medical facility, which he terms lab A1C. Starting from 5/5/2018, along with his finger glucose readings, he accumulated 96 glucose data per day over 1,116 days using a continuous glucose monitoring (CGM) sensor device for a total of ~107,136 glucose data. He noticed that from 5/5/2018 through 5/25/2021, his average daily sensor glucose (124.49 mg/dL) is 12% higher than the average daily finger glucose (111.24 mg/dL); therefore, if he uses the same formula to predict HbA1C, it will result in a 12% higher sensor A1C (7.4%) than his finger A1C (6.6%). Using another expression, he could also use two different CFs with a 12% difference in order to produce two identical HbA1C values for finger estimated average glucose-based equation and sensor estimated average glucose-based equation. In this article, he uses the 90-days moving average daily glucose data, which he designates as eAG, and his glucose fluctuation (GF), defined as maximum glucose minus minimum glucose during a day, as his calculation base. Finally, he develops the following 5 equations to calculate his predicted HbA1C values. The first 3 are his predicted HbA1C and the next 2 are American Diabetes Association (ADA) defined HbA1C. (1) Sensor A1C-1 = (67% eAG +33% GF) / 16, (2) Sensor A1C-2 = sensor eAG / 18.94, (3) Finger A1C = finger eAG / 16.84. Please note that the ratio of 18.94 over 16.84 is 1.12 which is a result of the 12% difference between his average sensor eAG and finger eAG. (4) ADA defined sensor A1C = (sensor eAG + 46.7) / 28.7, (5) ADA defined finger A1C = (finger eAG + 46.7) / 28.7. In summary, comparing his three predicted HbA1C values and two ADA defined HbA1C values against the 12 lab-tested HbA1C results, which is his daily A1C, he determined the following 5 major conclusions: (1) From the correlation study, the daily A1C vs. all of his 3 predicted A1C curves and 2 ADA defined A1C curves, except for the sensor A1C-1 curve, (67% eAG +33% GF)/16, achieved high correlation coefficients (92% - 99%). The comparison of daily A1C against the sensor A1C-1 equation has a lower correlation of 69%. The sensor A1C-1 used two different variables, eAG of wave average and GF of wave fluctuation; therefore, the sensor A1C-1 vs. daily A1C would produce a distinct waveform shape from the other 4 equations using a single variable of the wave's mean value eAG. (2) Based on the 12 lab-testing dates, the lab A1C curve and finger A1C with a CF of 16.84 curve has an identical average A1C value of 6.6 with a similar wave shape (R=66%). (3) Using the daily A1C data for comparison against ADA defined results, it is disappointing to discover the two ADA defined A1C values have a high correlation against daily A1C (92%-99%), but the ADA sensor A1C has a negative -35% correlation with lab A1C. This finding is not surprising to the author since the ADA defined equation was based on finger data from multiple patients, where it is not developed on sensor data. Furthermore, the ADA A1C prediction accuracy against daily A1C is only 83%-91%, while the other 3 predicted A1C curves have a 100% prediction accuracy. (4) It seems that GF plays a hidden role in diabetes, which requires additional research on the GF impact on glucose control of diabetes patients. (5) The conclusion is that his 3 predicted A1C models can provide high accuracy for patients to receive pre-warning of their expected A1C values prior to lab tests.

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

Abbreviations: CGM: continuous glucose monitoring; GF: glucose fluctuation; ADA: American Diabetes Association; CF: conversion factor; HbA1C: glycated hemoglobin

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1. INTRODUCTION

The author uses his measured data of finger pierced glucose values 4x per day over a period of 3+ years, from 5/5/2018 to 5/25/2021, and a conversion factor (CF) of 16.84 to calculate his predicted daily HbA1C values, which he terms daily A1C[1,2].

He also collected and displayed his lab-tested HbA1C from 12 different testing dates at the same medical facility, which he terms lab A1C.

Starting from 5/5/2018, along with his finger glucose readings, he accumulated 96 glucose data per day over 1,116 days using a continuous glucose monitoring (CGM) sensor device for a total of ~107,136 glucose data. He noticed that from 5/5/2018 through 5/25/2021, his average daily sensor glucose (124.49 mg/dL) is 12% higher than the average daily finger glucose (111.24 mg/dL); therefore, if he uses the same formula to predict HbA1C, it will result in a 12% higher sensor A1C (7.4%) than his finger A1C (6.6%). Using another expression, he could also use two different CFs with a 12% difference in order to produce two identical HbA1C values for finger estimated average glucose-based equation and sensor estimated average glucose-based equation[3,4].

In this article, he uses the 90-days moving average daily glucose data, which he designates as eAG, and his glucose fluctuation (GF), defined as maximum glucose minus minimum glucose during a day, as his calculation base[5].

Finally, he develops the following 5 equations to calculate his predicted HbA1C values. The first 3 are his predicted HbA1C and the next 2 are American Diabetes Association (ADA) defined HbA1C.

Sensor A1C-1 = (67% eAG +33% GF) / 16

Sensor A1C-2 = sensor eAG / 18.94

Finger A1C = finger eAG / 16.84

Please note that the ratio of 18.94 over 16.84 is 1.12 which is a result of the 12% difference between his average sensor eAG and finger eAG.

ADA defined sensor A1C = (sensor eAG + 46.7) / 28.7

ADA defined finger A1C = (finger eAG + 46.7) / 28.7

2. METHODS

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 he has adopted the 120-days model in his previous sensor HbA1C studies and customized software, 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 12 lab-tested HbA1C data[6,7].

For 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.

(2) As a reference, he also accumulates his customized software calculated finger A1C with a CF of 16.84 based on finger-pierced glucose and sensor A1C with a CF of 18.94 based on CGM sensor collected glucose. The CF ratio of 18.94 over 16.84 is 1.12 which is a result of the 12% difference between his average sensor eAG and finger eAG.

(3) He further develops the following 5 different equations to calculate the predicted HbA1C values. The first 3 are his predicted HbA1C and the next 2 are ADA defined HbA1C.

Sensor A1C-1 = (67% eAG +33% GF) / 16

Sensor A1C-2 = sensor eAG / 18.94

Finger A1C = finger eAG / 16.84

ADA defined sensor A1C = (sensor eAG + 46.7) / 28.7

ADA defined finger A1C = (finger eAG + 46.7) / 28.7

(4) Finally, he calculates the HbA1C prediction accuracy and correlation coefficients (R) of any predicted HbA1C values to compare against either the lab A1C on x-scale of 12 dates or the daily A1C on x-scale of 3+ years[8-10].

3. RESULTS

In Figure 1, the upper diagram shows the lab-tested HbA1C values on the 12 testing dates. Over the 3+ year period from 5/5/2018 through 5/25/2021, his average daily sensor glucose (124.49 mg/dL) is 12% higher than the average daily finger glucose (111.24 mg/dL).

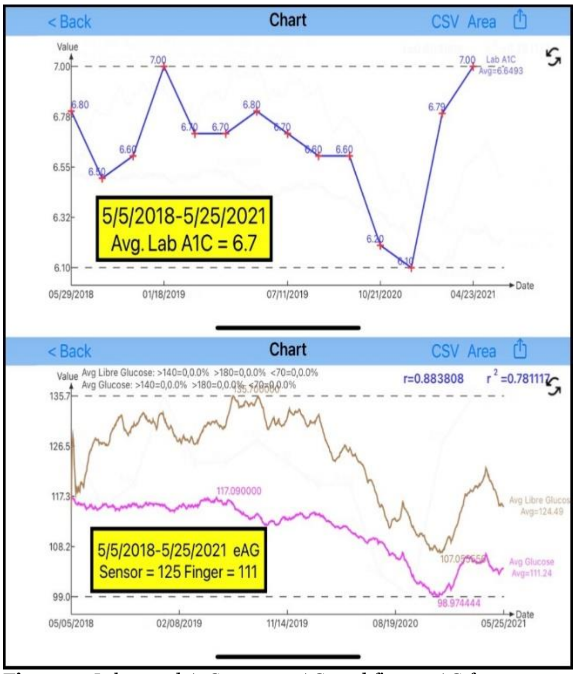
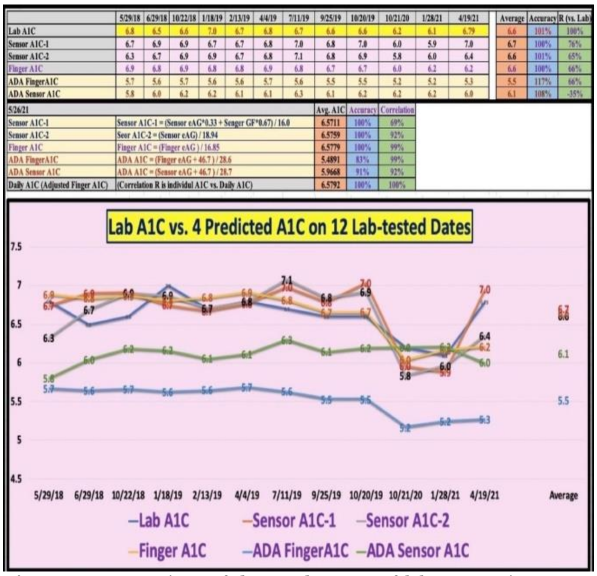


Figure 1: Lab-tested A1C, sensor eAG, and finger eAG for 3 years (5/5/2018 - 5/25/2021).

Figure 2 illustrates the comparison of data and curves, over 12 lab-tested dates, of lab A1C against 3 predicted A1C (finger, sensor-1, and sensor-2) and 2 ADA defined A1C (ADA-finger and ADA-sensor). It is obvious that the two ADA defined A1C curves deviate from his lab A1C result, while his 3 predicted A1C curves converge more with the lab A1C curve.



	5/29/18	6/29/18	10/22/18	1/18/19	2/13/19	4/4/19	7/11/19	9/25/19	10/20/19	10/21/20	1/28/21	4/19/21	Average	Accuracy	R (vs. Lab)
Lab A1C	6.8	6.5	6.6	7.0	6.7	6.8	6.7	6.6	6.6	6.2	6.1	6.79	6.6	101%	100%
Sensor A1C-1	6.7	6.9	6.9	6.7	6.7	6.8	7.0	6.8	7.0	6.0	5.9	7.0	6.7	100%	76%
Sensor A1C-2	6.3	6.7	6.9	6.9	6.7	6.8	7.1	6.8	6.9	5.8	6.0	6.4	6.6	101%	65%
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	100%	66%
ADA FingerA1C	5.7	5.6	5.7	5.6	5.6	5.7	5.6	5.5	5.5	5.2	5.2	5.3	5.5	117%	66%
ADA Sensor A1C	5.8	6.0	6.2	6.2	6.1	6.1	6.3	6.1	6.2	6.2	6.2	6.0	6.1	108%	-35%

5/26/21		Avg. A1C	Accuracy	Correlation
Sensor A1C-1	Sensor A1C-1 = (Sensor eAG*0.33 + Senger GF*0.67) / 16.0	6.5711	100%	69%
Sensor A1C-2	Seor A1C-2 = (Sensor eAG) / 18.94	6.5759	100%	92%
Finger A1C	Finger A1C = (Finger eAG) / 16.85	6.5779	100%	99%
ADA FingerA1C	ADA A1C = (Finger eAG + 46.7) / 28.6	5.4891	83%	99%
ADA Sensor A1C	ADA A1C = (Sensor eAG + 46.7) / 28.7	5.9668	91%	92%
Daily A1C (Adjusted Finger A1C)	(Correlation R is individul A1C vs. Daily A1C)	6.5792	100%	100%

Figure 2: Comparison of data and curves of lab A1C against 3 predicted A1C (finger, sensor-1, sensor-2) and 2 ADA defined A1C (ADA-finger, ADA-sensor).

In Figure 3, the upper diagram depicts the daily A1C vs. 3 predicted A1C and the lower diagram reflects the daily A1C vs. 2 ADA defined A1C. The upper diagram shows finger A1C and sensor-2 A1C converging with the daily A1C on both accuracy (average A1C results are 6.6) and shape similarity (correlation of 92%-99%). However, the sensor-1 A1C with 67% GF input also has the same A1C value of 6.6% with a lower correlation of 69%. The lower diagram indicates that the ADA A1C results have high correlation with the daily A1C (92%-99%), but they have a lower prediction accuracy (82%-91%). The ADA finger A1C is 5.5% and the ADA sensor A1C is 6.0%, while the daily A1C is 6.6%. This magnitude of A1C prediction difference is not acceptable to the author.

Figure 4 demonstrates the correlation analyses for any pair of two A1C results. It has a comparison of 5 correlation coefficients of lab A1C compared against the A1C curves (3 predicted and 2 ADA defined). Some of the findings have been discussed in figures 1-3. However, the remaining diagram at the lower right corner, over 12 lab-tested dates, requires further explanation. His A1C data utilize both the daily A1C model and lab A1C model, where they are identical to each other (6.6) but also have a high waveform shape similarity (correlation of 66%).

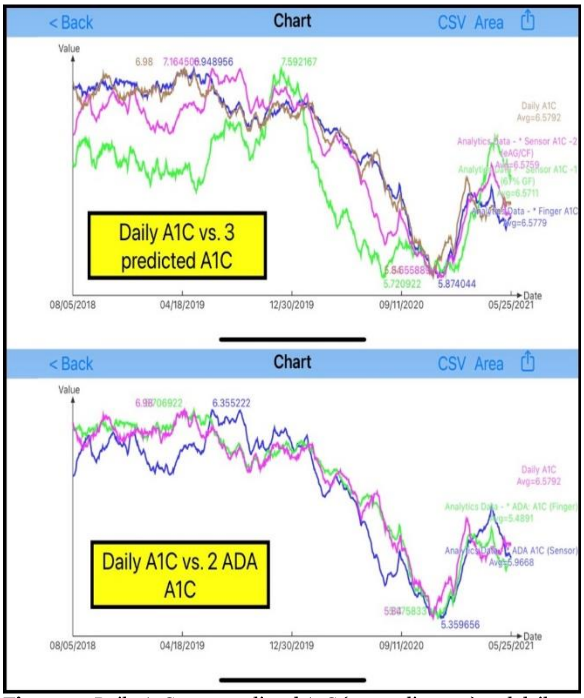


Figure 3: Daily A1C vs. 3 predicted A1C (upper diagram) and daily A1C vs. 2 ADA defined A1C (lower diagram).

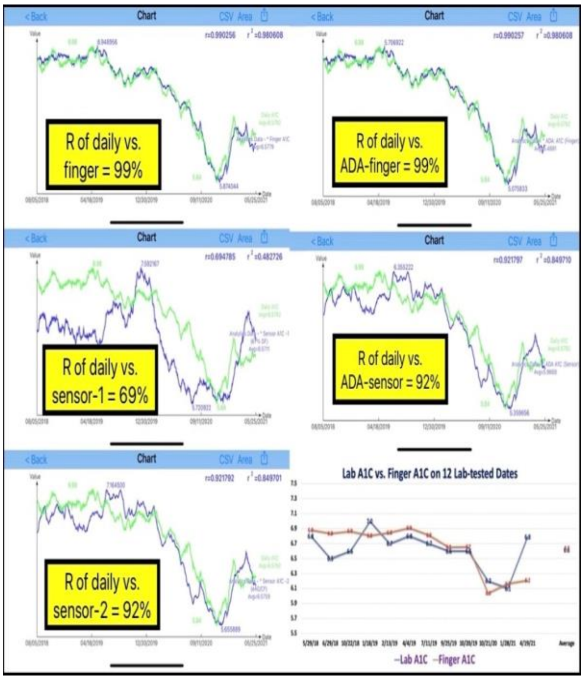


Figure 4: 5 correlation coefficients of lab A1C compared against A1C curves (3 predicted plus 2 ADA defined).

4. CONCLUSION

In summary, comparing his three predicted HbA1C values and two ADA defined HbA1C values against the 12 lab-tested HbA1C results, which is his daily A1C, he determined the following 5 major conclusions:

(1) From the correlation study, the daily A1C vs. all of his 3 predicted A1C curves and 2 ADA defined A1C curves, except for the sensor A1C-1 curve, (67% eAG +33% GF)/16, achieved high correlation coefficients (92% - 99%). The comparison of daily A1C against the sensor A1C-1 equation has a lower correlation of 69%. The sensor A1C-1 used two different variables, eAG of wave average and GF of wave fluctuation; therefore, the sensor A1C-1 vs. daily A1C would produce a distinct waveform shape from the other 4 equations using a single variable of the wave's mean value eAG[11].

(2) Based on the 12 lab-testing dates, the lab A1C curve and finger A1C with a CF of 16.84 curve has an identical average A1C value of 6.6 with a similar wave shape (R=66%)[12].

(3) Using the daily A1C data for comparison against ADA defined results, it is disappointing to discover the two ADA defined A1C values have a high correlation against daily A1C (92%-99%), but the ADA sensor A1C has a negative -35% correlation with lab A1C. This finding is not surprising to the author since the ADA defined equation was based on finger data from multiple patients, where it is not developed on sensor data. Furthermore, the ADA A1C prediction accuracy against daily A1C is only 83%-91%, while the other 3 predicted A1C curves have a 100% prediction accuracy[13].

(4) It seems that GF plays a hidden role in diabetes, which requires additional research on the GF impact on glucose control of diabetes patients[14].

(5) The conclusion is that his 3 predicted A1C models can provide high accuracy for patients to receive pre-warning of their expected A1C values prior to lab tests[15].

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