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The GH-Method

Predicted HbA1C Values Using a Continuous Glucose Monitor Sensor for a Type 2 Diabetes Patient's Clinical Data from Six Long Periods and Two Short Periods Based on GH-Method: Math-Physical Medicine (No. 444)

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Abstract

On 4/23/2021, the author, who has a 26-year history of multiple chronic diseases, had blood tests conducted at two different medical laboratories which provided varying HbA1C results of 6.79% vs. 7.0% along with a set of vastly different lipid profiles. He understands that different labs may yield contrasting test results due to some issues related to the testing environment, operating procedure, and performing technician. For example, the triglycerides result of 380 mg/dL at Lab A is almost 4 times higher than the other reading of 100 mg/dL at Lab B. These significant differences in results performed on the same day from two different laboratories shocked him. Therefore, on 4/27/2021, he went back to Lab A which tested his higher-than-normal lipid data to conduct another blood work examination. This time, all of his lipid values were within the normal range within 4 days, along with the triglycerides of 98 mg/dL, which almost matched the other reading at Lab B. This personal experience demonstrates how wide of a margin on medical examination results can occur. Although his lab-tested A1C varying results puzzled him, he expected that his HbA1C level in the recent period would be higher than his previous period of 6.2% from 10/20/2020. Therefore, he did not request to re-measure his HbA1C at Lab A, which provided an absurd lipid profile. The higher HbA1C value of 7.0% from the 4/23/2021 examination is a direct result of his recent food and meal experiments along with his on-and-off intermittent fasting (IF) experiments. During the period of 1/20/2021 to 4/20/2021, he has eaten more meals with higher amounts of carbohydrates and sugar, which included starchy foods made from white rice, white flour, potato, etc. Since 7/1/2015, he abstained from eating starchy foods and maintaining his average carbs/sugar intake amount below 20 grams per meal. Lately, he decided to continue his research on both pancreatic beta cells self-recovery and IF impact on his health conditions. So, he changed his diet practice to some degree in order to determine the durability of his pancreatic beta cells. He should have been more cautious to monitor the food impact on his overall HbA1C. These two recent lab-tested HbA1C results of 7.0% and 6.79% opened his eyes and he decided to refocus on the HbA1C situation. Not only does this report covers the difference in his A1C test results, but it also concentrates on the reasons and sources for his recent elevated A1C. It should be noted that the average A1C between 6.79% and 7.0% is 6.9%; therefore, he chose to use 6.8% as the base for this analysis. As a comparison, he selects six identical length periods of six-months each from the long period of 5/5/2018 through 4/27/2021. In addition, he has also included Period Y20 for 9/20/20 to 12/20/20 with lab-tested HbA1C of 6.2% and Period Y21 for 1/20/21 to 4/20/21 with lab-tested HbA1C of 6.8%. Next, he defined three different equations for calculating his predicted HbA1C values in order to compare against the lab-tested HbA1C results over the past 3 years. However, to achieve a better curve-fitting purpose, he has chosen two different sets of weighting factors in these equations between Period 1 through Period 6 along with Periods Y20 and Y21. In summary, comparing his predicted HbA1C values using three different equations against the lab-tested HbA1C values have the following three key observations: (1) His average HbA1C over the 6 periods is 6.6%, while his average predicted HbA1C values is 6.8% (97% accuracy) using Equation 1, 6.6% (100% accuracy) using Equation 2, and 6.5% (98% accuracy) using Equation 3. It seems that Equation 2 using both estimated average glucose (eAG) and glucose fluctuations (GF) yields the best result. The same observation also holds true for the two shorter periods of Y20 and Y21 (6.5% vs. 6.5%). (2) In terms of shape similarity of HbA1C waveforms, all three predicted HbA1C curve shapes are highly similar to each other (R=83%, 91%, 98%). Regarding their comparison against the lab-tested HbA1C curve, both Equation 2 curve and Equation 3 curve have a high correlation against the lab-tested A1C curve (R=65%, 59%), but the Equation 1 curve vs. the lab curve has a low correlation (R=31%). (3) Equation 1 uses a combination of finger-pierced A1C and sensor collected A1C which is a less satisfactory equation, whereas Equation 2 uses a combination of eAG and GF which is a more acceptable equation. Even with a different set of weighting factors between eAG and GF for Periods Y20 and Y21, Equation 2 with GF influences can offer an extremely high prediction accuracy on A1C. Equation 3 utilizes overall conversion factors between eAG and A1C, which is also a satisfactory equation. Furthermore, Equation 3 is an extremely easy tool for patients to use. This article describes three different equations to predict HbA1C values. Although their predicted A1C values may not be 100% accurate as compared to the lab-tested A1C data, the author provided his experience with a wide margin of error in the lab-tested A1C readings. As a result, the author questions the true accuracy of some lab-tested A1C results. It would make the task of performing an A1C prediction more difficult if the lab-tested A1C is a moving target as it is dependent on the testing environment, procedures, chemical compounds, human errors, etc. This is the reason why he developed a range of equations as tools to predict his forthcoming A1C value prior to the lab-testing day. Having knowledge in disease prevention is more important than medical treatment; however, patients with type 2 diabetes who have accurate information and ease-of-use tools will have better control over their chronic diseases.

Keywords: Glucose; Type 2 diabetes; Chronic diseases; Pancreatic beta cells; HbA1C

Abbreviations: HbA1C: hemoglobin A1C; IF: intermittent fasting; eAG: estimated average glucose; GF: glucose fluctuations; CGM: continuous glucose monitor; FPG: fasting plasma glucose; PPG: postprandial plasma glucose; WF: weight factors

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1. INTRODUCTION

On 4/23/2021, the author, who has a 26-year history of multiple chronic diseases, had blood tests conducted at two different medical laboratories which provided varying HbA1C results of 6.79% vs. 7.0% along with a set of vastly different lipid profiles. He understands that different labs may yield contrasting test results due to some issues related to the testing environment, operating procedure, and performing technician. For example, the triglycerides result of 380 mg/dL at Lab A is almost 4 times higher than the other reading of 100 mg/dL at Lab B. These significant differences in results performed on the same day from two different laboratories shocked him. Therefore, on 4/27/2021, he went back to Lab A which tested his higher-than-normal lipid data to conduct another blood work examination. This time, all of his lipid values were within the normal range within 4 days, along with the triglycerides of 98 mg/dL, which almost matched the other reading at Lab B. This personal experience demonstrates how wide of a margin on medical examination results can occur[1,2].

Although his lab-tested A1C varying results puzzled him, he expected that his HbA1C level in the recent period would be higher than his previous period of 6.2% from 10/20/2020. Therefore, he did not request to re-measure his HbA1C at Lab A, which provided an absurd lipid profile. The higher HbA1C value of 7.0% from the 4/23/2021 examination is a direct result of his recent food and meal experiments along with his on-and-off intermittent fasting (IF) experiments. During the period of 1/20/2021 to 4/20/2021, he has eaten more meals with higher amounts of carbohydrates and sugar, which included starchy foods made from white rice, white flour, potato, etc. Since 7/1/2015, he abstained from eating starchy foods and maintaining his average carbs/sugar intake amount below 20 grams per meal. Lately, he decided to continue his research on both pancreatic beta cells self-recovery and IF impact on his health conditions. So, he changed his diet practice to some degree in order to determine the durability of his pancreatic beta cells. He should have been more cautious to monitor the food impact on his overall HbA1C. These two recent lab-tested HbA1C results of 7.0% and 6.79% opened his eyes and he decided to refocus on the HbA1C situation.

Not only does this report covers the difference in his A1C test results, but it also concentrates on the reasons and sources for his recent elevated A1C. It should be noted that the average A1C between 6.79% and 7.0% is 6.9%; therefore, he chose to use 6.8% as the base for this analysis[3,4].

As a comparison, he selects six identical length periods of six-months each from the long period of 5/5/2018 through 4/27/2021. In addition, he has also included Period Y20 for 9/20/20 to 12/20/20 with lab-tested HbA1C of 6.2%, and Period Y21 for 1/20/21 to 4/20/21 with lab-tested HbA1C of 6.8%. Next, he defined three different equations for calculating his predicted HbA1C values in order to compare against the lab-tested HbA1C results over the past 3 years. However, to achieve a better curve-fitting purpose, he has chosen two different sets of weighting factors in these equations between Period 1 through Period 6 along with Periods Y20 and Y21[5-7].

2. METHODS

The author conducted the glucose research by applying his developed GH-method: math-physical medicine (MPM) approach along with the following contribution factors of HbA1C:

(1) The continuous glucose monitor (CGM) sensor based A1C variances contributed by 29% from fasting plasma glucose (FPG), 38% from postprandial plasma glucose (PPG), and 33% from between meals and pre-bedtime periods. Therefore, all of these three segments have 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 should be noted that in the research work using his developed glucose prediction model and HbA1C prediction model, he utilized his CGM collected glucose from the previous 3-months prior to the day of lab-testing. 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.

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

(1) He collects his daily average CGM sensor glucose where he uses the abbreviation eAG and average glucose fluctuation (maximum glucose minus minimum glucose) with the abbreviation GF.

(2) 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 defines the following three different equations for his predicted HbA1C with different weight factors (WF) and A1C conversion factors.

(4) Equation 1 = (finger A1C * WF1 + sensor A1C * WF2) where WF1=80% and WF2=20% for 6 periods and WF1=50% and WF2=50% for 2 periods.

(5) Equation 2 = (eAG * WF3 + GF * WF4) / (A1C conversion factor) where WF3=70% and WF4=30% for 6 periods and WF3=85% and WF4=15% for 2 periods; A1C conversion factor=17.13 for both 6 period and 2 period.

(6) Equation 3 = eAG / A1C conversion factor where A1C conversion factor=19.13 for 6 periods and A1C conversion factor=17.13 for 2 periods.

(7) Finally, he calculates all of the correlation coefficients in the predicted A1C datasets as compared against the lab-tested A1C dataset.

3. RESULTS

Figure 1 shows a data table with his input data of eAG, GF, finger A1C, sensor A1C, and lab-tested A1C. His calculated predicted HbA1C results utilize three different equations.

4/29/21		5/5/18-11/4/18	11/5/18-5/4/19	5/5/19-11/4/19	11/5/19-5/4/20	5/5/20-11/4/20	11/5/20-4/27/21		9/20/20-12/20/20	1/20/21-4/20/21
GA / A1C Ratio Study		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Average	Period Y20	Period Y21
	Lab A1C	6.7	6.8	6.7	6.6	6.2	6.8	6.6	6.2	6.8
	Finger A1C	6.9	6.9	6.8	6.7	6.3	6.1	6.6	6.0	6.2
	Sensor A1C	7.7	7.9	8.1	7.9	7.0	7.0	7.6	6.7	7.2
Daily averaged sensor glucose	eAG	128	129	132	128	111	116	124	107	120
GF = (Max. eAG - Min. eAG)	GF	100	95	104	96	84	96	96	85	106

4/29/21		5/5/18-11/4/18	11/5/18-5/4/19	5/5/19-11/4/19	11/5/19-5/4/20	5/5/20-11/4/20	11/5/20-4/27/21	
Predicted A1C by 3 Equations		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Average
Eq.1=(80% Finger + 20% Sensor)	A1C by Eq.1 (Finger&Sensor)	7.0	7.1	7.0	6.9	6.5	6.3	6.8
	Lab A1C	6.7	6.8	6.7	6.6	6.2	6.8	6.6
	A1C Accuracy %	6%	4%	6%	5%	4%	-7%	3%
Eq.2=(70% eAG +30% GF)/17.13	A1C byEq.2 (eAG & GF)	6.8	6.7	7.1	6.7	5.8	6.3	6.6
	Lab A1C	6.7	6.8	6.7	6.6	6.2	6.8	6.6
	A1C Accuracy %	3%	-1%	6%	2%	-6%	-7%	0%
Eq.3=(eAG / 19.13)	A1C by Eq.3 (Hsu Equation)	6.7	6.8	6.9	6.7	5.8	6.1	6.5
	Lab A1C	6.7	6.8	6.7	6.6	6.2	6.8	6.6
	A1C Accuracy %	1%	-1%	4%	2%	-7%	-10%	-2%

4/29/21		9/20/20-12/20/20	1/20/21-4/20/21	
Predicted A1C by 3 Equations		Period Y20	Period Y21	Average
Eq.1=(50% Finger + 50% Sensor)	A1C by Eq.1 (Finger&Sensor)	6.3	6.7	6.5
	Lab A1C	6.2	6.8	6.5
	A1C Accuracy %	2%	-1%	0%
Eq.2=(85% eAG +15% GF)/17.13	A1C byEq.2 (eAG & GF)	6.1	6.9	6.5
	Lab A1C	6.2	6.8	6.5
	A1C Accuracy %	-2%	2%	0%
Eq.3=(eAG / 17.13)	A1C by Eq.3 (Hsu Equation)	6.3	7.0	6.6
	Lab A1C	6.2	6.8	6.5
	A1C Accuracy %	1%	3%	2%

6-periods:	R
Eq.1 vs. Lab	31%
Eq.2 vs. Lab	65%
Eq.3 vs. Lab	59%
Eq.1 vs. Eq.2	83%
Eq.1 vs. Eq.3	91%
Eq.2 vs. Eq.3	98%

Figure 1: Input data of eAG and GF with calculated results of predicted HbA1C values using three different equations.

Figure 2 depicts the HbA1C comparison between the lab-tested A1C vs. the predicted A1C using three different equations.

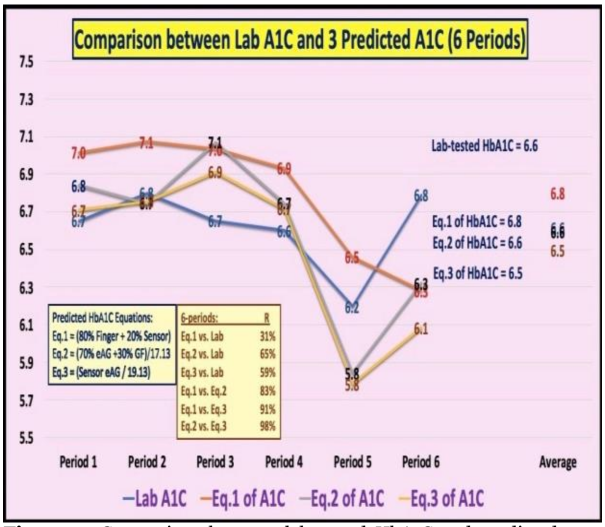

Figure 2: Comparison between lab-tested HbA1C and predicted HbA1C using three equations for 6 periods data of eAG and GF.

In this diagram, the curve shape results using Equations 2 and 3 are quite similar to each other. Although Equation 1 has a different curve shape compared to the others, it also has a higher average HbA1C (6.8% of predicted A1C vs. 6.6% of lab A1C). The author had prior knowledge of his average finger glucose value being lower than the average CGM sensor glucose level by approximately 15% to 18%. This is due to the fact that his finger-pierced glucose points were measured at 120-minutes after the first bite of meals which can be observed at the bottom of the sensor PPG waveform. Both Equations 2 and 3 have produced a similar curve shape above 98% prediction accuracy (6.5% and 6.6% predicted A1C values vs. 6.6% A1C lab value).

4. CONCLUSION

In summary, comparing his predicted HbA1C values using three different equations against the lab-tested HbA1C values have the following three key observations:

(1) His average HbA1C over the 6 periods is 6.6%, while his average predicted HbA1C value is 6.8% (97% accuracy) using Equation 1, 6.6% (100% accuracy) using Equation 2, and 6.5% (98% accuracy) using Equation 3. It seems that Equation 2 using both eAG and GF yields the best result. The same observation also holds true for the two shorter periods of Y20 and Y21 (6.5% vs. 6.5%).

(2) In terms of shape similarity of HbA1C waveforms, all three predicted HbA1C curve shapes are highly similar to each other (R=83%, 91%, 98%). Regarding their comparison against the lab-tested HbA1C curve, both Equation 2 curve and Equation 3 curve have a high correlation against the lab-tested A1C curve (R=65%, 59%), but the Equation 1 curve vs. the lab curve has a low correlation (R=31%).

(3) Equation 1 uses a combination of finger-pierced A1C and sensor collected A1C which is a less satisfactory equation, whereas Equation 2 uses a combination of eAG and GF which is a more acceptable equation. Even with a different set of weighting factors between eAG and GF for Periods Y20 and Y21, Equation 2 with GF influences can offer an extremely high prediction accuracy on A1C. Equation 3 utilizes overall conversion factors between eAG and A1C, which is also a satisfactory equation. Furthermore, Equation 3 is an extremely easy tool for patients to use.

This article describes three different equations to predict HbA1C values. Although their predicted A1C values may not be 100% accurate compared to the lab-tested A1C data, the author provided his experience with a wide margin of error in the lab-tested A1C readings. As a result, the author questions the true accuracy of some lab-tested A1C results. It would make the task of performing an A1C prediction more difficult if the lab-tested A1C is a moving target as it is dependent on the testing environment, procedures, chemical compounds, human errors, etc. This is the reason why he developed a range of equations as tools to predict his forthcoming A1C value prior to the lab-testing day. Having knowledge in disease prevention is more important than medical treatment; however, patients with type 2 diabetes who have accurate information and ease-of-use tools will have better control over their chronic diseases[8-11].

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