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Six International Clinical Cases Demonstrating Prediction Accuracies of Postprandial Plasma Glucoses and Suggested Methods for Improvements Using Linear Elastic Glucose Theory of GH-Method: Math-Physical Medicine, Part 10 (No. 362)

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Abstract

This article is Part 10 of the author's linear elastic glucose behavior study. It focuses on validating his recently defined two glucose coefficients of GH.f-modulus and GH.p-modulus, while interpreting their biomedical meaning and correlations with chronic disease conditions, specifically, obesity and diabetes. In addition, this article illustrates the applicability of his developed predicted postprandial plasma glucose (PPG) equation through data from six international clinical cases. I hope that this linear elastic glucose model would be useful in real life applications to most of type 2 diabetes (T2D) patients worldwide on controlling their conditions.

Here is the step-by-step explanation of the predicted PPG equation from the six clinical cases using linear elastic glucose theory as described in [10, 18]:

1. ***Baseline PPG** equals to 97% of FPG value, or 97% * (weight * GH.f-Modulus).*
2. *Baseline PPG **plus** increased amount of PPG due to food, i.e. plus (carbs/sugar intake amount * GH.p-Modulus).*
3. *Baseline PPG **plus** increased PPG due to food, and then subtracts reduction amount of PPG due to exercise, i.e. minus (post-meal walking k-steps * 5).*
4. *The **Predicted PPG** equals to **Baseline PPG plus the food influences, and then subtracts the exercise influences.***

The linear elastic glucose equation is:
Predicted PPG = (0.97 * GH.f-modulus * Weight) + (GH.p-modulus * Carbs&sugar) - (post-meal walking k-steps * 5)

By using this linear equation, a diabetes patient only needs the input data of body weight, carbs & sugar intake amount, and post-meal walking steps in order to calculate the predicted PPG value without obtaining any measured glucose data.

The biomedical interpretation of these two glucose coefficients are as follows:

When a patient's obesity is worsening (i.e, gaining weight), then the GH.f-Modulus would be lower; however, when the same patient's diabetes is worsening (FPG higher), then the GH.f-Modulus would be higher. Usually, a patient's weight and FPG are closely related to each other with a higher than 90% of correlation. Therefore, the combination in severity of both obesity and diabetes is reflected in the magnitude of GH.f-modules.

On the other hand, the situation of GH.p-Modulus is simpler which mainly shows a patient's glucose sensitivity to carbs/sugar intake amount (the higher the glucose sensitivity depicts worsening diabetes conditions). When a more severe diabetes patient who has a higher GH.p-Modulus consumes the same amount of carbs/sugar, his/her PPG value would be higher than a not-so-severe diabetes patient would. GH.p-modulus (similar to Young's modulus in engineering) indicates the linear relationship between the carbs/sugar intake amount (similar to stress) and the incremental PPG amount (similar to strain) with different slopes for different patients.

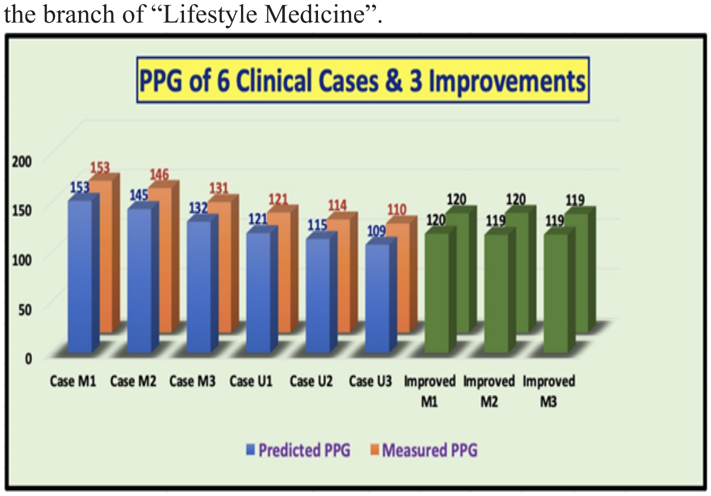
This GH.p-modulus also reflects the health state of pancreatic beta cells of a particular patient. In addition, it may involve the neuroscience of communication model between brain and stomach regarding specific physical state of food entering stomach. This neurology viewpoint will be described in one of his future papers.

The ultimate PPG value is determined by the combination of weight, FPG, carbs/sugar intake amount, post-meal walking steps, with two glucose coefficients of GH.f-Modulus, and GH.p-Modulus.

It should be mentioned here that different from engineering inorganic material which does not change during a long period of time, human blood contains millions organic living red blood cells which have an average lifespan of 115 to 120 days. Therefore, the glucose coefficients of GH.f-Modulus and GH.p-Modulus are "pseudo-constants" during a time span of 3 to 4 months, similar to the tested values of HbA1C. Giving his observed personal HbA1C data during the past 10 years with a change rate within 1% to 11%, the author guesses that these two glucose coefficients should have a similar change rate within 1% to 11% as well. The maximum 11% change rate of GH.p-Modulus from 3.6 to 4.0 would increase his predicted PPG value from 121 mg/dL to 127 mg/dL. In addition, both of weight reduction and glucose change are slow processes. A significant change usually takes a reasonable long period of time, such as years.

This study provides a quantitative proof with high precision from six clinical cases of obesity and diabetes conditions, either by adopting or by rejecting the lifestyle management program. Linear elastic glucose theory and its associated predicted PPG equation have shown their power and applicability on diabetes control for a wide range of patients.

By adopting this theory and linear equation, the author is capable of providing customized quantitative advice and precise recommendations to three Myanmar patients on how to better control their obesity and T2D conditions. This chronic diseases control via a lifestyle management program using linear elastic glucose theory of GH-Method: math-physical medicine can indeed provide a solid scientific background to support the practical guidance as the branch of "Lifestyle Medicine".



Introduction

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Methods

Background

To learn more about the author's GH-Method: math-physical medicine (MPM) methodology, readers can refer to his article to understand his developed MPM analysis method in Reference 1.

Highlights of the Related Research & Engineering Theory of Elasticity

The readers can view the details of his previous research work related to this subject listed in the Reference section.

Here is the step-by-step explanation of the predicted PPG equation from the six clinical cases using linear elastic glucose theory as described in [10, 18]:

1. ***Baseline PPG*** *equals to 97% of FPG value, or 97% * (weight * GH.f-Modulus).*
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The linear elastic glucose equation is:

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By using this linear equation, a diabetes patient only needs the input data of body weight, carbs & sugar intake amount, and post-meal walking steps in order to calculate the predicted PPG value without obtaining any measured glucose data.

Linear Elastic Glucose Behaviors

By utilizing the concept of Young's modulus with stress and strain, which the author learned from engineering schools, he has initiated and engaged this linear elastic glucose behaviors research since 10/14/2020. The following paragraphs describe his research findings over the past month:

First, he discovered that there is a "pseudo-linear" relationship existed between carbs & sugar intake amount and incremental PPG amount. Based on this finding, he defined his first glucose coefficient of GH.p-modulus for PPG.

Second, similar to Young's modulus relating to stiffness of engineering inorganic materials, he found that the GH.p-modulus is depended upon the patient's severity level of diabetes, i.e. patient's glucose sensitivity on carbs/sugar intake amount.

Third, comparable to GH.p-modulus for PPG, he uncovered a similar pseudo-linear relationship existing between weight and FPG in 2017. Therefore, he defined his second glucose coefficient of GH.f-modulus as the FPG value divided by the weight value. This GH.f-modulus is related to the severity of both obesity and diabetes.

Fourth, he inserted these two glucose coefficients of GH.p-modulus and GH.f-modulus, into the predicted PPG equation to remove the burden of collecting measured glucoses by patients.

Fifth, by experimenting and calculating many predicted PPG values over a variety of time length from different diabetes patients with different health conditions, he finally revealed that GH.p-modulus seems to be "near-constant" or "pseudo-linearized" over a short period of 3 to 4 months. This short period is compatible with the known lifespan of red blood cells, which are living organic cells that are different from the engineering inorganic materials, such as steel or concrete. The same conclusion was also observed using the monthly GH.p-modulus data from one particular patient during the 2020 COVID-19 period when his lifestyle became routine and stabilized.

Sixth, he used three US clinical cases during the 2020 COVID-19 period to delve into the hidden characteristics of the physical parameters and their biomedical relationships. More importantly, through the comparison study in Part 7, he found explainable biomedical interpretations of his two defined glucose coefficients of GH.p-modulus and GH.f-modulus.

Seventh, he conducted a PPG boundary analysis by discovering a lower bound and an upper bound of predicted PPG values for eight hypothetical standard cases and three US clinical cases. The derived numerical values of these two boundaries make sense from a biomedical viewpoint and matched with the situations of the three US clinical cases. He even conducted two extreme stress tests, i.e. increasing carbs/sugar intake amount to 50 grams per meal and boosting post-meal walking steps to 5k after each meal, to examine the impacts on the lower-bound and upper-bound of PPG values.

Clinical Cases in This Article

He selected three clinical cases from Myanmar (Cases M1, M2, and M3) and three clinical cases from the US (Cases U1, U2, and U3) in order to cover a broader range of race, gender, food, weather temperature, and environment.

Described below are the key status of each patient's chronic diseases, obesity and diabetes:

- M1 is a male around 40-50 years old, with normal weight, but has severe diabetes conditions.
- M2 is a female around 40-50 years old, who is obese, and has severe diabetes conditions.
- M3 is a female around 40-50 years old, who is obese, and has pre-diabetes conditions.
- U1 is a male over 70 years old, with normal weight, and has a controlled diabetes conditions.
- U2 is a female over 70 years old, who is overweight, but has a controlled diabetes conditions.
- U3 is a male around 40-50 years old, who is extremely obese (BMI over 40), and has pre-diabetes conditions.

It should be mentioned that the three US cases are based on 9-months data in 2020. While the three Myanmar cases are based on around 6-months data in 2019.

Results

Figure 1 shows the data table of the measured health data and calculated PPG data using the step-by-step-process described in the Method section.

T2D Patients	Case M1	Case M2	Case M3	Case U1	Case U2	Case U3	Improved M1	Improved M2	Improved M3
Weight (pound)	150	237	228	167	157	273	150	200	200
FPG (mg/dL)	141	137	133	101	103	105	120	125	120
GH.f-modulus	0.94	0.58	0.58	0.60	0.66	0.38	0.80	0.63	0.60
Baseline PPG 9mg/dL)	137	133	129	98	100	102	116	121	116
GH.p-modulus	1.4	1.6	0.5	3.6	2.6	1.0	1.4	1.6	0.5
Carbs/Sugar (standard gram)	15.42	15.35	15.61	12.34	9.81	12.38	13.42	12.34	15.61
Carbs *GH.p-modulus	22	25	8	44	26	12	19	20	8
Walking (standard k-steps)	1.0	2.5	1.0	4.4	2.1	1.0	3.0	4.4	1.0
T2D Patients	Case M1	Case M2	Case M3	Case U1	Case U2	Case U3	Improved M1	Improved M2	Improved M3
Predicted PPG	153	145	132	121	115	109	120	119	119
Measured PPG	153	146	131	121	114	110	120	120	119
T2D Patients	Case M1	Case M2	Case M3	Case U1	Case U2	Case U3	Improved M1	Improved M2	Improved M3
Accuracy of Predicted PPG	100%	100%	101%	100%	101%	99%	100%	99%	100%

Figure 1: Data table and PPG calculations of 6 clinical cases

The three clinical cases U1, U2, and U3 have adopted the author's recommended lifestyle management program during the entire year of 2020. Therefore, all of their measured FPG values are between 101 mg/dL to 105 mg/dL and their measured PPG values are between 109 mg/dL to 121 mg/dL.

The three Myanmar cases did not follow the author's advice on lifestyle management providing excuses such as difficulty in reducing weight, unable to reduce food portions, and incapable to exercise in hot weather. As a result, all of their measured FPG values are between 133 mg/dL to 141 mg/dL and their measured PPG values are between 131 mg/dL to 153 mg/dL.

Therefore, the author has different suggestions in improving the PPG values for cases M1, M2, and M3. For M1, he will reduce his carbs/sugar intake amount by 2 grams from 15.42g down to 13.42g, while increasing his post-meal walking from 1k to 3k steps; this will drop his PPG value to 120 mg/dL.

For both M2 and M3, the major problem causing their hyperglycemia is due to their heavy weight, if they could reduce their weight to 200 lbs. by cutting 20% off from their normal meal portion, most of their diabetes problems will go away. For M2, the author also suggested for her to reduce carbs/sugar intake amount by 3 grams, from 15.35g to 12.34g, while increasing the post-meal walking from 2.5k to 4.4K steps. For M3, there is no need to adjust her diet and exercise for diabetes concerns, but to focus on her weight reduction.

If cases M1, M2, and M3 could follow his advice and suggestions, all of their predicted PPG values would be dropped down to ~120 mg/dL.

Figure 2 demonstrated the final comparison of the predicted PPG using linear elastic glucose theory versus measured PPG. It is obviously that they match each other extremely well. Figure 2 is extended into to Figure 3 for the prediction accuracy bars for each case. All of these prediction accuracies are within +/- 1% margin of error, which means they have reached 99% to 100% of prediction accuracies.

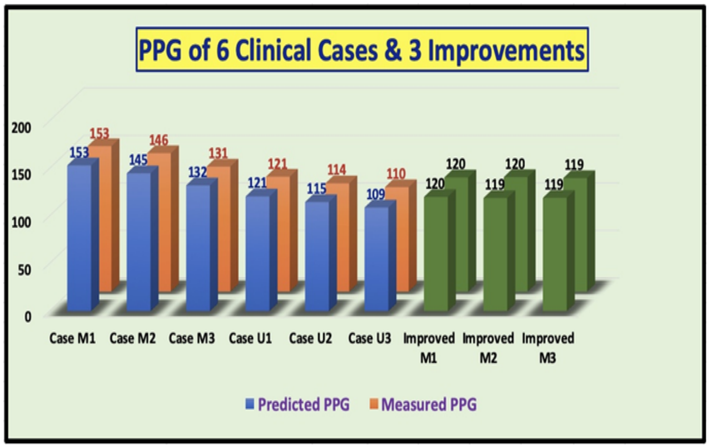

Figure 2: Comparison between predicted PPG and measured PPG for 6 clinical cases with customized recommendations of improvements for 3 Myanmar patients

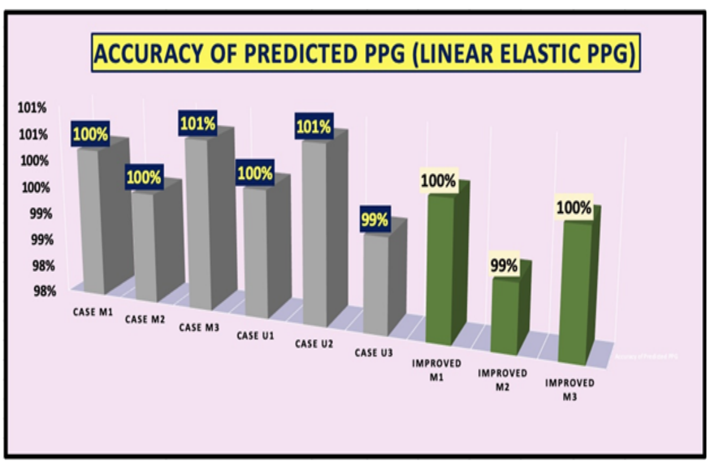

Figure 3: Prediction accuracies for 6 clinical cases

Conclusions

The biomedical interpretation of these two glucose coefficients are as follows:

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Acknowledgement

Foremost, I would like to express my deep appreciation to my former professors: professor James Andrews at the University of lowa, who helped develop my foundation in basic engineering and computer science, and professor Norman Jones at the Massachusetts Institute of Technology, who taught me how to solve tough scientific problem through the right attitude and methodology.

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