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High Glucose Predication Accuracy of Postprandial Plasma Glucose and Fasting Plasma Glucose During the COVID-19 Period Using Two Glucose Coefficients of GH-Modulus from Linear Elastic Glucose Theory Based on GH-Method: Math-Physical Medicine, Part 7 (No. 359)

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Abstract
This article is Part 7 of the author's linear elastic glucose behavior study, which focuses on the prediction accuracy of the postprandial plasma glucose (PPG) and fasting plasma glucose (FPG) over the COVID-19 quarantined period, from 1/1/2020 to 11/8/2020. This research is the continuation of his previous six studies on linear elastic glucose behaviors.

The main objective is to offer numerical proof for the high prediction accuracy of both PPG and FPG based on linear elastic glucose theory with two newly defined biomedical coefficients of GH-modulus, during the COVID-19 period when his overall health conditions have reached to the best performed state.

The following lists the average values over this period of 10+ months from 1/1/2020 to 11/8/2020:

Weight: 170 lbs.
Measured FPG: 102 mg/dL
Predicted FPG: 102 mg/dL
Carbs/sugar: 12.19 grams
Post-meal Walking: 4.447 k-steps
Measured PPG: 108.3 mg/dL
Predicted PPG: 109.2 mg/dL
Average GH.f-modulus: 0.60
Average GH.p-modulus: 2.64
Accuracy of predicted FPG: 100.0%
Accuracy of predicted PPG: 99.2%

Where Predicted PPG
= baseline PPG + carbs - walking
= 99.3 + 32.2 - 22.2
= 109.2 mg/dL

The most important finding in this study is ***the extremely high accuracies of predicted glucoses, including FPG with 100.0% accuracy and PPG with 99.2% accuracy***. The result proves the applicability of his developed linear elastic glucose behaviors models on his glucose predictions efforts during a "better-controlled" COVID-19 quarantined period.

Here is the equation again:

Predicted PPG = (0.97 * GH.f-modulus * Weight) +(GH.p-modulus * Carbs&sugar) - (post-meal walking k-steps * 5)

In practice, when diabetes patients use the above equation, they only need the input data of weight, carbs/sugar intake amount, and post-meal walking steps, without glucose measurement.

The author will continue his research work to develop corresponding ranges for these two biomedical "glucose coefficients" from GH.p-modulus and GH.f-modulus to match the different groups of health states for patients. He will cover this subject in article No. 360.

The secondary finding for the two "pseudo-linear" or "near-constant" relationship associated with the two glucose coefficients, GH.p-modulus and GH.f-modulus, are also observed in this particular period, which is similar to the cases in his previous research work. The relatively lower values of glucose coefficients have further indicated that his diabetes control during the COVID-19 period has been successful.

Introduction
This article is Part 7 of the author's linear elastic glucose behavior study, which focuses on the prediction accuracy of the postprandial plasma glucose (PPG) and fasting plasma glucose (FPG) over the COVID-19 quarantined period, from 1/1/2020 to 11/8/2020. This research is the continuation of his previous six studies on linear elastic glucose behaviors.

The main objective is to offer numerical proof for the high prediction accuracy of both PPG and FPG based on linear elastic glucose theory with two newly defined biomedical coefficients of GH-modulus, during the COVID-19 period when his overall health conditions have reached to the best performed state.

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 his Related Research
In 2015 and 2016, the author decomposed the PPG waveforms (data curves) into 19 influential components and identified carbs/sugar intake amount and post-meal walking exercise contributing to approximately 40% of PPG formation, respectively. Therefore, he could safely discount the importance of the remaining ~20% contribution by the 16 other influential components.

In March of 2017, he also detected that body weight contributes to over 85% to FPG formation. Furthermore, in 2019, he identified that FPG could serve as a good indicator of the pancreatic beta cells' health status; therefore, he can apply the FPG value (more precisely, 97% of FPG value) to serve as the baseline PPG value to calculate the PPG incremental amount in order to obtain the predicted PPG.

In 2019, all of his developed PPG prediction models achieved high percentages of prediction accuracy, but he also realized that his prediction models are too difficult for use by the general public. As a result, he supplemented his complex models with a simple linear equation of predicted PPG (see References 2 and 3).

Here is his simple linear formula (Reference 4):

Predicted PPG= FPG * M1 + (carbs-sugar * M2) - (post-meal walking k-steps * M3)

Where M1, M2, M3 are 3 multipliers.

After lengthy research, trial and error, and data tuning, he finally identified the best multipliers for FPG and exercise as 0.97 for M1 and 5.0 for M3. In comparison with PPG, the FPG is a more stabilized biomarker since it is directly related to body weight, not food or exercise. We know that weight reduction is a hard task. However, weight is a calmer and more stabilized biomarker in comparison to glucose which changes from minute to minute with a bigger magnitude of fluctuation. The influence of exercise (specifically, post-meal walking steps) on PPG (41% contribution and >80% negative correlation with PPG) is almost equal to the influence from the carbs/sugar intake amount on PPG (39% contribution and >80% positive correlation with PPG). In terms of intensity and duration, exercise is a simple and straightforward subject to study. Especially, normal-speed walking is a safe and effective form of exercise for the large portion of diabetes patients, particularly senior citizens.

The parameters, FPG and walking, have a lower chance of variation for the author since he is stringent on maintaining his body weight and his daily exercise routine.

On the other hand, the relationship between food nutrition and glucose is a quite complex and difficult subject to fully understand and effectively manage due to many types of available food (in terms of both quality and quantity of meals) with different nutritional ingredients, including carbohydrates and sugar contents. For example, in the author's developed database of food material and nutritional ingredients, it contains over six million data. As a result, the author decided to implement two multipliers, M1 for FPG and M3 for exercise, as the two "constants", and keep M2 as the only "variable" in his PPG prediction equation.

Therefore, an easier linear equation for predicted PPG is listed below:

Predicted PPG
*= (0.97*FPG) +(Carbs&sugar * M2) - (post-meal walking k-steps * 5)*

He further created two new terms for his developed two linear elastic glucose coefficients:

Term 1
GH.p-modulus = M2

The incremental PPG from diet
= Predicted PPG - baseline PPG
*(i.e. 0.97 * FPG) + (walking * 5)*

Glucose Coefficient for PPG
GH.p-modulus= (Incremental PPG)/(Carbs&sugar)

Glucose Coefficient for FPG
GH.f-modulus = (FPG) / (Weight)

After combining the above 2 terms and 2 glucose coefficients, he has finally obtained the following linear equation of predicted PPG:

Predicted PPG =(0.97 * GH.f-modulus * Weight) +(GH.p-modulus * Carbs&sugar) - (post-meal walking k-steps * 5)

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

Stress, Strain, & Young's Modulus

Prior to his medical research work, he was an engineer in the various fields of structural engineering (aerospace, naval defense, and earthquake engineering), mechanical engineering (nuclear power plant equipments, and computer-aided-design), and electronics engineering (computers, semiconductors, graphic software, and software robot).

The two biomedical coefficients of GH-modulus mentioned above were inspired by his prior knowledge in the theory of elasticity in strengths of engineering materials which has the following engineering equation developed in 1807 by a British scientist, Thomas Young:

Stress = Young's modulus * Strain

Note: Young's modulus and the two biomedical coefficients, both GH.f-modulus and GH.p-modulus, are reciprocal to each other.

The following excerpts comes from internet public domain, including Google and Wikipedia:

Strain - ε
Strain is the "deformation of a solid due to stress" - change in dimension divided by the original value of the dimension - and can be expressed as
ε = dL / L
where
ε = strain (m/m, in/in)
dL = elongation or compression (offset) of object (m, in)
L = length of object (m, in)

Stress - σ
Stress is force per unit area and can be expressed as
σ = F / A
where
σ = stress (N/m2, lb/in2, psi)
F = applied force (N, lb)
A = stress area of object (m2, in2)

Stress includes tensile stress, compressible stress, shearing stress, etc.

E, Young's Modulus
It can be expressed as:
E = stress / strain
= σ / ε
= (F / A) / (dL / L)

where
E = Young's Modulus of Elasticity (Pa, N/m2, lb/in2, psi) was named after the 18th-century English physicist Thomas Young.

Elasticity

Elasticity is a property of an object or material indicating how it will restore it to its original shape after distortion. A spring is an example of an elastic object - when stretched, it exerts a restoring force which tends to bring it back to its original length (Figure 1).

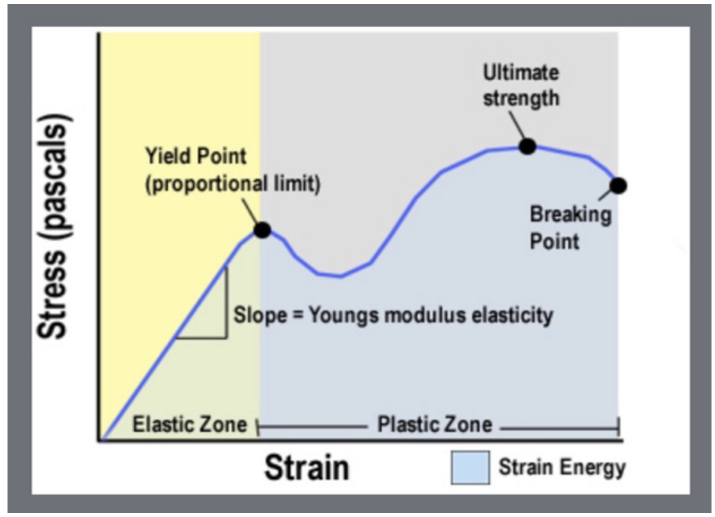

Figure 1: Stress-Strain-Young's modulus, Elastic Zone vs. Plastic Zone

Plasticity

When the force is going beyond the elastic limit of material, it is into a plastic zone which means even when force is removed, the material will not return back to its original state (Figure 1).

Based on various experimental results, the following table lists some Young's modulus associated with different materials:

Nylon: 2.7 GPa
Concrete: 17-30 GPa
Glass fibers: 72 GPa
Copper: 117 GPa
Steel: 190-215 GPa
Diamond: 1220 GPa

Young's modules in the above table are ranked from soft material (low E) to stiff material (higher E)."

Professor James Andrews taught the author linear elasticity at the University of Iowa and Professor Norman Jones taught him nonlinear dynamic plasticity at Massachusetts Institute of Technology. These two great academic mentors provided him the necessary foundation knowledge to understand these two important subjects in engineering.

Data Collection

The author is a 73-year-old male with a 25-year history of T2D. He began collecting his carbs/sugar intake amount and post-meal walking steps on 6/1/2015. Therefore, from 6/1/2015 to 11/6/2020, he has collected 7 data per day, i.e. weight, one FPG, three PPG, carb/sugar intake amount, and post-meal walking steps. He utilized these big data associated to conduct various studies.

The period of 9/1/2015 to 12/31/2019 is his "better-controlled" diabetes period, where his average daily glucoses is maintained at 116 mg/dL (<120 mg/dL, the normal range). He named this period as his "linear elastic zone" of diabetes health. It should also be noted that in 2010, his average glucose was 280 mg/dL and HbA1C was 10%, while taking three diabetes medications. The strong chemical interventions from various diabetes medications would seriously alter glucose physical behaviors. He called the period prior to 2015 as his "nonlinear plastic zone" of diabetes health.

It should be pointed out that 2020 is his "best-performed" health period due to his stabilized routine without any traveling for the duration of the COVID-19 quarantined timeframe. During this special period, his 90-days average daily glucose dropped to 101 mg/dL and his weight went below 170 lbs. (BMI <25). He reduced his weight from 200+ lbs. to approximately 175 lbs. in 2015, while maintaining the same level for 5 years. This means that his pancreatic beta cells' health condition has reached to his "best state" in the 25 years of his diabetes history (References 5 and 6).

Recent Linear Elastic Glucose Studies

Utilizing the concept of Young's modulus and stress/strain, during the past 30 days, the author has initiated and engaged in this linear elastic glucose behaviors research. The following highlights have outlined his findings during this process.

First, he discovered that there is a "pseudo-linear" relationship existed between carbs & sugar intake amount and incremental PPG amount. Therefore, he defined a new 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 obesity and diabetes.

Third, similar to GH.p-modulus for PPG, he uncovered a similar pseudo-linear relationship existed between weight and FPG. Therefore, he defined another new glucose coefficient of GH.f-modulus for FPG.

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

Fifth, by experimenting and calculating many predicted PPG values over a variety of time length of different 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. They are living organic materials which is different from engineering materials, such as steel or concrete. The same finding can also be observed in the monthly GH.p-modulus values from this particular study in the COVID-19 period.

Results

There are only two graphic figures which demonstrate the findings in this study.

	lbs	mg/dL	FPG / Weight		grams	K-steps	Incremental PPG	mg/dL	mg/dL	PPG Prediction
Case A:	Weight	Measured FPG	GH.f-modulus	Case A:	Carbs/Sugar	Walking	GH.p-modulus	Predicted PPG	Measured PPG	Accuracy %
Jan, 2020	170	117	0.69	Jan, 2020	14.38	4.587	1.65	114	114	100%
Feb, 2020	171	112	0.66	Feb, 2020	11.36	4.574	2.13	110	110	100%
Mar, 2020	172	108	0.63	Mar, 2020	12.93	4.869	2.20	109	109	100%
Apr, 2020	172	113	0.66	Apr, 2020	13.49	4.365	1.75	111	111	100%
May, 2020	173	100	0.58	May, 2020	15.41	4.013	2.05	108	108	100%
Jun, 2020	172	100	0.58	Jun, 2020	11.59	3.850	2.95	112	112	100%
Jul, 2020	170	95	0.56	Jul, 2020	10.43	4.250	3.70	109	109	100%
Aug, 2020	171	99	0.58	Aug, 2020	10.79	3.962	2.68	105	105	100%
Sept, 2020	169	100	0.59	Sept, 2020	11.38	4.024	2.45	104	104	100%
Oct, 2020	167	93	0.56	Oct, 2020	11.94	4.807	3.01	102	102	100%
Nov, 2020	167	89	0.53	Nov, 2020	10.42	5.614	4.45	105	105	100%
Case A:	Weight	Measured FPG	GH.f-modulus	Case A:	Carbs/Sugar	Walking	GH.p-modulus	Predicted PPG	Measured PPG	Accuracy %
Calculated	170	102	0.60	Calculated	12.19	4.447	2.64	109.2	108.3	99.2%
Averaged	170	102	0.60	Averaged	12.19	4.447	2.64	108.3	108.3	100.0%
Case A:	Weight	Measured FPG	GH.f-modulus	Case A:				Predicted FPG	Measured FPG	Accuracy %
Averaged	170	102	0.60	Averaged				102.4	102.4	100.0%

Baseline PPG	99.3	= 0.97* (Weight * GH.f-modulus, i.e. FPG)
+ Carbs/sugar	32.2	= Carbs/sugar * GH.p-modulus
- walking	22.2	= Walking k-steps * 5
Predicted PPG	109.2	= baseline PPG + carbs/sugar - walking k-steps

Figure 2: Data table and equation calculations during COVID-19 period (1/1/2020 - 11/8/2020)

Predicted PPG =(0.97 * GH.f-modulus * Weight) +(GH.p-modulus * Carbs&sugar) - (post-meal walking k-steps * 5)

The following lists the average values over this period of 10+ months from 1/1/2020 to 11/8/2020:

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Where
Predicted PPG
= baseline PPG + carbs - walking= 99.3 + 32.2 - 22.2= 109.2 mg/dL

Figure 3 depicts monthly values of GH.f-modulus and GH.p-modulus. There are two noteworthy observations. First, the GH.f-modulus values seem to be more stabilized than the GH.p-modulus values. They are within the range of 0.53 to 0.69, but most of coefficient values are within the range of 0.56 to 0.66. This phenomenon is due to both weight and FPG as being more of a stable biomarker than PPG. Second, the coefficient values of GH.p-modulus has more fluctuations (i.e., amplitude difference) than the GH.f-modulus. However, within a shorter time span of 3 to 4 months, there are several "more-closely clustered" patterns, such as from January through April, June through August, August through October, and September through November. Within these more closely, clustered sub-periods, the coefficients act more like "pseudo-constants".

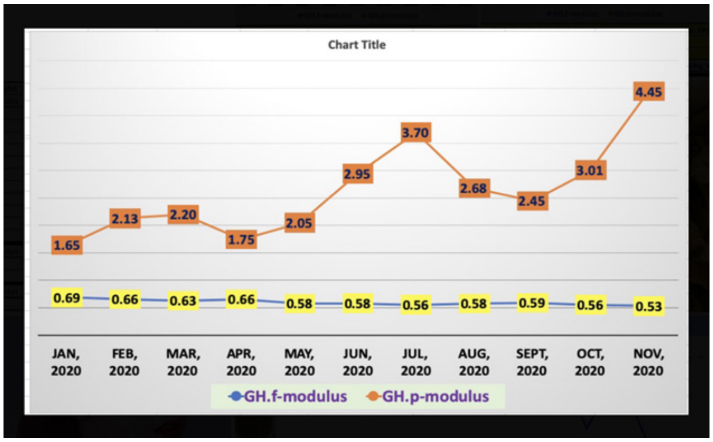

Figure 3: Glucose coefficients of both GH.f-modulus and GH.p-modulus during COVID-19 period (1/1/2020 - 11/8/2020)

Conclusions

The most important finding in this study is ***the extremely high accuracies of predicted glucoses, including FPG with 100.0% accuracy and PPG with 99.2% accuracy.*** The result proves the applicability of his developed linear elastic glucose behaviors models on his glucose predictions efforts during a "better-controlled" COVID-19 quarantined period.

Here is the equation again:

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The author will continue his research work to develop corresponding ranges for these two biomedical "glucose coefficients" of GH.p-modulus and GH.f-modulus to match the different groups of health states for patients. He will cover this subject in one of his future articles.

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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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