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GH.p-Modulus Study of Linear Elastic Glucose Theory Based on Data From 159 Liquid Egg Meals, 126 Solid Egg Meals, and 2,843 Total Meals Using GH-Method: Math-Physical Medicine, Part 12 (No. 364)

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Abstract

This article is Part 12 of the author's linear elastic glucose behavior study. It focuses on a deeper investigation of GH.p-modulus through the comparison of the results from his neuroscience study of egg meals against his 2,843 total meals during the period of 5/5/2018 to 11/17/2020. In the comparison study, he can explore the potential range (variance) of GH.p-modulus values with special cases of 285 egg meals and general case of 2,843 total meals. As a result, it extends to connect the study of his eight hypothetical standard cases presented in paper No. 361 (Reference 17).

Here is the step-by-step explanation of the predicted postprandial plasma glucose (PPG) equation using linear elastic glucose theory as described in References 9 through 19:

*(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)*

Where
(1) Incremental PPG = Predicted PPG - Baseline PPG + Exercise impact
(2) GH.f-modulus = FPG / Weight
(3) GH.p-modulus = Incremental PPG / Carbs intake

It is quite interesting to put the author's 285 special egg meals experimental data side by side with his 2,843 total meals data together. The differences of the carb amount and GH.p-modulus values between the egg meals and total meals are vast and obvious.

The neuroscience egg meals are offered as extreme cases for the GH.p-modulus boundary situations by having an extremely low carb intake amount per meal with an associated much higher GH.p-modulus value. However, the conclusions from the case of 2,843 total meals could offer general guidelines for type 2 diabetes patients who want to control their diabetic conditions via lifestyle management program. The author thinks that a general GH.p-modulus

range of 1.0 to 5.0 is probably suitable for the majority of clinical cases (the author's own range is 2.1 to 3.4). From a practical angle, a patient can use this GH.p-modulus value as a multiplier of his carbs/sugar amount and use a number of 5 as his multiplier to the post-meal walking k-steps and then plug them into the following "quick but not so dirty" formula in order to obtain the predicted PPG.

*Predicted PPG =FPG + (GH.p * Carbs) - (k-steps *5)*

Where the patient can attempt to use different numbers between 1 through 5 as the GH.p input value to determine the suitable GH.p-modulus.

By using the above estimated PPG formula, diabetes patients can find their PPG level very quickly and accurately without delving into the details of the linear elastic glucose theory.

Introduction

This article is Part 12 of the author's linear elastic glucose behavior study. It focuses on a deeper investigation of GH.p-modulus through the comparison of the results from his neuroscience study of egg meals against his 2,843 total meals during the period of 5/5/2018 to 11/17/2020. In the comparison study, he can explore the potential range (variance) of GH.p-modulus values with special cases of 285 egg meals and general case of 2,843 total meals. As a result, it extends to connect the study of his eight hypothetical standard cases presented in paper No. 361 (Reference 17).

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 Linear Elastic Glucose Theory

Here is the step-by-step explanation of the predicted PPG equation using linear elastic glucose theory as described in References 9 through 19:

(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)

Where
(1) Incremental PPG = Predicted PPG - Baseline PPG + Exercise impact
(2) GH.f-modulus = FPG / Weight
(3) GH.p-modulus = Incremental PPG / Carbs intake

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.

In 2014, the author came up with the analogy between theory of elasticity and plasticity and the severity of diabetes when he was developing his mathematical model of metabolism.

On 10/14/2020, by utilizing the concept of Young's modulus with stress and strain, which was taught in engineering schools, he initiated and engaged this linear elastic glucose behaviors research. The following paragraphs describe his research findings at different stages of this research period:

First, he discovered that there is a "pseudo-linear" relationship existing between carbs & sugar intake amount and incremental PPG amount. Based on this finding, he defined the 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 dependent 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, in 2017, he uncovered a similar pseudo-linear relationship existing between weight and FPG with high correlation coefficient of above 90%. Therefore, he defined the 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 combined chronic diseases, including 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 human red blood cells, which are living organic cells. This is quite different from the engineering inorganic materials, such as steel or concrete which can last for an exceptionally long period of time. The same conclusion was observed using his monthly GH.p-modulus data during the COVID-19 period in 2010 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 specific clinical cases. The derived numerical values of these two boundaries make sense from a biomedical viewpoint and also 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.

Eighth, based on six international clinical cases, he further explored the influences from the combination of obesity and diabetes. Using a "lifestyle medicine" approach, he offered recommendations to reduce their PPG from 130-150 mg/dL down to below 120 mg/dL via reducing carbs/sugar intake and increasing exercise level in walking.

Ninth, based on his neuroscience research work using both 126 solid eggs and 159 liquid eggs with a very low carbs/sugar intake amount of ~2.5 grams producing two totally different sets of PPG values and waveforms, he identified a different set of much higher values of GH.p-modules for these egg meals. Even though this research served as a special boundary case in the study, nevertheless, it has further proven that the GH.p-modules is also influenced directly by the human brain.

Meal Cases in this Article

In multiple published articles from his previous neuroscience research work, he separated his egg meals into two distinctive physical states, liquid state (159 egg drop soup) and solid state (126 pan-fried egg or hard broiled egg), during the period from 5/5/2018 to 11/17/2020. This period is selected due to the same glucose measuring period via a continuous glucose monitoring (CGM) sensor device on his arm. His 285 egg meals have an average carb intake amount around 2.5 grams and his average post-meal walking approximately 4.5 k-step. His sensor measured PPG levels are 111 mg/dL for liquid eggs PPG and 128 mg/dL for solid eggs PPG.

During the same time period, he has consumed a total of 2,843 meals with an average carb intake amount of 13.8 grams and his post-meal walking is 4.3 k-step. It should be mentioned that he also continued to measure his PPG using the traditional finger-piercing method at 120-minutes after the first bite of his meal. For this total meal's group, his measured PPG levels are 131 mg/dL for sensor PPG and 113 mg/dL for finger PPG.

He then segregated his collected data according to the categories of weight, FPG, carbs, walking, and PPG. By using the average data within each type of meals and the total period using both sensor and finger methods, he then calculated the four sets of corresponding glucose coefficients of GH.f-modulus and GH.f-modulus.

Finally, he compared his calculated glucose coefficients of these four groups to study their relationships, specific meaning, and identify the proper biomedical interpretations.

Results

Figure 1 shows the comparison of PPG waveforms between 126 solid egg meals, 159 liquid egg meals, and 2,843 ***total meals. It is obvious that the total meals PPG waveform (average PPG 131 g/dL and carbs 13.8 grams)*** is the highest one. ***The solid egg PPG waveform (average PPG 128 g/dL and carbs 2.2 grams)*** is slightly lower than the total meals. However, the ***liquid egg PPG waveform (average PPG 111 g/dL and carbs 2.8 grams)*** is the lowest one among these three groups. The finger total meals are not included because they contain only one glucose number per meal instead of 13 PPG data points per meal for a sensor waveform. The Finger PPG value's measuring time (120 minutes after the first bite of meal) usually occurs around the lowest levels of sensor PPG waveform and the average finger PPG is about 16% lower than the average sensor PPG.

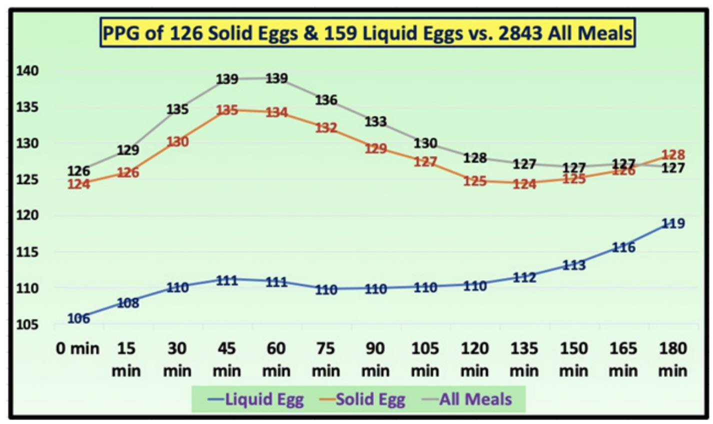

Figure 1: Three PPG waveforms comparison between 159 liquid eggs (egg drop soup), 126 solid eggs (pan-fried egg and hard broiled egg), and 2,843 total meals using sensor device for measuring PPG

Figure 2 depicts the background data for the calculations of predicted PPG and derivations of two glucose coefficients, both GH.f-modulus and GH.p-modulus.

Total: 5/5/2018-11/7/2020	Meals:	159	126	2843	2843
	The Author	Liquid Eggs	Solid Eggs	All Meals - Sensor	All Meals -Finger
	GH.f-modulus (%)	59	64	64	64
	Sensor FPG (mg/dL)	100	109	110	110
Formula	Weight (pound)	170	172	171	171
= FPG / Weight	GH.f-modulus	0.59	0.64	0.64	0.64
= 0.97 * Weight * GH.f-modulus	Baseline PPG (mg/dL)	97	106	106	106
	GH.p-modulus	12.7	20.7	3.4	2.1
	Carbs&Sugar (gram)	2.8	2.2	13.8	13.8
	Carbs *GH.p-modulus	35	46	46	28
	Walking (k-steps)	4.2	4.7	4.3	4.3
= Baseline+Carbs*GH.p-Walk*5	Predicted PPG	111.3	128.3	131.0	113.0
	Measured PPG (mg/dL)	111.3	128.3	131.0	113.0
= Predicted PPG / Measured PPG	Accuracy of Predicted PPG	100%	100%	100%	100%
	The Author	Liquid Eggs	Solid Eggs	All Meals - Sensor	All Meals -Finger
	Carbs&Sugar (gram)	2.8	2.2	13.8	13.8
= predcted PPG - Baseline PPG + K-steps*5	Incremental PPG (mg/dL)	35.4	45.6	46.3	28.3
= Incremental PPG / Carbs&Sugar	GH.p-modulus	12.7	20.7	3.4	2.1

Figure 2: Data, definition, and formula using GH.f-modulus, GH.p-modulus, Baseline PPG, Incremental PPG and calculation

of Predicted PPG for liquid eggs, solid eggs, and total meals

Here again is the step-by-step explanation of the predicted PPG equation:

(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)

Where
(1) Incremental PPG = Predicted PPG - Baseline PPG + Exercise impact
(2) GH.f-modulus = FPG / Weight
(3) GH.p-modulus = Incremental PPG / Carbs intake

It is interesting to list his calculated results of GH.f-modulus elbow:

Liquid eggs: 0.59
Solid eggs: 0.64
Total meals: 0.64

Regardless of the variety of his meal contents, his overall weight and FPG values are highly consistent. Therefore, this "near-constant" GH.f-modulus values indicate that the conditions of his chronic diseases are under well controlled during the past 2.5-years period.

Figures 3 reflects the GH.p-modulus values link together with Carbs/Sugar amounts and Incremental PPG values for these four groups: liquid eggs, solid eggs, total meals sensor, and total meals finger. As a result, this indicates his glucose sensitivity to carbs & sugar intake amounts of these three groups of meals, excluding total meals finger.

The GH.p-modulus and Incremental PPG relationship can be expressed in the following linear equation:

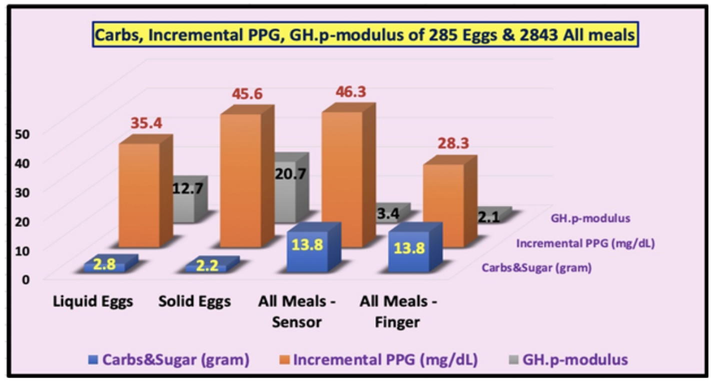

Figure 3: GH.p-modulus linking Carbs and Incremental PPG for liquid eggs, solid eggs, and total meals

Incremental PPG =Carbs intake * GH.p-modulus

The two ***GH.p-modulus values are 12.7 for liquid eggs and 20.7 for solid eggs which are much higher than his two total meals GH.p-modulus values of 3.4 for total sensor PPG*** and 2.1 for total finger PPG. The large differences are due to the extremely low carb intake amount of ~2.5 grams which produces 111 mg/dL for liquid eggs PPG, but a much higher 128 mg/dL for solid eggs PPG resulting from the neuro-communication between the brain and internal organs. Although the total meals finger PPG of 113 mg/dL is quite close to the liquid eggs PPG of 111 mg/dL, but their significant difference of carbs amount (13.8g vs. 2.8g) produces two vastly different GH.p-modulus values (2.1 vs. 12.7).

Here are the key numbers put together in the form of carbs, GH.p:
Liquid eggs: (2.8g, 12.7)
Solid eggs: (2.2g, 20.7)
Total sensor: (13.8g, 3.4)
Total finger: (13.8g, 2.1)

Based on the above findings, during the last 2.5 years, ***the author has applied one multiplier of 2.1 for his predicted finger PPG and another multiplier of 3.4 for his predicted sensor PPG to achieve highly accurate PPG prediction.***

Another sanity checks to conduct the following calculation in the formula:
"Incremental PPG = carbs * GH.p"

Liquid Eggs

2.8g * 12.7 = 35.6 mg/dL
Solid eggs:
2.2g * 20.7 = 45.5 mg/dL
Total meals sensor:
13.8g * 3.4 = 46.9 mg/dL
Total meals finger:
13.8g * 2.1 = 29.0 mg/dL

When he adds the corresponding baseline PPG values of the above calculated incremental PPG values, he accurately obtained the four sets of predicted PPG values which are identical to his measured PPG values.

Conclusions

It is quite interesting to put the author's 285 special egg meals experimental data side by side with his 2,843 total meals data together. The differences of the carb amount and GH.p-modulus values between the egg meals and total meals are vast and obvious.

The neuroscience egg meals are offered as extreme cases for the GH.p-modulus boundary situations by having an extremely low carb intake amount per meal with an associated much higher GH.p-modulus value. However, the conclusions from the case of 2,843 total meals could offer general guidelines for type 2 diabetes patients who want to control their diabetic conditions via lifestyle management program. The author thinks that a general GH.p-modulus range of 1.0 to 5.0 is probably suitable for the majority of clinical cases (the author's own range is 2.1 to 3.4). From a practical angle, a patient can use this GH.p-modulus value as a multiplier of his carbs/sugar amount and use a number of 5 as his multiplier to the post-meal walking k-steps and then plug them into the following "quick but not so dirty" formula in order to obtain the predicted PPG.

Predicted PPG =FPG + (GH.p * Carbs) - (k-steps *5)

Where the patient can attempt to use different numbers between 1 through 5 as the GH.p input value to determine the suitable GH.p-modulus.

By using the above estimated PPG formula, diabetes patients can find their PPG level very quickly and accurately without delving into the details of the linear elastic glucose theory.

Acknowledgement

Foremost, I would like to express my deep appreciation to my former professors: professor James Andrews at the University of Iowa, 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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