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GH.p-Modulus Study using both Finger and Sensor Glucoses and Linear Elastic Glucose Theory of GH-Method: Math-Physical Medicine, Part 16 (No. 370)

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Abstract

This article is Part 16 of the author's linear elastic glucose behavior study. It focuses on a deeper investigation of GH.p-modulus over the period from 8/5/2018 through 11/27/2020 using both finger-piercing measured glucoses (finger) and continuous glucose monitor (CGM) sensor collected glucoses (sensor).

The author plans to conduct additional studies on linear elastic glucose behavior theory in order to obtain a solid and better understanding on the glucose coefficient of GH.p-modulus.

Here is the step-by-step explanation for the predicted postprandial plasma glucose (PPG) equation using linear elastic glucose theory as described in References 9 through 22:

*(1) Baseline PPG equals to 97% of fasting plasma glucose (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

Therefore,
GH.p-modulus = (PPG - (0.97 * FPG) + (post-meal walking k-steps * 5)) / (Carbs&Sugar intake)

The study in this article calculates and analyzes the glucose coefficient of GH.p-modulus values over the period from 8/5/2018 through 11/27/2020 using both finger glucoses and sensor glucoses. The calculated GH.p-modulus values are 2.0 for finger glucoses, and 3.3 for sensor glucoses.

This paper investigates the likely situations of the author's health conditions and lifestyle details based on two different glucose measuring methods. These two GH.p-modulus values have a relatively small and insignificant variance of 1.2, which is between 2.0 and 3.2. Actually, any number located between the range of 1.8 to 3.3, even if it skews

toward the higher side of this scale, can be used as an application to the GH.p-modulus for PPG prediction.

This study utilizes a step-by-step illustration, moving from the difference between PPG and FPG, going through the Incremental PPG, and then arriving at the Predicted PPG. In the described steps, the most important variable of the linear elastic glucose behaviors is the coefficient of GH.p-modulus (similar to Young's modules in theory of engineering elasticity). That is why the author has conducted a massive amount of research on linear elastic glucose behaviors theory in order to acquire a good and solid understanding for the GH.p-modulus.

Introduction

This article is Part 16 of the author's linear elastic glucose behavior study. It focuses on a deeper investigation of GH.p-modulus over the period from 8/5/2018 through 11/27/2020 using both finger-piercing measured glucoses (finger) and continuous glucose monitor (CGM) sensor collected glucoses (sensor).

The author plans to conduct additional studies on linear elastic glucose behavior theory in order to obtain a solid and better understanding on the glucose coefficient of GH.p-modulus.

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.

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, and software robot).

The following excerpts come from the 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.

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 of 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 strength of materials and linear elasticity at the University of Iowa and Professor Norman Jones taught him nonlinear and dynamic plastic behaviors of structures at Massachusetts Institute of Technology. These two great academic mentors provided him with the foundational knowledge to understand these two important subjects in engineering.

Highlights of Linear Elastic Glucose Theory

Here is the step-by-step explanation for the predicted PPG equation using linear elastic glucose theory as described in References 9 through 22:

(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 influ-

ences, 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

Therefore,

*GH.p-modulus = (PPG - (0.97 * FPG) + (post-meal walking k-steps * 5)) / (Carbs&Sugar 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 early 2014, the author came up with the analogy between theory of elasticity and plasticity and the severity of his diabetes conditions when he was developing his mathematical model of metabolism using topology concept and finite element method.

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:

1. 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.

2. 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., the patient's glucose sensitivity on carbs/sugar intake amount, which reflects this patient's health state of liver cells and pancreatic beta cells.

3. 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. More than 33 million Americans, about 1 in 10, have diabetes, and approximately 90% to 95% of them have type 2 diabetes (T2D), where 86% also have problems with being overweight or obese. In other words, 7.7% to 8.2 % of the US population or 25 to 27 million Americans have issues with both obesity and diabetes.

4. 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.

5. 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 2020 when his lifestyle became routine and stabilized.

6. 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.

7. 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 the situations of the three US clinical cases. He 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.

8. 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.

9. Based on his neuroscience research work using both 126 solid eggs and 159 liquid eggs with an extremely low carbs/sugar intake amount of ~2.5 grams, producing two totally different sets of PPG data and waveforms based on neurosciences viewpoint. He has also identified a different set of much higher values for GH.p-modulus from the exceptionally low carbs/sugar intake of egg meals. Even though this egg neuroscience research results can be served as a special boundary case, it has also further proven that the GH.p-modulus is influenced directly by the human brain and nervous system.

10. He compared the above two egg meals results, including PPG values and glucose coefficients, in particular the GH.p-modulus, against the total results of his 2,843 meals. He discov-

ered the vast differences of GH.p-modulus magnitudes and also learned the tight relationship between GH.p-modulus value and carbs/sugar intake amount. By distinguishing the GH.p-modulus results from the special boundary cases of 12.7 for liquid egg meals and 20.7 for solid egg meals, his general GH.p-modulus values from his 2,843 total meals are 2.1 using finger PPG and 3.4 using sensor PPG.

11. He used his 365 egg meal data from his neurosciences research papers to further calculate detailed variations of their associated GH.p-modulus.
12. He applied the linear elastic glucose theory to formulate certain guidelines as a part of his practical "lifestyle medicine" approach for family medicine branch.
13. He calculates three GH.p-modulus values, 1.8, 2.2, and 1.8, for three different periods, i.e., pre-virus period, COVID-19 period, and total period, respectively. This data range between 1.8 to 2.2 matches with his observed personal lifestyle and acquired biomedical knowledge through his medical research work during the past 9 years.

Results

Figures 1 and 2 show the 90-days moving average value of FPG, PPG, Carbs/sugar intake amount, and post-meal walking steps for finger glucose case and sensor glucose case, respectively.

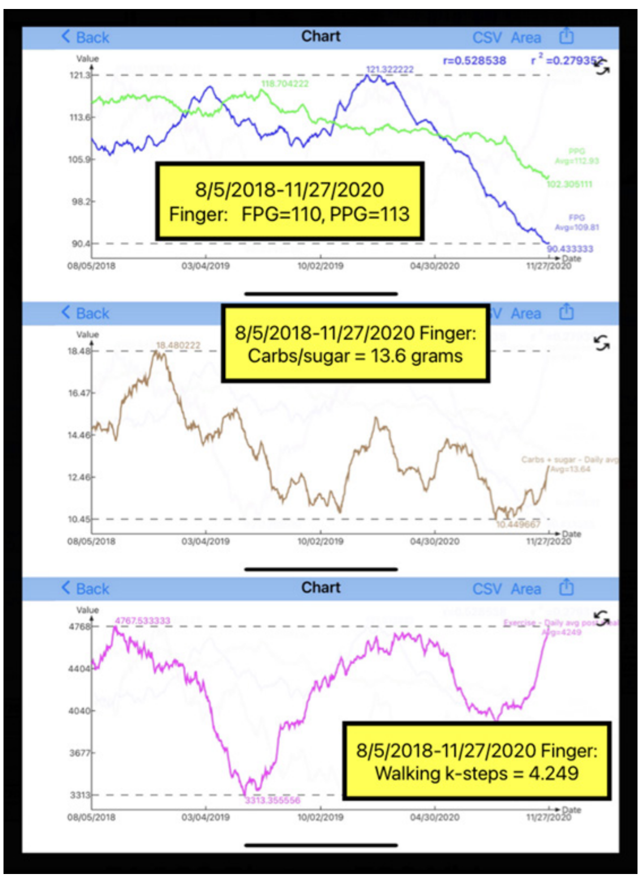

Figure 1: Finger measured FPG, PPG, Carbs, Walking during 8/5/2018 - 11/27/2020

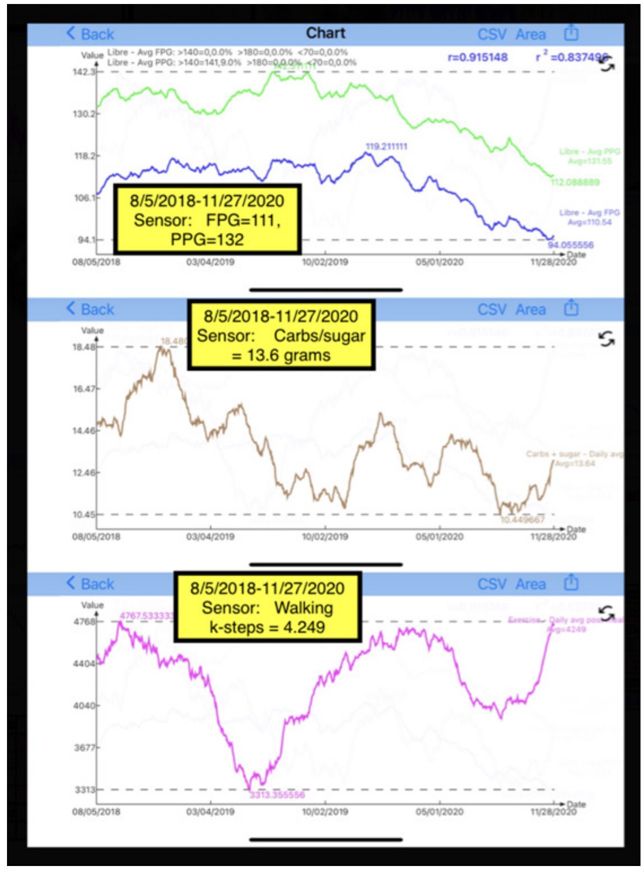

Figure 2: Sensor measured FPG, PPG, Carbs, Walking during 8/5/2018 - 11/27/2020

Here again is the step-by-step explanation for 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

Therefore,

GH.p-modulus = (PPG - (0.97 * FPG) + (post-meal walking k-steps * 5)) / (Carbs&Sugar intake)

The following is the list of his average values in the form of FPG, PPG, Carbs&sugar intake grams, Walking k-steps for both finger and sensor cases.

Finger: (110, 113, 13.64, 4.249)
Sensor: (111, 132, 13.64, 4.249)

During this period from 8/5/2018 to 11/27/2020, the Sensor PPG is 17% higher than the Finger PPG while the Sensor FPG is almost identical to the Finger FPG.

Figure 4 is the combined data tables deploying the GH.p-modulus equation. For better viewing and comparing purposes, the author presents the collected results from both paper No. 369 for three different time periods (Reference 23) and paper No. 370 for finger glucose and sensor glucose cases during the same period of 8/5/2018-11/27/2020.

(8/5/18-11/27/20	Finger	Sensor
PPG	113	132
FPG	110	111
Carbs gram	13.6	13.6
Walking k-steps	4.25	4.25
(8/5/18-11/27/20	Finger	Sensor
GH.p (avg. data)	2.0	3.3

Finger	Y2017-2019	Y2020	Y2017-2020
PPG	116	109	114
FPG	116	106	114
Carbs gram	14.3	12.7	13.9
Walking k-steps	4.32	4.37	4.33
Finger	Y2017-2019	Y2020	Y2017-2020
GH.p (avg. data)	1.8	2.2	1.8

Figure 3: GH.p-modulus values for both finger and sensor and 3 different time periods

For the comparison between finger and sensor, the average GH.p-modulus value for finger glucoses is 2.0, while the average GH.p-modulus value for the sensor glucoses is 3.3. This higher GH.p-modulus value for the sensor glucoses is a result finding from the higher sensor PPG values (+19 mg/dL or +17%).

Furthermore, the comparison of the data from three different time periods in Reference 23 (No. 369), the GH.p-modulus value of 2.0 for finger glucoses are within the boundary of 1.8 for both 2017-2019 (pre-virus) period and 2017-2020 total period and 2.2 for the 2020 COVID-19 period (Reference 22). The reason for the +0.2 GH.p difference from the pre-virus period and total period is due to the combination of his lower FPG (-6 mg/dL), lower PPG (-3 mg/dL), and lower carbs/sugar intake amount (-0.7 grams).

However, the GH.p-modulus value of 3.3 for sensor glucoses are +1.3 higher than finger glucose GH.p value, and +1.5 higher than the 2017-2019 pre-virus period and 2017-2020 total period, and +1.1 higher than the 2020 COVID-19 period. The reason for the higher GH.p values from the sensor glucose GH.p is due to its higher PPG values: 19 mg/dL higher than finger, 16 mg/dL higher than pre-virus period, 23 mg/dL higher than virus period, and 18 mg/dL higher than total period. It should be noted that both finger and sensor cases have identical carbs/sugar intake amount and post-meal walking k-steps.

In summary, the GH.p-modulus value coordinates with a patient's weight, FPG, PPG, carbs/sugar intake, and post-meal exercise that fluctuates within a reasonable numerical range. In this study, the GH.p-modulus indeed reflects the general health conditions of the author.

Conclusions

The study in this article calculates and analyzes the glucose coefficient of GH.p-modulus values over the period from 8/5/2018 through 11/27/2020 using both finger glucoses and sensor glucoses. The calculated GH.p-modulus values are 2.0 for finger glucoses, and 3.3 for sensor glucoses.

This paper investigates the likely situations of the author's health conditions and lifestyle details based on two different glucose-measuring methods. These two GH.p-modulus values have a relatively small and insignificant variance of 1.2, which is between 2.0 and 3.2. Actually, any number located between the range of 1.8 to 3.3, even if it skews toward the higher side of this scale, can be used as an application to the GH.p-modulus for PPG prediction.

This study utilizes a step-by-step illustration, moving from the difference between PPG and FPG, going through the Incremental PPG, and then arriving at the Predicted PPG. In the described steps, the most important variable of the linear elastic glucose behaviors is the coefficient of GH.p-modulus (similar to Young's modules in theory of engineering elasticity). That is why the author has conducted a massive amount of research on linear elastic glucose behaviors theory in order to acquire a good and solid understanding for the GH.p-modulus [1-23].

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