GH-Method: Math-Physical Medicine
Special Issue

Linear Relationship Between Carbohydrates and Sugar Intake Amount and Incremental PPG Amount *via* Engineering Strength of Materials Using GH-Method: Math-Physical Medicine, Part 1 (No. 346)

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Abstract
This article is a special research on the linear elasticity behavior of glucose using his defined GH-modulus (or M2) to link the input of carbs/sugar intake amount and output of incremental postprandial plasma glucose (PPG) amount.
Here is the formula he used in his previously published papers:
*Predicted PPG = (FPG * 0.97) + (carbs/sugar grams * M2) - (post-meal walking k-steps * 5)*
He has connected this biomedical equation with a basic concept of stress and strain, along with the Young's modulus of strength of materials in structural and mechanical engineering. Using his collected 11,580 data of glucose, food, and exercise, he has demonstrated that a pseudo-linear relationship indeed existing between the carbs/sugar intake amount multiplied with a GH-modulus (i.e., M2), which is similar to the stress on an engineering system; and the incremental PPG amount, which is similar to the strain of an engineering system. A newly defined coefficient of GH-modulus as the value of M2 multiplier is similar to the Young's modulus of stress-strain relationship in the subject of engineering strength of materials.
This investigation has proven the existing pseudo-linear relationship between food as stress on the liver and incremental glucose as strain from the liver, particularly during his better controlled period of diabetes from 7/1/2015–10/13/2020.
This article is a special research on the linear elasticity of glucose with his defined GH-modulus (or M2) and engineering modeling methodologies to investigate various biomedical problems. This methodology and approach are resulted from his specific academic background and different professional experiences prior to his medical research work beginning in 2010. Therefore, he has been trying to link his newly acquired biomedical knowledge over the past decade with his previously acquired mathematics, physics, computer science, and engineering knowledge over 40 years.
The human body is the most complex system he has dealt with. However, by applying his previous acquired knowledge to his newly found interest of medicine, he can discover many hidden facts or truths inside the biomedical systems. Many basic concepts, theoretical frame of

thoughts, and practical modeling techniques from his fundamental disciplines in the past can be applied to his medical research endeavor. After all, science is based on theory via creation and proof via evidence, and as long as we can discover hidden truths, it does not matter which method we use and which way we take. This is the foundation of the GH-method: math-physical medicine (MPM).

Keywords: carbohydrates, sugar, elasticity, glucose, exercise

Abbreviations: PPG: postprandial plasma glucose; MPM: math-physical medicine; AI: artificial intelligence; FPG: fasting plasma glucose; HbA1C: hemoglobin A1C

Introduction

This article is a special research on the linear elasticity behavior of glucose using his defined GH-modulus (or M2) to link the input of carbs/sugar intake amount and output of incremental postprandial plasma glucose (PPG) amount.

Here is the formula he used in his previously published papers:

Predicted PPG = (FPG * 0.97) + (carbs/sugar grams * M2) - (post-meal walking k-steps * 5)

He has connected this biomedical equation with a basic concept of stress and strain, along with the Young's modulus of strength of materials in structural and mechanical engineering. Using his collected 11,580 data of glucose, food, and exercise, he has demonstrated that a pseudo-linear relationship indeed existing between the carbs/sugar intake amount multiplied with a GH modulus (*i.e.*, M2), which is similar to the stress on an engineering system; and the incremental PPG amount, which is similar to the strain of an engineering system. A newly defined coefficient of GH-modulus as the value of M2 multiplier is similar to the Young's modulus of stress-strain relationship in the subject of engineering strength of materials.

This investigation has proven the existing pseudo-linear relationship between food as stress on the liver and incremental glucose as strain from the liver, particularly during his better controlled period of diabetes from 7/1/2015–10/13/2020.

Methods

Background

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

Highlights of his previous research

In 2015, 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 2016, he utilized optical physics, big data analytics, and artificial intelligence (AI) techniques to develop computer software to predict PPG based on the patient's food pictures or meal photos. This sophisticated AI approach and iPhone app software product have reached to a 98.8% prediction accuracy based on ~6,000 meal photos.

In 2017, he also detected that body weight contributes to over 85% to fasting plasma glucose (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 of his predicted PPG.

In 2018, based on his collected ~2,500 meals and associated sensor PPG waveforms, he applied the perturbation theory from quantum mechanics at first-bite moment of his meal to further predict the PPG waveform (*i.e.*, PPG curve) covering the entire follow-on 180 min with a 95% of PPG prediction accuracy.

In 2019, all of his developed PPG prediction mathematical models have achieved high percentages of prediction accuracy, but he also realized that his prediction models are too difficult to use by the general public. The above-mentioned sophisticated MPM methods would be difficult for healthcare professionals and diabetes patients to understand, let alone use them in their daily life for diabetes control. Therefore, he tried to supplement his complex models with a simple linear equation of predicted PPG [2–4].

Here is the simple linear formula:

Predicted PPG = FPG * M1 + (carbs and 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. Weight reduction is a hard undertaking but is a far calmer and more stabilizing biomarker in comparison to glucose which fluctuate from moment to moment. 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 much simpler subject to study and deal with. On the other hand, the relationship between food nutrition and glucose is an exceedingly complex and difficult subject to fully understand and effectively manage, since there are many types of food and their associated carbs/sugar contents. For example, the author's food nutrition database already contains over six million data. As a result, he decided to implement two multipliers, *i.e.*, M1 for FPG and M3 for exercise, as two constants and keep M2 as the only variable in his PPG prediction equation.

This further simplified his linear equation for predicted PPG as follows:

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

He also defines the following three new terms in equations 2, 3, and 4:

- Term 1: GH modulus = M2
- Term 2: The incremental PPG amount = predicted PPG - PPG baseline (*i.e.*, 0.97 * FPG) + exercise effect (*i.e.*, walking k-steps * 5)
- Term 3: GH modulus (*i.e.*, M2) = (incremental PPG) / (carbs and sugar)

Stress, strain, and Young's modulus

Prior to the past decade in his self-study and medical research work, he was an engineer in the fields of structural (aerospace and naval defense), mechanical (nuclear power plants and computer-aided-design), and electronics (computers and semiconductors). The following excerpt comes from the public domain, e.g., Google, 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/m^2, lb/in^2, psi), F = applied force (N, lb), A = stress area of object (m^2, in^2)

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

- Young's modulus (E)

It can be expressed as E = stress / strain

= σ / ε

= (F / A) / (dL / L)

where E = Young's Modulus of elasticity (Pa, N/m^2, lb/in^2, 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).

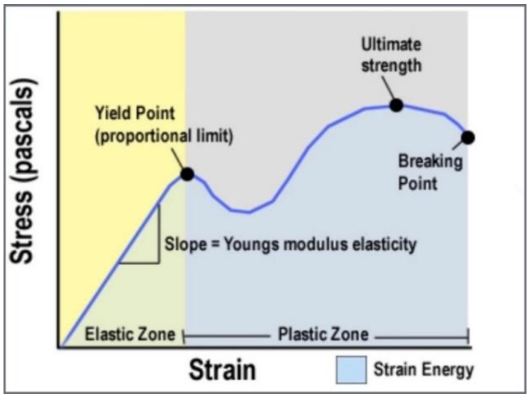


Figure 1: Stress-strain Young's modulus, elastic zone *vs.* plastic zone.

- 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).

In this particular study, the above-mentioned equation 4 is remarkably similar in concept and format to the stress-strain equation as shown below except GH modulus and Young's modulus are reverse to each other.

GH modulus (*i.e.*, M2) = (incremental PPG) / (Carbs and sugar)

Young's modulus E = stress / strain = σ / ε

The author visualizes the carbs/sugar intake amount as the stress (the force, cause, or stimulator) on his liver and the incremental PPG amount as the strain (the response, consequence, or stimulation) from the liver. The GH modulus (*i.e.*, 1/M2) is similar to the Young's modulus (*i.e.*, E) which describes the pseudo-linear relationship existing between the carbs/sugar (stress) and incremental PPG (strain).

Finally, conceptually, he is able to connect together the subject of liver glucose production in endocrinology with the subject of strength of materials in structural and mechanical engineering.

Results

The author has recorded his glucose and weight data since 1/1/2012 and then began collecting carbs/sugar intake amount and post-meal walking steps on 7/1/2015. This period coincides with his best-controlled diabetes period, where his average daily glucose reduced to around or under 120 mg/dL (*i.e.*, near a normal range) without any medications. He named this as his linear elastic zone of diabetes health. It should also be noted that in 2010, his average glucose was 280 mg/dL and hemoglobin A1C (HbA1C) was 10%, while taking 3 diabetes medications (*i.e.*, strong chemical interventions). Prior to 2015, he called that period as his nonlinear plastic zone of diabetes health.

From 7/15/2015–10/13/2020 (1,930 days), he had collected 6 data per day, 1 FPG, 3 PPG, carb/sugar, and post-meal walking steps. He utilized these 11,580 data and then organized them into 6 years to conduct his annual calculations. The collected raw data and two sets of calculations are shown in the figure (Figure 2). The calculations in this figure have used two different sets of M2 values.

Predicted PPG = (FPG*0.97)+(Carbs*M2)-(Steps*5)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Predicted Finger PPG	119	120	117	117	114	109	116
Finger PPG	119	120	117	117	114	109	116
Prediction Accuracy (Finger PPG)	100%	100%	100%	100%	100%	100%	100%
Predicted Finger Daily Glucose	119.28	119.42	117.41	116.40	114.37	107.70	116
Finger Daily Glucose	119.28	119.42	117.38	116.36	114.38	107.74	116
Predicted Accuracy (Finger Daily)	100%	100%	100%	100%	100%	100%	100%
Equation Multipliers (5/5/18-10/10/20)	M2	M2	M2	M2	M2	M2	Average
Finger PPG Prediction Equation	1.56	1.76	1.59	1.87	1.75	2.41	1.82
Finger Daily Prediction Equation	1.52	1.56	1.82	1.70	1.79	1.99	1.73
Predicted PPG = (FPG*0.97)+(Carbs*M2)-(Steps*5)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Predicted Finger PPG	123	121	120	116	115	102	116
Finger PPG	119	120	117	117	114	109	116
Prediction Accuracy (Finger PPG)	103%	101%	103%	99%	101%	93%	100%
Predicted Finger Daily Glucose	122	122	116	117	114	104	116
Finger Daily Glucose	119	119	117	116	114	108	116
Predicted Accuracy (Finger Daily)	103%	102%	99%	100%	99%	97%	100%
Equation Multipliers (5/5/18-10/10/20)	M2	M2	M2	M2	M2	M2	Average
Finger PPG Prediction Equation	1.82	1.82	1.82	1.82	1.82	1.82	1.82
Finger Daily Prediction Equation	1.73	1.73	1.73	1.73	1.73	1.73	1.73

Figure 2: Raw data for the period of 7/1/2015–10/13/2020.

In case A, calculation is based on different M2 values (*i.e.*, variables) each year in order to obtain 100% of the PPG prediction accuracy for every year in this period. The 100% accuracy indicates that the annual predicted PPG is identical to the annual measured PPG. In case B, calculation is based on a constant value of 1.82 for M2 (using the 6-years' average) to obtain 6 different annual PPG prediction accuracies ranging from 93–103%. The figure (Figure 3) illustrates calculated data table of these two cases, case A with different M2 and case B with constant M2.

The figures (Figure 4 and 5) show the graphic results of case A and case B reflectively, based on the calculated data table in figure 3.

The figure (Figure 4) depicts the results from using variable M2 values to achieve a 100% match between the predicted PPG and measured PPG of each year.

Listed below are the values for the M2 multiplier (GH-modulus) for each year:

- Year 2015 - 1.56
- Year 2016 - 1.76
- Year 2017 - 1.59
- Year 2018 - 1.87
- Year 2019 - 1.75
- Year 2020 - 2.41
- Average - 1.82

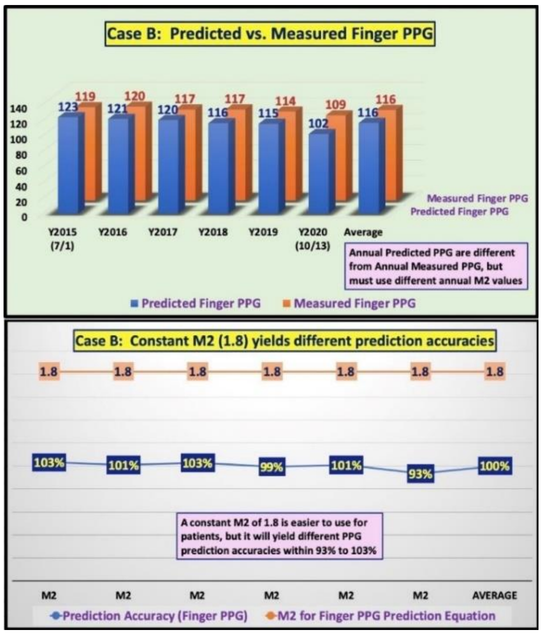


Figure 3: Calculated PPG prediction using both case A (variable M2) and case B (constant M2) for the period of 7/1/2015–10/13/2020.

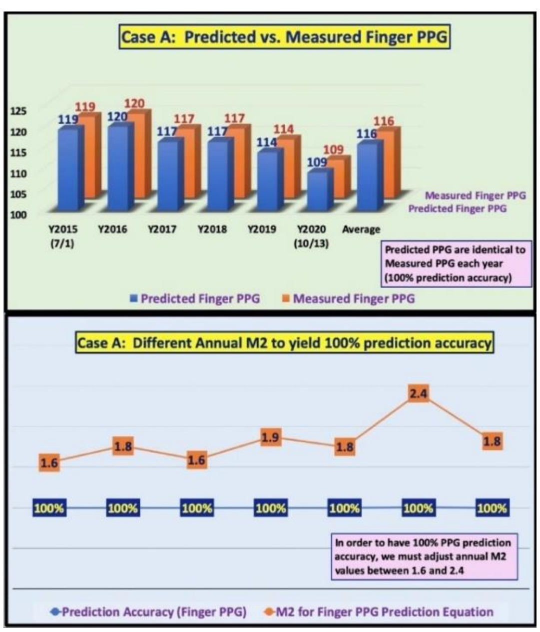


Figure 4: Calculated PPG prediction using case A (variable M2) to have 100% prediction accuracy for each year of the period of 7/1/2015–10/13/2020.

The figure (Figure 5) reflects the results from using a constant GH-modulus (M2) of 1.82 to achieve different predicted PPG values from the measured PPG values, with different prediction accuracy for each year (from 93–103%).

Listed below are the values of the prediction accuracy for each year:

- Year 2015 - 103%
- Year 2016 - 101%
- Year 2017 - 103%
- Year 2018 - 99%
- Year 2019 - 101%
- Year 2020 - 93%
- Average - 100%

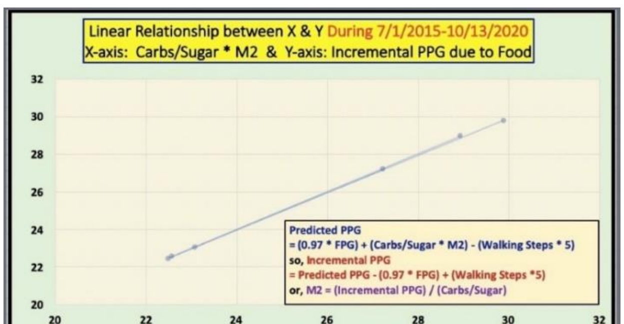
(5/5/18-1/18/20) & (1/19/20-10/10/20)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Carb/Sugar (grams)	14.46	15.47	14.19	15.47	13.19	12.40	14.20
Post-meal Walking (k-steps)	3.681	4.110	4.440	4.538	4.038	4.296	4.184
(5/5/18-1/18/20) & (1/19/20-10/10/20)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Finger FPG	119	117	120	114	115	104	115
Finger PPG	119	120	117	117	114	109	116
Finger Daily	119	119	117	116	114	108	116
Predicted PPG = (FPG*0.97)+(Carbs*M2)-(Steps*5)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Predicted Finger PPG	119	120	117	117	114	109	116
Measured Finger PPG	119	120	117	117	114	109	116
Equation Multipliers (5/5/18-10/10/20)	M2	M2	M2	M2	M2	M2	Average
Prediction Accuracy (Finger PPG)	100%	100%	100%	100%	100%	100%	100%
M2 for Finger PPG Prediction Equation	1.6	1.8	1.6	1.9	1.8	2.4	1.8
Predicted PPG = (FPG*0.97)+(Carbs*M2)-(Steps*5)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)	Average
Predicted Finger PPG	123	121	120	116	115	102	116
Measured Finger PPG	119	120	117	117	114	109	116
Equation Multipliers (5/5/18-10/10/20)	M2	M2	M2	M2	M2	M2	Average
Prediction Accuracy (Finger PPG)	103%	101%	103%	99%	101%	93%	100%
M2 for Finger PPG Prediction Equation	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Figure 5: Calculated PPG prediction using case A (constant M2) to have different prediction accuracy for each year (between 93% and 103%) of the period of 7/1/2015–10/13/2020.

In fact, the prediction accuracies varying between 93–103% with a 6-years average accuracy of 100% are acceptable for the purpose of practical glucose control. This is equivalent to a diabetes patient's situation of glucose prediction accuracy ranging from 112 mg/dL (93%) to 124 mg/dL (103%) using a normal dividing line of 120 mg/dL (100%).

The figure (Figure 6) shows an x-y data diagram with a pseudo-linear relationship between x-values of carbs/sugar multiplied by M2, and y-values of the incremental PPG due to FPG and exercise as defined in the following equation:

The incremental PPG amount = predicted PPG - (FPG * 0.97) + (walking k-steps * 5)



Key Data (7/1/2015 - 10/13/2020)	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)
Carb/Sugar (grams)	14.46	15.47	14.19	15.47	13.19	12.4
Post-meal Walking (k-steps)	3.681	4.11	4.44	4.538	4.038	4.296
Finger FPG	118.98	117.04	119.76	113.73	114.55	103.86
Finger PPG	119.45	120.19	116.53	116.6	113.99	109.07
M2 for Finger PPG Prediction Equation	1.56	1.76	1.59	1.87	1.75	2.41
Linear Equation Multiplier: M2	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)
X-axis: Carbs/Sugar * M2	22	27	23	29	23	30
Y-axis: Incremental PPG due to Food	22.44	27.21	22.56	28.97	23.07	29.81

Figure 6: A pseudo-linear relationship between x-values and y-values during the linear elastic zone.

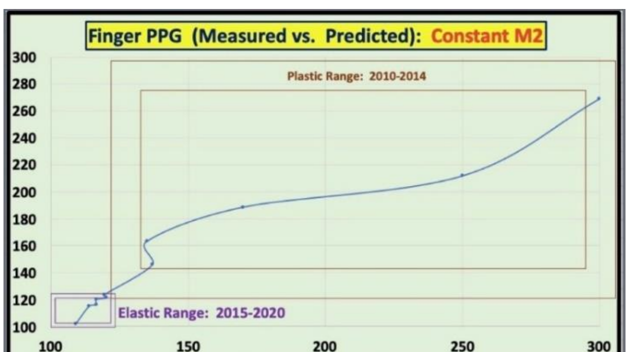
The data ranges of x-axis and y-axis are from 20–32. It is obvious that the six-annual data almost form a straight line with a slope of 45% and a very small degree of deviations which is why the author calls it a pseudo-linear relationship. This is similar to the elastic zone of the stress-strain Young's modulus diagram in strength of materials of structural and mechanical engineering (Figure 1). This linear relationship makes the task of PPG prediction and diabetes control much easier.

Discussion

The author was a severe type 2 diabetes patient since 1995. He suffered many life-threatening diabetic complications during the period of Y2000–Y2012. After experiencing 5 cardiovascular episodes, with an average glucose value of 280 mg/dL and HbA1C of 10%, he started to self-study and research diabetes and food nutrition in 2010. He collected his diet and exercise data since 6/1/2015. After 2015, his diabetes conditions have been under control *via* a stringent lifestyle program without taking any diabetes medications; therefore, in this study, he used his collected big data of lifestyle details and glucose to conduct his rather completed numerical analysis. From 7/1/2015–10/13/2020, his diabetes conditions are more or less falling into a linear elastic zone which suggests that his PPG would land in a reasonable range (around 120 mg/dL or below) when he consumes lesser amount of carbs/sugar along with exercising adequately.

On the other hand, during the period of 2000–2010, when his diabetes was totally out of control, he believes that he should belong to a nonlinear plastic zone, or at least a bi-linear plastic zone, meaning his PPG would remain at a certain elevated level even if he reduced or stopped the intake of carbs/sugar. Worse than having elevated glucoses (hyperglycemia *i.e.*, > 180 mg/dL), he could suffer from hypoglycemia (glucose < 70 mg/dL) leading to insulin shock and eventually sudden death. However, due to the lack of sufficient data collection, he cannot conduct a similar detailed and completed numerical analysis to prove his suspicion of nonlinear plastic zone. He can only try to use his scattered data collection from 2010–2014 to obtain a guesstimated observation and some partial conclusions.

As shown in the figure (Figure 7), he displayed an x-y diagram of predicted PPG *vs.* measured PPG over both periods, the smaller area of linear elastic period of 2015–2020 and lager area of nonlinear plastic period of 2010–2014. The comparison between these two strength of materials zones are interesting, but yet he needs to find other ways to prove his suspicion on the linkage between his glucose spikes and fluctuations (*i.e.*, nonlinearity) of glucoses in the plastic zone and carbs/sugar intake amount in order to compare against his controlled glucoses situations of the pseudo-linear elastic zone.



PPG Comparison	Y2010	Y2011	Y2012	Y2013	Y2014	Y2015 (7/1)	Y2016	Y2017	Y2018	Y2019	Y2020 (10/13)
M2 for Finger PPG Prediction Equation	1.45	1.45	1.45	1.45	1.45	1.82	1.82	1.82	1.82	1.82	1.82
Measured Finger PPG	300	250	170	135	137	119	120	117	117	114	109
Predicted Finger PPG	269	212	188	163	146	123	121	120	116	115	102

Figure 7: Discussion of variety of relationship between predicted PPG and measured PPG during 2010–2020 (pseudo-linear elastic zone and nonlinear plastic zone).

In his published research papers since 2019, he has proven that his pancreatic beta cells' insulin capability of production and quality have been self-repaired at a rather slow speed of an annual rate of 2.7% [5, 6]. It means that at least 16% of his insulin production and quality problems have been repaired from the beginning of 2015 which is in the elastic zone. Perhaps even 27% of his insulin production and quality problems have been repaired since 2011 which covers both partial plastic and elastic zones. This type of organic cells' regeneration capability and biomedical phenomena was unknown to him when he was an engineer and only dealing with various inorganic materials, such as metal, concrete, and silicon. As a result, since 2010, he has been fascinated working with the various stimulators and complex stimulations of the biomedical system. The more research work he performs, the more unknown phenomena occur, and the more questions enter his mind, causing him to search for more problems and seek for better answers.

Conclusion

This article represents the author's special interest in using math-physical and engineering modeling methodologies to investigate various biomedical problems. This methodology and approach are resulted from his specific academic background and different professional experiences prior to his medical research work beginning in 2010. Therefore, he has been trying to link his newly acquired biomedical knowledge over the past decade with his previously acquired knowledge in mathematics, physics, computer science, and engineering for over 40 years.

The human body is the most complex system he has ever dealt with. However, by applying his previous acquired knowledge to his newly found interest of medicine, he can discover many hidden facts or truths inside the biomedical systems. Many basic concepts, theoretical frame of thoughts, and practical modeling techniques from his previously acquired fundamental disciplines can be applied to his medical research endeavor. After all, science is based on theory from creation and proof *via* evidence, and as long as we can discover hidden truths, it does not matter which method we use and what option we take. This is the foundation of the GH-method: MPM.

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