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Applying the First-Order Perturbation Theory of Quantum Mechanics to Build Highly-Accurate Predicted Postprandial Plasma Glucose Waveforms within the Range of Low-Carbs and High-Carbs using GH-Method: Math-Physical Medicine (MPM #1) No. 420

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Abstract
In this paper, the author presents his techniques of applying the first-order perturbation theory of quantum mechanics to predict and build a postprandial plasma glucose (PPG) waveform based on the "perturbation factor" i.e., slope of carbs/sugar intake amount. This is a part of his GH-Method: math-physical medicine research methodology.

This perturbation theory for glucose applications is described as follows:

Perturbation Equation
Perturbed Y= Y1 + slope * (Y2 - Y1)

Perturbed Glucose= Glucose at T1 + (Slope A or Slope B) * (Glucose at T2 - Glucose at T1)

Where the slope is an arbitrarily selected real parameter that controls the size of the perturbation.

Slope A= (Selected Carbs - Low-bound Carbs) / (High-bound Carbs - Low-bound Carbs)

Slope B= (Low-bound Carbs / High-bound Carbs)

Glucose variance is an extremely sophisticated biochemical process with outcomes and is also a complex biophysical phenomenon. It takes various applications mathematical tools to analyze them. After a diabetes patient measures and establishes two separate initial waveforms with one low-carb meals group and another high-carb meals group, we can then develop a perturbed (i.e. predicted) PPG waveform accordingly.

In other words, we can predict the glucose behavior resulting from functions of the brain, liver, and pancreas by using the perturbation theory of quantum mechanics to obtain an approximated PPG waveform according to the selected carbs/sugar intake amount. Of course, the same method can also be applied using the secondary influential factor, such as by different post-meal waking steps or by different eating places (combination of both carbs and exercise). In this way, diabetes patients will have the ability to predict their own PPG behavior prior to consuming a meal or initiate certain level of post-meal exercise.

Introduction
In this paper, the author presents his techniques of applying the first-order perturbation theory of quantum mechanics to predict and build a postprandial plasma glucose (PPG) waveform based on the "perturbation factor" i.e., slope of carbs/sugar intake amount. This is a part of his GH-Method: math-physical medicine research methodology.

Methods
Perturbation Theory
The author applies the first-order interpolation perturbation method to establish a predicted "perturbed PPG" waveforms based on different carbs/sugar intake amounts and "real-measured PPG" waveforms.

Normally, a given complex function can obtain certain approximated solutions through a class of simpler and approximated operations. A biomarker, such as PPG, has multiple influential factors, including carbs/sugar intake amount and post-meal exercise quantity, and other secondary factors. If we maintain the post-meal exercise amount at a constant level, then we only need to deal with a single variable of the carbs/sugar intake amount.

Most general complex problems can be expressed by the following polynomial function of nth degree:

Y= P(X)= A0 + A1*X**1 + A2*X**2 + ... + An*X**n

This nth degree polynomial function could be solved by approximating the Y-values based on the available data set with the help of some external but small "perturbation factor", such as a "slope", to adjust the neighboring datapoint on X-scale with a corresponding Y-value which is approximate to the original Y-value in the available data set. This mathematical approximation approach could be achieved through the interpolation tool with the perturbation method.

First, in many cases, this nth degree polynomial function could be further simplified via truncating off the higher order terms to achieve the following first-order polynomial function:

Y = f(X) = A0 + A1*X

Second, the above first-order polynomial function's approximate solution could be obtained through a specific "interpolation" or "extrapolation" method.

Interpolation is implemented within the range covered by data of both the PPG due to high-carbs amount ("high glucose") and PPG due to low-carbs amount ("low glucose"). The interpolation method replaces Y (glucose level) with an easily calculated function, usually a polynomial and a simple straight line. In short, the interpolation method, also known as the intermediate value, is a scientific term that could be defined as arriving to unknown intermediate values (e.g., glucose level Y mg/dL) of a function by using known values (e.g., carbs amount X grams). For the complex problem of glucose variation study, this simplified equation can be expressed in the following format of the perturbation equation:

New glucose value of Y mg/dL corresponding to a new X carbs gram, where X carbs can be any amount within the range of a high-bound of carbs and a low-bound of carbs.
= function of carbs amount, i.e. f(X)
= Y1 + slope * (Y2 - Y1)
Y1 = original glucose on Y-scale
Y2 = advanced glucose on Y-scale

Where:

Slope A = (newly selected X carbs minus low-bound carbs) / (high bound carbs minus low-bound carbs)

We may use another formula such as Slope B:

Slope B = (low-bound carbs / high-bound carbs)

where the high-bound carbs amount would be better if it is within the range of 4 times higher than the low-bound carbs amount.

The above descriptions of the perturbation theory can then be summarized into the following glucose perturbation equation:

Perturbation Equation
Perturbed Y= Y1 + ***Slope*** ** (Y2 - Y1)*

Perturbed Glucose *= Glucose at T1 +* ***(Slope A or Slope B) **** *(Glucose at T2 - Glucose at T1)*

Where the slope is an arbitrarily selected real parameter that controls the size of the perturbation.

Slope A= (Selected Carbs - Low-bound Carbs) / (High-bound Carbs - Low-bound Carbs)

Slope B= (Low-bound Carbs / High-bound Carbs)

It should be noted that, for better and more accurate predicted glucose value, the selected carbs amount should be within the range between the high-bound carbs and the low-bound carbs, where these two carbs values should be within 4 times magnitude to each other.

The above-described steps of the calculation (the Perturbation Equation) have utilized an applied mathematics methodology of the "first-order interpolation perturbation method" which have been frequently used in quantum mechanics, fluid dynamics, and solid mechanics.

Analysis Case

Initially, the author applies a segmentation pattern analysis method to analyze his collected sensor PPG values of 3,218 meals which include 2,128 low-carbs meals (between 0 gram to 15 grams with an average carbs amount of 7.2 grams per meal) and 1,090 high-carbs meals (between 15.1 grams to 200 grams with an average carbs amount of 27.7 grams per meal) from 5/5/2018 to 3/27/2021. A standard sensor PPG waveform (or curve) contains 13 data points for each PPG curve and one input data for each 15-minute time segment.

Originally, his chosen two carbs-segments were based on both "first influential factor" of the meal's carbs/sugar intake amounts and "second influential factor" of post-meal walking steps. His low-carb meals occupy about 2/3 (66%) of the total meals and high-carb meals occupy about 1/3 (34%) of the total meals; however, his post-meal walking steps are comparable (4,323 for low-carbs vs. 4,490 steps for high-carbs). Therefore, he decided to utilize the first influential factor of carbs/sugar amount only for his perturbation analysis.

Next, he applied the first-order perturbation theory of quantum mechanics to continue and extend his glucose prediction research work.
The mathematical perturbation equation is expressed again in the following with a similar format:

A = ~ (A0 + ε * A1)

Where A0 would be the known solution to a simpler but solvable initial problem and A1 represents the first-order term which may be found interactively by some systematic procedure. For a small *ε (epsilon)*, this higher-order term in the series becomes successively smaller and derives to an approximate solution.

Therefore, for this particular perturbation analysis, he uses 7.2 grams as his lower-bound carbs and 27.7 grams as his high-bound carbs.

The author conducted the two following two perturbation cases:

1. Using the Slope A equation of (low carbs of 7.2 divided by high carbs of 27.7) as the slope for perturbed PPG of both low-carbs PPG and high-carbs PPG.
2. Using a selected mean value of 7.2 and 27.7, i.e. 17.5 grams, as his selected carbs amount and the chosen Slope B equation: *((selected carbs 17.5 - low carbs 7.2) / (high carbs 27.7 - low carbs 7.2))* as the slope for perturbed PPG of both low-carbs PPG and high-carbs PPG.

He will then be able to construct two new perturbed and approximate PPG waveforms (or curves) between 0-minute and 180-minutes by applying the perturbation theory as described above.

Results

Figures 1 display both the data table of low-carb pattern PPG vs. high-carb PPG pattern. Although their opening glucoses at 0-minute (125 mg/dL vs. 129 mg/dL) and both PPG curve shapes with quite similar "mountain" shapes to each other, but both of their peak glucoses (134 mg/dL vs. 147 mg/dL) and closing glucoses at 180-minutes (123 mg/dL vs. 132 mg/dL) have quite different results. These differences have resulted from varying glucose decaying speeds after 60-minutes. The significance of these differences from a segmentation analysis has already been discussed in his previous publications.

Low-Carbs PPG (Slope A)	Low Real (2128)	Low Perturbed	High-Carbs PPG (Slope A)	High Real (1090)	High Perturbed
0 min	124	125	0 min	129	131
15 min	127	129	15 min	133	136
30 min	131	132	30 min	140	143
45 min	134	134	45 min	146	147
60 min	133	131	60 min	147	146
75 min	130	128	75 min	145	144
90 min	126	125	90 min	142	141
105 min	123	122	105 min	140	139
120 min	121	121	120 min	137	136
135 min	121	121	135 min	135	135
150 min	121	122	150 min	134	134
165 min	122	122	165 min	134	133
180 min	123	123	180 min	132	132
Average PPG	126	126	Average PPG	138	138
	Low bound Carbs	Selected Carbs		High bound Carbs	
Carbs grams	7.2	17.5	Carbs grams	27.7	

Low-Carbs PPG (Slope A)	Low Real (2128)	Low Perturbed	High-Carbs PPG (Slope A)	High Real (1090)	High Perturbed
0 min	124	125	0 min	129	131
15 min	127	129	15 min	133	136
30 min	131	132	30 min	140	143
45 min	134	134	45 min	146	147
60 min	133	131	60 min	147	146
75 min	130	128	75 min	145	144
90 min	126	125	90 min	142	141
105 min	123	122	105 min	140	139
120 min	121	121	120 min	137	136
135 min	121	121	135 min	135	135
150 min	121	122	150 min	134	134
165 min	122	122	165 min	134	133
180 min	123	123	180 min	132	132
Average PPG	126	126	Average PPG	138	138
	Low bound Carbs	Selected Carbs		High bound Carbs	
Carbs grams	7.2	17.5	Carbs grams	27.7	

Pertubation Equation Slope A = Glucose at T1 + ((Selected Carbs - Low bound carbs) / (High bound Carbs - Low bound Carbs)) * (Glucose at T2 - Glucose at T1)
Pertubation Equation Slope B = Glucose at T1 + (Low carbs / High Carbs) * (Glucose at T2 - Glucose at T1)
Make sue that the High-Carbs is at > 4 times level higher than the Low-Carbs value

Figure 1: Data table of low-carbs and high-carbs PPG values (both real and perturbed) with two perturbation slope equations

These higher glucose values for high-carbs case have deeper biomedical meanings, and are extremely critical to a patient's risk probabilities of having diabetes complications, particularly problems with heart, brain and kidney.

The bottom of this table describes his two different defined slope equations for A and B which cause the actual perturbation of this PPG waveform from the original collected PPG waveforms.

Figures 2 illustrates the graphical difference between low-carbs PPG and high-carbs PPG waveforms. The rather noticeable gap between these two waveforms further demonstrates the above-described sentences for Figure 1. The top diagram shows the measured two PPG waveforms while the bottom diagram depicts four waveforms, including both of two measured PPG and two extra "perturbed" PPG waveforms. It is obvious that the perturbed curve is remarkably close to the measured curve which means this perturbation method has resulted into an extremely high accuracy on its glucose predictability.

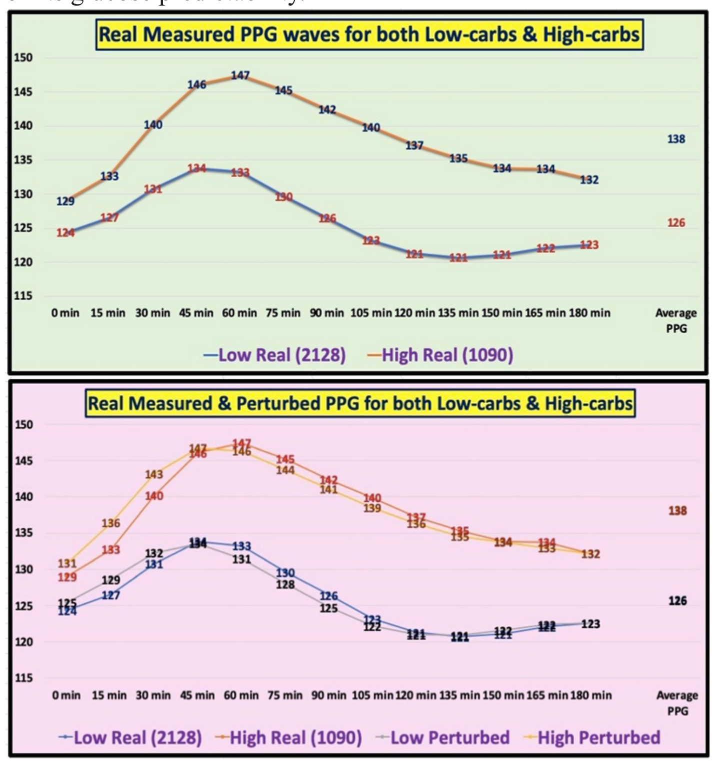

Figure 2: Top is two measured PPG waves, and bottom is measured PPG vs. perturbed PPG for both low-carbs PPG and high-carbs PPG waveforms

Figure 3 reflects the 2,128 low-carbs PPG comparison between measured and perturbed PPG curves from using Slopes A and B equations.

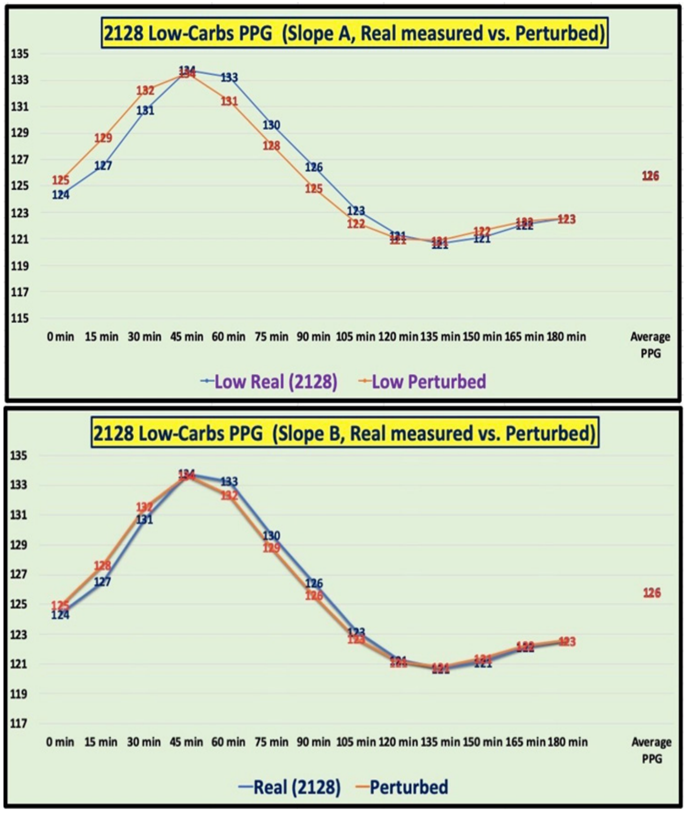

Figure 3: 2,128 low-carbs PPG waveforms between measured PPG vs. perturbed PPG using both slope A and slope B equations

Figure 4 reflects the 1,09 high-carbs PPG comparison between measured and perturbed PPG curves from using Slopes A and B equations.

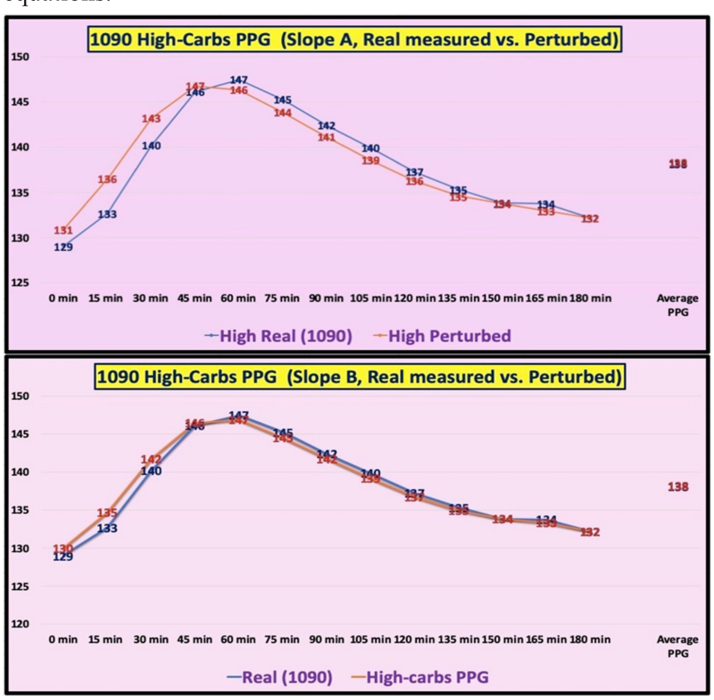

Figure 4: 1,090 high-carbs PPG waveforms between measured PPG vs. perturbed PPG using both slope A and slope B equations

By visually examining Figures 2, 3 and 4, they have demonstrated that the ***high correlations (greater than 95%) between measured PPG and perturbed PPG and extremely high accuracy on the predicted PPG values (greater than 99%).***

Conclusion

Glucose variance is an extremely sophisticated biochemical process with outcomes and is also a complex biophysical phenomenon. It takes various applications mathematical tools to analyze them. After a diabetes patient measures and establishes two separate initial waveforms with one low-carb meals group and another high-carb meals group, we can then develop a perturbed (i.e. predicted) PPG waveform accordingly.

In other words, we can predict the glucose behavior resulting from functions of the brain, liver, and pancreas by using the perturbation theory of quantum mechanics to obtain an approximated PPG waveform according to the selected carbs/sugar intake amount. Of course, the same method can also be applied using the secondary influential factor, such as by different post-meal waking steps or by different eating places (combination of both carbs and exercise). In this way, diabetes patients will have the ability to predict their own PPG behavior prior to consuming a meal or initiate certain level of post-meal exercise [1-8].

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