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Estimated Relative Energy Level of Four Different Finger PPG Ranges Using Wave Theory and Frequency Domain Analysis Using GH-Method: Math-physical Medicine

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Introduction

In this paper, the author describes his research results on the relative energy level of four different finger PPG ranges using wave theory and frequency domain analysis.

Methods

Database

Since 6/1/2015, the author collected all of his meal-related data, including carbs/sugar amount, post-meal waking steps, finger PPG at two-hours after the first bite of food, and key contents of each meal. In addition, from 5/5/2018 until 6/6/2020, he has collected 58,370 glucoses via a continuous glucose monitor (CGM) sensor device at ~76.5 data per day.

In this particular analysis, he utilized the data from 2,351 meals including 62 snacks/fruits within 763 days from 5/5/2018 through 6/6/2020. Since he collected 13 glucose data for each meal (every 15-minute time interval), these 13 data points build up a "waveform" which contain sufficient characteristics of a wave such as frequency, amplitude, and period (wavelength). He can then apply the wave theory techniques to decompose, analyze, or convert each PPG waveform for further investigation or discovery of many hidden information regarding diabetes disease and overall health conditions.

For this particular research project, he selected four glucose ranges from the database of his Finger PPG: below 120 mg/dL (no diabetes conditions), between 120 and 140 mg/dL (prediabetes range), between 140 and 180 mg/dL (typical range of type 2 diabetes), and above 180 mg/dL (extremely dangerous state).

He has already published a few medical papers regarding this subject, from different perspectives [1,2].

His customized software program can extract the needed data for a specific research purpose by searching for certain keywords. The presentation of analysis results can be displayed in the form of time-series, spatial, frequency domain, or author-defined specific empirical formula or academic equation.

Wave Theory & Frequency Domain

The following descriptions are directly quoted from what the author has learned from physics and mathematics in his college days.

This "time-domain" analysis results are represented by the horizontal x-axis as time (in day) and the vertical y-axis as glucose (in mg/dL), similar to an EKG chart for the heart. Next, he utilized a mathematical algorithm using "Fourier Transform" operation to convert these time-domain data into frequency-domain data. In the frequency domain chart, the x-axis becomes frequency, instead of time, and the y-axis becomes an amplitude scale associated with distinctive frequency, instead of the glucose itself. In one of his published paper, he has proved that this frequency domain's y-axis amplitude value actually indicates the "relative" energy associated with that particular glucose frequency on x-axis [3]. How many data points on x-axis of frequency curve depends on how many data points on x-axis of time-domain wave. These two waveforms from time-domain and frequency-domain look very different.

Based on this frequency-domain data chart, he can then segregate the total span of frequency-domain data into either three frequency sub-ranges of low, medium, and high, or two frequency sub-ranges of low and high. The boundary number of frequency sub-ranges, two or three, is based on a deeper understanding of biomedical waveforms of glucose, and specific objectives of the research project. For this particular project, since his synthesized PPG waveform for each range has a three-hour time span which is covered by a smaller amount of data, 13 glucoses at 15-minute time intervals; therefore, he chose two frequency ranges, i.e. low (0 - 2) and high (3 to 6).

It should be pointed out that he chose Finger PPG data (discrete values) in determining these four PPG ranges; however, he needed to use the Sensor PPG data (waveform shape) for his wave and frequency domain analysis.

In the glucose related frequency domain diagram, we can see that its waveform (or curve) pattern is usually a symmetric salad bowl shape with the high edge on each rim. Let us focus on the left half portion of the chart. The far-left side indicates the lower-frequency range. There is a much higher glucose energy associated with lower frequencies of glucose components (less of glucose happening times), but the near-center portion indicates the higher-frequency range. There is a much lower glucose energy associated with higher frequencies of glucose components (more of glucose happening times).

Energy Theory

After converting the time-series glucose curve into the frequency-domain energy curve, it will be easier to distinguish the difference between primary glucoses (i.e. elevated glucose values associated with higher energy and provide the organs a higher degree of impact or damage) versus secondary glucoses (i.e. moderate glucose values associated with lower energy and provide the organs a lesser degree of impact or damage). In other words, the degree of impact or damage on the human internal organs are actually due to the energy associated with different glucose values, not the glucose directly. This situation is similar to a tsunami wave or earthquake wave hitting a building. It is the energy associated with the wave which damages the building.

Therefore, we must integrate the energy theory from mechanical and structural engineering with the wave theory from geophysics and radio wave communication engineering together. Through this effort, we can then identify and calculate the level of relative energy resulting from glucose components within a certain frequency sub-range. Finally, we can utilize the level of relative energy from glucoses to provide a proper and reasonable biomedical interpretation of the degree of impact or damage on the human organs. The author will conduct more research work and then write more papers regarding how to interpret high energy's impact on his major organs, specifically cardiovascular diseases (CVD and Stroke) and chronic kidney diseases (CKD).

In order to accomplish his research objectives, he had to modify and enhance his software programs in order to be able to calculate the relative energy level of any user-defined frequency range. This research project has been on-going for more than two years since early 2018.

Results

Figure 1 through Figure 4 display four distinctive Finger PPG ranges. They include many key data such as number of meals, carbs/sugar amount, post-meal walking steps, average finger PPG, five prominent values of sensor PPG waveform (opening, closing, maximum, minimum, and average), time-series waveform, and frequency-domain waveform with both low-frequency range and high-frequency range. Readers can delve deeper into each of these four figures to find out more detailed information regarding each PPG range.

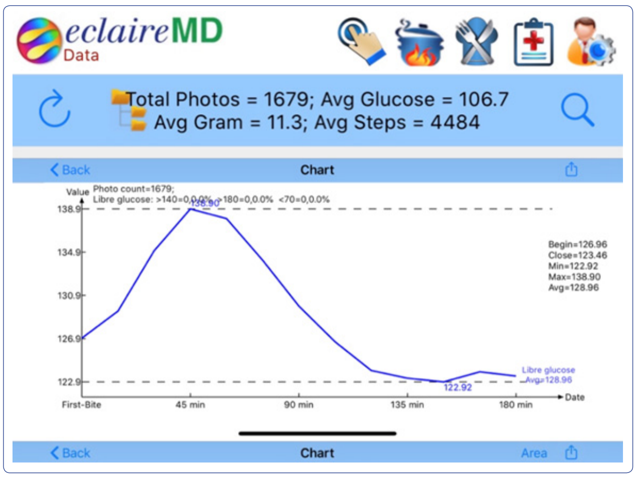


Figure 1: Case of PPG < 120

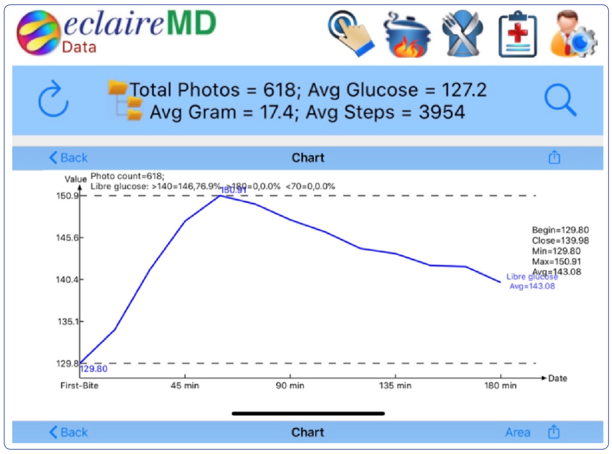


Figure 2: Case of PPG (120 - 140)

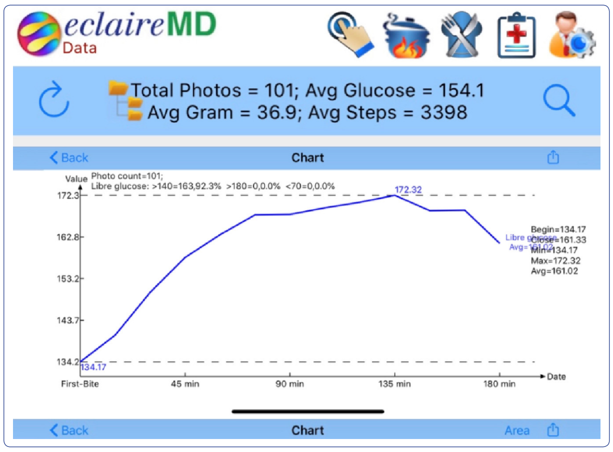


Figure 3: Case of PPG (140 - 180)

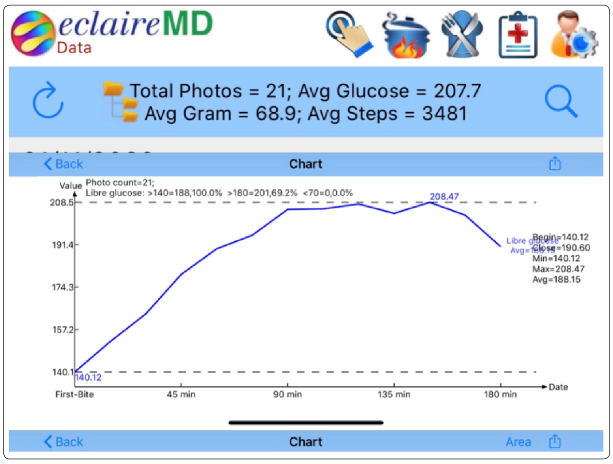


Figure 4: Case of PPG > 180

Figure 5 is a diagram which includes these four frequency-domain analysis results together for a better visual comparison of both frequency curve shapes and relative energy values. Although his objectives are to discover relative energy level from PPG related to these four glucose ranges, he must start with a better understanding of the behaviors of sensor PPG continuous waveform and Finger PPG discrete values. Figure 6 shows a line chart with four sets of glucose range data, including energy, finger PPG, sensor PPG, and carbs/sugar intake amount in grams. The correlation among these four lines are very obvious because all data are moving together. It means that when he eats meals with higher carbs/sugar content, both of his finger PPG and sensor PPG are rising, although sensor PPG is about 17% higher than finger PPG. His relative energies are also proportional to his average sensor PPG values; however, the width of the energy band is much wider than the widths of two glucose bands due to the fact that energy is proportional to the square of glucose. On the other hand, the width of the carbs/sugar intake amount band is remarkably close to the widths of both sensor PPG and Finger PPG bands due to the linear relationship between the glucose and carbs/sugar intake.

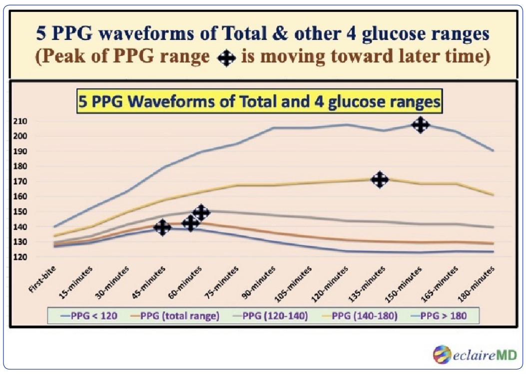
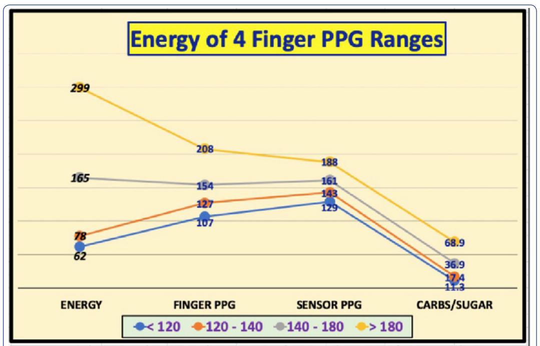


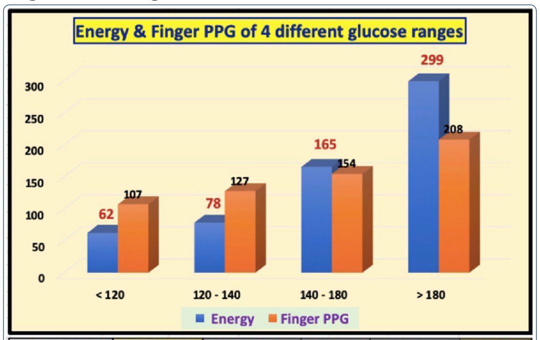
Figure 5: Summary of time- domain waveforms of PPG and other 4 glucose ranges



Finger PPG Range	# of meals	% of meals	Finger PPG Range	Energy	Finger PPG	Sensor PPG	Carbs/Sugar
< 120	1,679	69%	< 120	62	107	129	11.3
120 - 140	618	26%	120 - 140	78	127	143	17.4
140 - 180	101	4%	140 - 180	165	154	161	36.9
> 180	21	1%	> 180	299	208	188	68.9

Figure 6: Data table and Line chart of Energy, Finger PPG, Sensor PPG, carbs/sugar grams

Figure 7 is the most important conclusive diagram of this paper. It depicts his energy level with his average finger PPG for each different glucose range.



Finger PPG Range	Energy Ratio	Finger PPG Ratio	PPG square	Multiplier	Calculation
< 120	1.00	1.0	1.0	1.00	1.00
120 - 140	1.26	1.2	1.4	0.89	1.26
140 - 180	2.66	1.4	2.1	1.28	2.66
> 180	4.82	1.9	3.8	1.27	4.82

Figure 7: Relative Energy of 4 different glucose ranges & the author's "Energy Equation" calculation results

In order to search for a simpler formula or equation which can describe these complex process of finding energy, the author has tried to develop an "Energy Equation".

When he applied the physics concept of wave energy is proportional to the square of wave's amplitude, he immediately thought about Albert Eisenstein's famous equation of theory of relativity.

$E = mc^2$

Where E is energy, m is mass, c is speed of light, and 2 is square.

This relativity theory equation gives him an idea to imitate into his "glucose energy equation" as follows:

e = m * g2

Where e is the associated energy ratio using the lowest energy level as its base, g is finger glucose ratio using the lowest glucose as its base, 2 is square. The dilemma in the equation is the variable "m" which is a varying multiplier factor:

m = 1.00 for PPG < 120
m = 0.89 for PPG is 120 - 140
m = 1.28 for PPG is 140 - 180
m = 1.27 for PPG > 180

The author admits that he has no justifications for these four different "m" values. There are just four constants to back fit into the equation in order to make the results right. Nevertheless, if he applied these four "m" values, he could use the simple formula mentioned above to obtain an identical set of four energy values. Obviously, he needs more research work on finding what "m" really means from a physics standpoint and how to get them mathematically correct.

Several prominent findings are described as follows:

1. Average sensor PPG of 134 md/dL is 17% higher than average finger PPG of 115 mg/dL.
2. In the energy analysis, the higher glucose range (both finger and sensor) would produce higher energy, vice versa.
3. The energy values are indeed directly proportional to the square of glucoses which they associated. In this observation, it matches with principles of wave theory in Physics.

It is worthwhile to list below the key information of relative energy levels from both Figure 6 and Figure 7.

Each Finger PPG range contains seven separate data: total energy level, energy ratio, Finger PPG value, Finger PPG ratio, Finger PPG square value, value of "m", and calculated energy ratio which matches with the energy ratio.

PPG < 120
*62, **1.00**, 107, 1.0, 1.0, 1.00, **1.00***
PPG in 120 - 140
*78, **1.26**, 127, 1.2, 1.4, 0.89, **1.26***
PPG in 140 - 180
*165, **2.66**, 154, 1.4, 2.1, 1.28, **2.66***
PPG >180
*299, **4.82**, 208, 1.9, 3.8, 1.27, **4.82***

Lessons the author has learned from the observations of this PPG energy study based on four different glucose ranges are:

1. *Avoiding too much carbs/sugar which would push the maximum glucose value too high.* ***Remember that the relative energy created by glucose is proportional to the square of glucose****.*
2. *Walking more steps after meal, particularly after eating a higher amount of carbs/sugar food. This exercise would bring down high glucose values quickly and reducing their relative energies.*
3. *Watching out for the entire PPG waveform's shape and size (i.e. area underneath the PPG wave) instead of looking at a few glucose points at certain discrete time instants. Again, watching out for total energy level instead of discrete glucose values.*

Conclusions

This study of relative energy resulting from PPG waveforms of four different frequency ranges offers a deeper understanding and a better view on the impact and damage on human organs due to elevated glucoses. This article is only a part of his series of research projects. Through the application of wave theory and frequency domain analysis from his developed GH-Method: math-physical medicine, he could better understand certain key behaviors and characteristic performance of "glucose" which are able to provide a more in-depth knowledge of diabetic complications prevention.

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