The GH-Method

A Study on the Glucose Waves and Fluctuations During Pre-Virus and COVID-19 Periods Using Time and Frequency Domains Along with Wave and Energy Theories of GH-Method: Math-Physical Medicine (No. 407)

Gerald C. Hsu*

eclaireMD Foundation, USA

Abstract

This particular study includes two parts covering data from the long period from 5/5/2018 to 2/28/2021. The first part investigates the sensor-collected daily average glucose and their associated relative energies. The second part examines the postprandial plasma glucose (PPG) wave fluctuations or glycemic variability (GV), where the maximum PPG value minus minimum PPG value for breakfast, lunch, and dinner. At first, the author utilizes wave theory to study the mean values of PPG waves in the time domain (TD). He then applies signal processing techniques and the Fast Fourier Transform (FFT) program to convert these PPG waves into a frequency domain (FD). He can then estimate the relative energy levels associated with different glucose, i.e., the Y-amplitudes of waveforms in the FD to understand the different degrees of organ impact via the relatively low-frequency energy segment vs. the relatively high-frequency energy segment. The relative energy is generated by glucose and carried by the red blood cells circulating in the blood system. In summary, his pre-virus lifestyle involved stressful traveling, a hectic schedule, disruption of his eating and exercise patterns which have caused both higher PPG in TD and higher relative energy levels in FD. On the contrary, his COVID-19 quarantine lifestyle contains no travel, no social contacts, no stress other than fear of the pandemic, routine lifestyle habits, regular mealtime, and exercise; therefore, not only did his glucose level significantly reduced in the TD but also resulted in lower relative energy level in FD. In a more detailed manner, there are two key observations from the daily glucose analyses for the pre-virus period and the COVID-19 period. First, the average daily glucose value during the pre-virus period is 13% higher than the average PPG in the COVID-19 period; and the Y-amplitude in FD during the pre-virus period is 29% higher than the COVID-19 period. This means that the healthier lifestyle during the COVID-19 period not only produced lower daily glucose but also resulted in a lower energy impact on his internal organs. Second, in the FD diagram, the selected 20% of the lower frequency segment with the higher FD's Y-amplitude components resulted in ~40% of the total energy level associated with the daily glucose (less components with higher level), while the 80% of the higher frequency segment with the lower FD's Y-amplitude components resulted into ~60% of total energy associated with daily glucose (more components with lower level). In other words, the daily glucose distribution pattern of 20% vs. 80% in the frequency segment would result in an amplified split pattern of 40% vs. 60% in energy associated with daily glucose. From the PPG fluctuations or GV (max minus min) analysis findings, there are two key conclusions described below. First, the lunch PPG has shown the following five highest amounts: (1) Y-amplitude in the TD (glucose fluctuation or GV), (2) Y-amplitude in FD (energy associated with GV), (3) Total frequency area, (4) Low-frequency segment of GV, (5) High-frequency segment of GV. The strength of the dinner PPG is in the middle in terms of the magnitude of Y-amplitude in both the TD and FD. The breakfast PPG has shown the lowest strengths or Y-amplitudes in all fronts of the five variables. The above explanations in regard to meals match his eating pattern of "heavy lunch, medium dinner, and light breakfast" which also means food quantity and quality results in glucose and then leads to the energy that impacts our organs. Second, in the FD diagram, the 20% of the lower frequency with higher amplitude components results in 22%-28% of total energy associated with PPG fluctuations, while the 80% of the higher frequency with lower amplitude components results in 72%-78% of total energy associated with PPG fluctuations. In other words, the PPG fluctuations (max minus min or GV) distribution pattern of 20% vs. 80% in the frequency segment would result in a similar split pattern of 25% vs. 75% in energy associated with fluctuation. Overall, the observations for the TD and FD analyses of the two time periods have revealed similar patterns, except for the distribution pattern or the split of PPG fluctuations of 25% vs. 75%. These phenomena make perfect biomedical sense to the author. The lower PPG values carry less energy which occupies the most volume of the total frequency quantity (i.e., the higher-frequency with lower-amplitude of glucose occurs most frequently in a day). On the other hand, the higher PPG values carry more energy occupying the least volume of the total frequency quantity (i.e., the lower-frequency with high-amplitude glucose occurs less frequently in a day).

Keywords: Glucose; Time domain; Frequency domain; Wave; Energy

Abbreviations: PPG: postprandial plasma glucose; GV: glycemic variability; TD: time domain; FFT: Fast Fourier Transform; FD: frequency domain; MPM: math-physical medicine; HbA1C: hemoglobin A1C

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*Corresponding author: Gerald C. Hsu, eclaireMD Foundation, USA

1. INTRODUCTION

This particular study includes two parts covering data from the long period from 5/5/2018 to 2/28/2021. The first part investigates the sensor-collected daily average glucose and their associated relative energies. The second part examines the postprandial plasma glucose (PPG) wave fluctuations or glycemic variability (GV), where the maximum PPG value minus minimum PPG value for breakfast, lunch, and dinner.

At first, the author utilizes wave theory to study the mean values of PPG waves in the time domain (TD). He then applies signal processing techniques and the Fast Fourier Transform (FFT) program to convert these PPG waves into a frequency domain (FD). He can then estimate the relative energy levels associated with different glucose, i.e., the Y-amplitudes of waveforms in the FD to understand the different degrees of organ impact via the relatively low-frequency energy segment vs. the relatively high-frequency energy segment. The relative energy is generated by glucose and carried by the red blood cells circulating in the blood system.

2. METHODS and RESULTS

2.1 MPM background

To learn more about his developed GH-method: math-physical medicine (MPM) methodology, readers can read the following three papers selected from the published 400+ medical papers.

The first paper, No. 386 describes his MPM methodology in a general conceptual format[1]. The second paper, No. 387 outlines the history of his personalized diabetes research, various application tools, and the differences between the biochemical medicine (BCM) approach vs. the MPM approach[2]. The third paper, No. 397 depicts a general flow diagram containing ~10 key MPM research methods and different tools[3].

2.2 The author's case of diabetes

The author was a severe type 2 diabetes patient since 1996. He weighed 220 lb. (100 kg) at that time. By 2010, he still weighed 198 lb. with average daily glucose of 250 mg/dL (HbA1C of 10%). During that year, his triglycerides reached 1161 and the albumin-creatinine ratio (ACR) at 116. He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him regarding his need for kidney dialysis treatment and his future high risk of dying from his severe diabetic complications.

In 2010, he decided to self-study endocrinology, diabetes, and food nutrition. During 2015 and 2016, he developed four prediction models related to diabetes conditions, i.e., weight, PPG, fasting plasma glucose (FPG), and HbA1C (A1C). As a result, from using his developed mathematical metabolism index (MI) model and those four prediction tools, by end of 2016, his weight was reduced from 220 lbs. (100 kg) to 176 lbs. (89 kg), waistline from 44 inches (112 cm) to 33 inches (84 cm), averaged finger glucose from 250 mg/dL to 120 mg/dL, and HbA1C from 10% to ~6.5%. One of his major accomplishments is that he no longer takes any diabetes medication since 12/8/2015[4,5].

In 2017, he had achieved excellent results on all fronts, especially glucose control. However, during the pre-COVID period of 2018 and 2019, he traveled to approximately 50+ international cities to attend 65+ medical conferences and made ~120 oral presentations. This hectic schedule inflicted damage to his diabetes control, through dining out frequently, post-meal exercise disruption, jet lag, and the overall metabolism impact due to his irregular life patterns through a busy travel schedule; therefore, his glucose control was affected during this two-year period.

By 2020, his weight was further reduced to 165 lbs. (BMI 24.4) and his HbA1C was at 6.2% without any medication intervention or insulin injection. Actually, during 2020 with the special COVID-19 quarantined lifestyle, not only has he published approximately 400 medical papers in journals, but he has also achieved his best health conditions for the past 26 years. These good results are due to his non-traveling, low-stress, and regular daily life routines. Of course, his strong knowledge of chronic diseases, practical lifestyle management experiences, and his developed various high-tech tools contribute to his excellent health status since 1/19/2020[6-8].

On 5/5/2018, he applied a continuous glucose monitoring (CGM) sensor device on his upper arm and checks his glucose measurements every 15 minutes for a total of ~96 times each day. He has maintained the same measurement pattern to the present day.

Therefore, during the past 11 years, he could study and analyze his collected ~2 million data regarding his health status, medical conditions, and lifestyle details. He applies his knowledge, models, and tools from mathematics, physics, engineering, and computer science to conduct his medical research work. His medical research work is based on the aim of achieving high precision with quantitative proof in his medical findings[9,10].

2.3 Input data for time domain

During the time frame from 5/5/2018 to 2/26/2021, he defined two periods as follows:

Pre-virus period: 5/5/18-1/18/20 (624 days)
COVID-19 period: 1/19/2020-2/28/21 (407 days)

2.4 Frequency domain of PPG wave

After conducting the TD analysis, he then utilizes the FFT algorithm-based software program to convert his PPG waves from the TD into a FD to conduct his FD analysis.

2.5 PPG fluctuation in TD and FD

He utilizes the maximum PPG minus the minimum PPG as the GV value of breakfast, lunch, and dinner to conduct both TD analysis and FD analysis of PPG fluctuation (GV).

2.6 Graphic results

Figure 1 shows the TD results comparison between these two periods. The average daily glucose (Y-amplitudes of TD) is 131 mg/dL for the pre-virus period and 116 mg/dL for the COVID-19 period. The difference is 13%.

Figure 2 depicts the FD results comparison between these two periods which are displayed in the format of Y-amplitude in the FD, total frequency area, low-frequency area, high-frequency area, and low vs. high ratio:

Pre-virus period: (259, 161392, 29894, 50677, 37% vs. 63%)
COVID-19 period: (201, 80960, 16616, 23965, 41% vs. 59%)

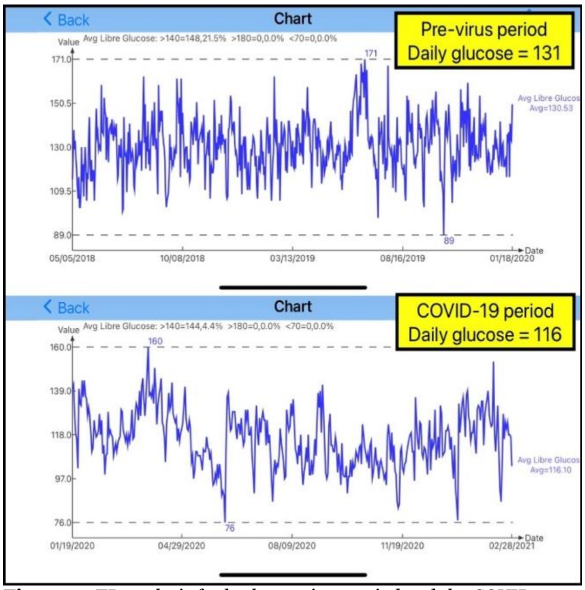


Figure 1: TD analysis for both pre-virus period and the COVID-19 period.

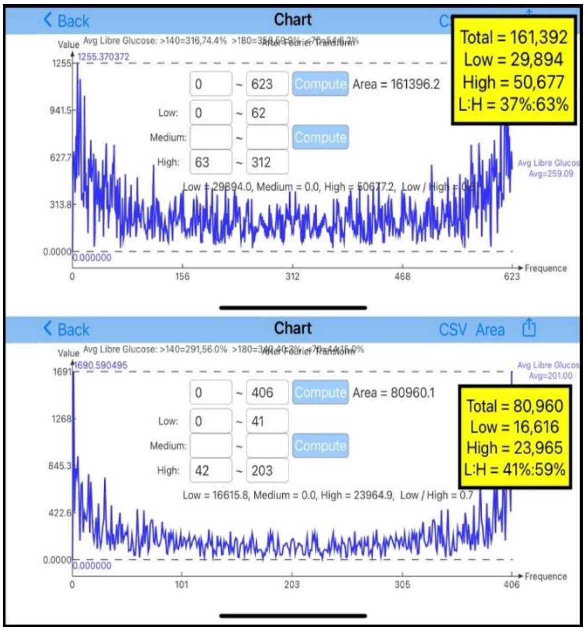


Figure 2: FD analysis for both pre-virus period and the COVID-19 period.

It is evident that all the numbers during the COVID-19 period are lower than the corresponding numbers of the pre-virus period. This means that his health state during the virus period is better than the pre-virus period.

Figure 3 illustrates his PPG fluctuations (i.e., max-min Y-amplitudes of PPG in the TD) during the pre-virus period: 46 mg/dL for breakfast (smallest), 52 mg/dL for lunch (biggest), and 47 mg/dL for dinner (medium). This means that the PPG fluctuations for the three meals are in the order of lunch (violent), dinner (middle), and breakfast (calmer).

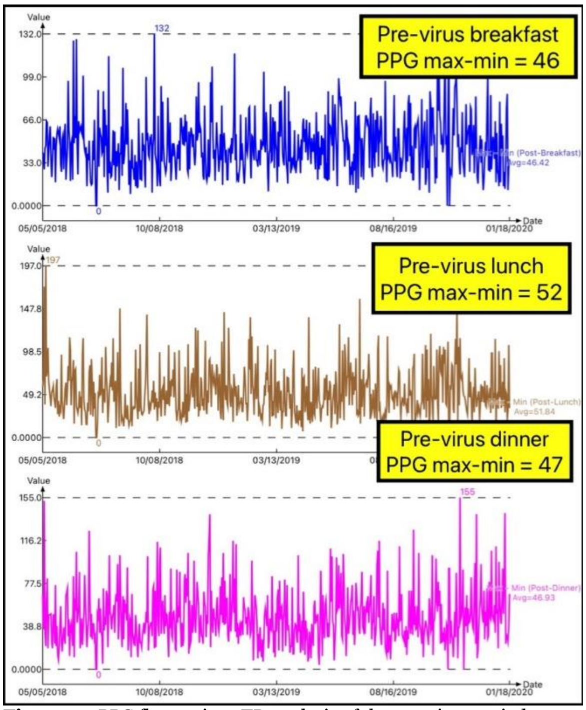


Figure 3: PPG fluctuations TD analysis of the pre-virus period.

Figure 4 reveals the energy associated with his PPG fluctuations (i.e., max-min Y-amplitudes of the FD) in the FD during the pre-virus period: 487 for breakfast (smallest), 646 for lunch (biggest), and 565 for dinner (medium). Other energy related data can also be seen in both Figures 4 and 7.

Figure 5 reflects his PPG fluctuations (i.e., max-min Y-amplitudes of the TD) during the COVID-19 period: 31 mg/dL for breakfast (smallest), 43 mg/dL for lunch (biggest), and 40 mg/dL for dinner (middle).

Figure 6 demonstrates the energy associated with his PPG fluctuations (i.e., max-min Y-amplitudes of the FD) during the COVID-19 period: 321 for breakfast (smallest), 389.1 for lunch (biggest), and 389.02 for dinner (middle). Other energy related data can be found in both Figures 6 and 7.

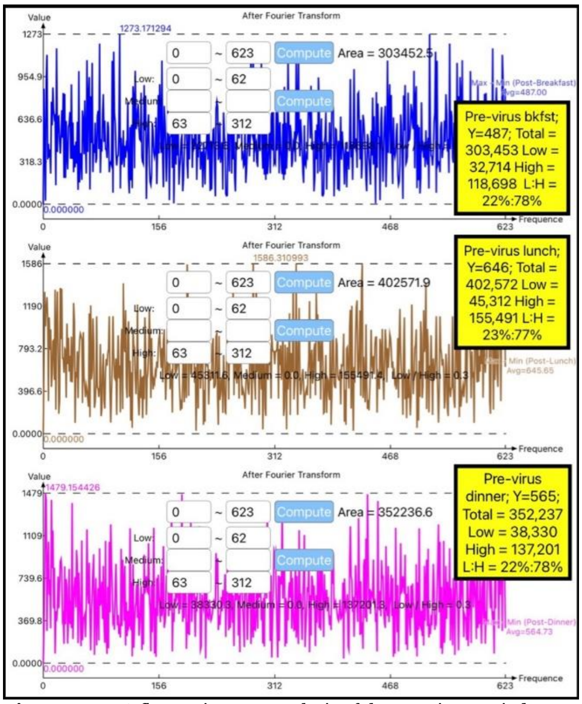


Figure 4: PPG fluctuations FD analysis of the pre-virus period.

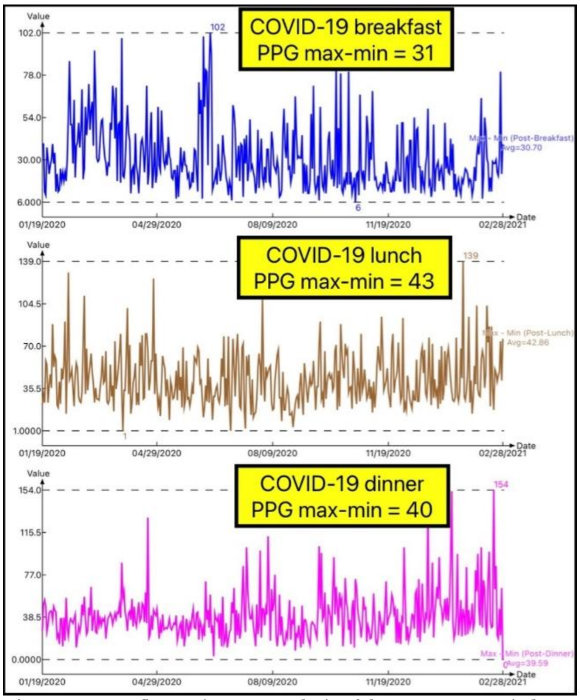


Figure 5: PPG fluctuations TD analysis of the COVID-19 period.

It should be reemphasized that all the numbers during the COVID-19 periods are smaller than the pre-virus period. Even when using the PPG fluctuation (GV), the data patterns are still similar to the daily glucose data patterns. Again, this means that his health state during the virus period is better than the pre-virus period.

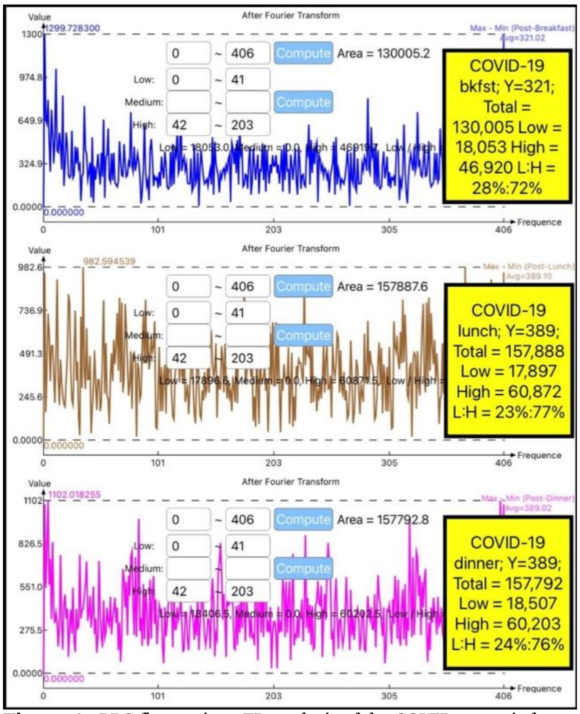


Figure 6: PPG fluctuations FD analysis of the COVID-19 period.

Figure 7 indicates the combined data table for the daily glucose analysis and PPG fluctuation (GV) analysis using both the TD and FD. These are the outcome of using the signal processing technique for glucose wave analysis, including both daily glucose and glucose fluctuation.

	5/5/2018-1/18/2020	1/19/2020-2/28/2021
2/28/21	Pre-virus	COVID-19
Y-amp in TD: Daily glucose	131	116
Y-amp in FD: Energy	259	201
Frequecy Area	161392	80960
Low Freq Area	29894	16616
High Freq Area	50677	23964
Low Frequency Ratio	20%	20%
High Frequency Ratio	80%	80%
Low/(Low+High) Energy Ratio	37%	41%
High/(Low+High) Energy Ratio	63%	59%

2/28/21	Pre-virus	COVID-19
Breakfast max-min TD-Y	46	31
Lunch max-min TD-Y	52	43
Dinner max-min TD-Y	47	40
Breakfast max-min FD-Y	487	321
Lunch max-min FD-Y	646	389
Dinner max-min FD-Y	565	389
Breakfast max-min Total	303485	130005
Lunch max-min Total	402572	157888
Dinner max-min Total	352237	157792
Breakfast max-min Low	32714	18053
Lunch max-min Low	45312	17897
Dinner max-min Low	38330	18507
Breakfast max-min High	118698	46920
Lunch max-min High	155491	60872
Dinner max-min High	137201	60203
Breakfast max-min Low %	22%	28%
Lunch max-min Low %	23%	23%
Dinner max-min Low %	22%	24%
Breakfast max-min High %	78%	72%
Lunch max-min High %	77%	77%
Dinner max-min High %	78%	76%

Figure 7: Data table of both daily glucose and PPG fluctuations.

Figure 8 exemplifies 2 bar diagrams of the TD and FD analyses for daily glucose.

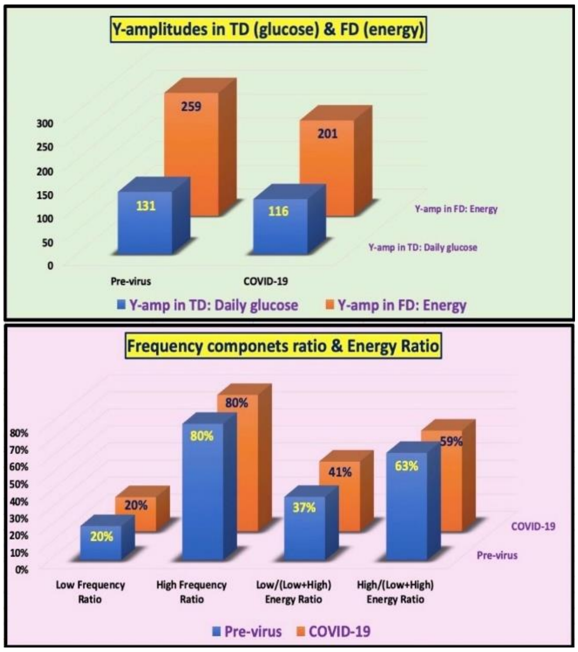
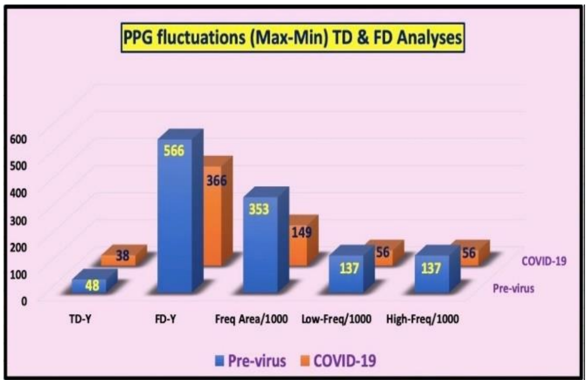


Figure 8: Two bar diagrams of Y-amplitudes of TD and FD and relative % of frequency areas.

Figure 9 shows 1 bar diagram and 1 data table of the TD and FD analyses for the PPG fluctuations. The data are the summary and the average daily meal values for breakfast, lunch, and dinner.



2/28/2021 (PPG Max-Min)	Pre-virus	COVID-19
TD-Y	48	38
FD-Y	566	366
Freq Area/1000	353	149
Low-Freq/1000	137	56
High-Freq/1000	137	56

Figure 9: PPG fluctuations TD and FD analysis results for daily combined three meals.

3. CONCLUSION

In summary, his pre-virus lifestyle involved stressful traveling, a hectic schedule, disruption in his eating and exercise patterns which have caused both higher PPG in the TD and higher relative energy levels in the FD. On the contrary, his COVID-19 quarantine lifestyle contains no travel, no social contacts, no stress other than fear of the pandemic, routine lifestyle habits, regular mealtime, and exercise; therefore, not only did his glucose level significantly reduced in the TD but also resulted in lower relative energy level in the FD(11,12).

In a more detailed manner, there are two key observations from the daily glucose analyses for the pre-virus period and the COVID-19 period. First, the average daily glucose value during the pre-virus period is 13% higher than the average PPG in the COVID-19 period; and the Y-amplitude in the FD during the pre-virus period is 29% higher than the COVID-19 period. This means that the healthier lifestyle during the COVID-19 period not only produced lower daily glucose but also resulted in a lower energy impact on his internal organs.

Second, in the FD diagram, the selected 20% of the lower frequency segment with the higher FD's Y-amplitude components resulted in ~40% of the total energy level associated with the daily glucose (less components with higher level), while the 80% of the higher frequency segment with the lower FD's Y-amplitude components resulted in ~60% of the total energy associated with daily glucose (more components with lower level). In other words, the daily glucose distribution pattern of 20% vs. 80% in the frequency segment would result in an amplified split pattern of 40% vs. 60% in energy associated with daily glucose(13-15).

From the PPG fluctuations or GV (max minus min) analysis findings, there are two key conclusions described below. First, the lunch PPG has shown the following five highest amounts:

(1) Y-amplitude in the TD (glucose fluctuation or GV),

(2) Y-amplitude in the FD (energy associated with GV),

(3) Total frequency area,

(4) Low frequency segment of GV,

(5) High frequency segment of GV.

The strength of the dinner PPG is in the middle in terms of the magnitude of Y-amplitude in both the TD and FD. The breakfast PPG has shown the lowest strengths or Y-amplitudes in all fronts of the five variables. The above explanations in regard to meals match his eating pattern of "heavy lunch, medium dinner, and light breakfast" which also means food quantity and quality results in glucose and then leads to the energy that impacts our organs.

Second, in the FD diagram, the 20% of the lower frequency with higher amplitude components result in 22%-28% of the total energy associated with PPG fluctuations, while the 80% of the higher frequency with lower amplitude components result in 72%-78% of the total energy associated with PPG fluctuations. In other words, the PPG fluctuations (max minus min or GV) distribution pattern of 20% vs. 80% in the frequency segment would result in a similar split pattern of 25% vs. 75% in energy associated with fluctuation.

Overall, the observations for the TD and FD analyses of the two time periods have revealed similar patterns, except for the distribution pattern or the split of PPG fluctuations of 25% vs. 75%. These phenomena make perfect biomedical sense to the author. The lower PPG values carry less energy which occupies the most volume of the total frequency quantity (i.e., the higher-frequency with lower-amplitude of glucose occurs most frequently in a day). On the other hand, the higher PPG values carry more energy occupying the least volume of the total frequency quantity (i.e., the lower-frequency with high-amplitude glucose occurs less frequently in a day)(16-18).

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Gerald C. Hsu

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