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A Study on Postprandial Plasma Glucose Waves for Three Time Periods Using Time and Frequency Domains Along with Wave and Energy Theories of GH-Method: Math-Physical Medicine (No. 406)

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Abstract

This particular study investigates postprandial plasma glucose (PPG) characteristics and their impact on internal organs from their associated relative energy for three time periods. At first, the author utilizes wave theory to study 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 frequency domain (FD). He can then estimate the relative energy levels associated with the amplitude of different glucose for each waveform in the TD. This provides a better understanding of the varying degree of organ impact via these relative energies generated from and carried by glucose circulating in the blood system. In summary, Periods A and B fall into the pre-virus timeframe where constant travel, hectic and stressful lifestyle, disruption on eating and exercise patterns caused higher PPG in TD. This converted into higher relative energy levels in FD as well. On the contrary, Period C occurs in the unique COVID-19 quarantine lifestyle which has brought down his PPG level in the TD and results in a lower relative energy level in FD. In a more detailed manner, there are three observations from the TD analysis of both synthesized waveform and the Candlestick K-line model. First, the average PPG values for Periods A and B are ~14% higher than Period C; and the PPG fluctuation (i.e., max-min) value for Periods A and B is 35% higher than the PPG fluctuation value of Period C. In other words, both the average PPG and PPG fluctuation for Periods A and B are higher or more aggressive than the Period C. Second, it should be pointed out that the Candlestick K-line model can capture more realistic maximum and minimum PPG values better than the synthesized PPG waveform model. Third, the top two influential factors which are carbs/sugar intake in grams and the post-meal walking steps are remarkably similar to each other in these three time periods. This means that the author has kept a very stringent lifestyle management program with an intake of less than 15 grams of carbs/sugar and walking more than 4,200 steps after each meal. The FD analysis provides two observations. First, the relative energy associated with the PPG wave reveals that the FD Y-amplitudes for Periods A and B are ~15% higher than Period C. The total frequency areas for Periods A and B are ~42% higher than the total frequency area of Period C. Second, the three time periods with the corresponding three relative energies associated with PPG within three equal-component segments are low, medium, and high with 1/3 of total frequency components each. Where the low-frequency with high-amplitude has the largest amount of total energy area, the medium range is next, and the segment of high-frequency with low-amplitude has the smallest total energy area. All of the three FD analyses for the time periods reveal a similar pattern. This phenomenon makes perfect biomedical sense to the author. The lower PPG values carry less energy but occupy 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 but occupy the least volume of the total frequency quantity (i.e., the lower-frequency with high-amplitude glucose happen the least times in a day) and cause the most damage to the internal organs.

Keywords: Postprandial plasma glucose; Internal organs; Time domain; Frequency domain; Lifestyle

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

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1. INTRODUCTION

This particular study investigates postprandial plasma glucose (PPG) characteristics and their impact on internal organs from their associated relative energy for three time periods.

At first, the author utilizes wave theory to study 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 frequency domain (FD). He can then estimate the relative energy levels associated with the amplitude of different glucose for each waveform in the TD. This provides a better understanding of the varying degree of organ impact via these relative energies generated from and carried by glucose 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 various developed high-tech tools contribute to his excellent health status since 1/19/2020[6-8].

In summary, Periods A and B fall into the pre-virus timeframe where constant travel, hectic and stressful lifestyle, disruption on eating and exercise patterns caused higher PPG in TD. This converted into higher relative energy levels in FD as well. On the contrary, Period C occurs in the unique COVID-19 quarantine lifestyle which has brought down his PPG level in the TD and results in a lower relative energy level in FD.

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 the medical findings, not just through linguistic expressions of qualitative words, vague statements, or complex terminologies[9,10].

2.3 Input data for time domain

During the period from 5/5/2018 to 2/26/2021, he defined three periods as follows:

Period A: 5/5/18-5/4/19 (365 days)
Period B: 5/5/19-5/4/20 (366 days)
Period C: 5/5/20-2/26/21 (296 days)

The following table lists his key input data in the format of 6 variables: the number of meals, carbs/sugar intake in grams, post-breakfast walking K-steps, finger-piercing measured PPG in g/dL, sensor collected PPG in mg/dL, percentage of the difference between sensor PPG and finger PPG:

Period A: 1153, 15.8, 4.3, 117, 135, 15%
Period B: 1102, 12.9, 4.4, 113, 135, 19%
Period C: 876, 14.2, 4.5, 107, 118, 10%

From the above table, it is obvious that he lived his daily life under a stringent low-carb/sugar and high-exercise lifestyle management program. His sensor collected PPG is about 15% higher than his finger measured PPG.

Figures 1, 2, and 3 show the TD results in comparison among those three periods. There are three key observations from these three TD figures.

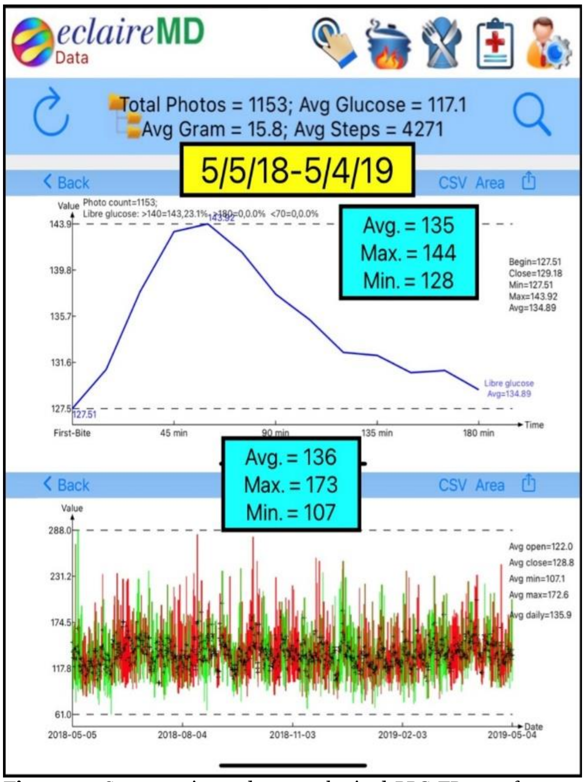

Figure 1: Summary input data, synthesized PPG TD waveform, and Candlestick K-line of Period A from 5/5/2018 to 5/4/2019.

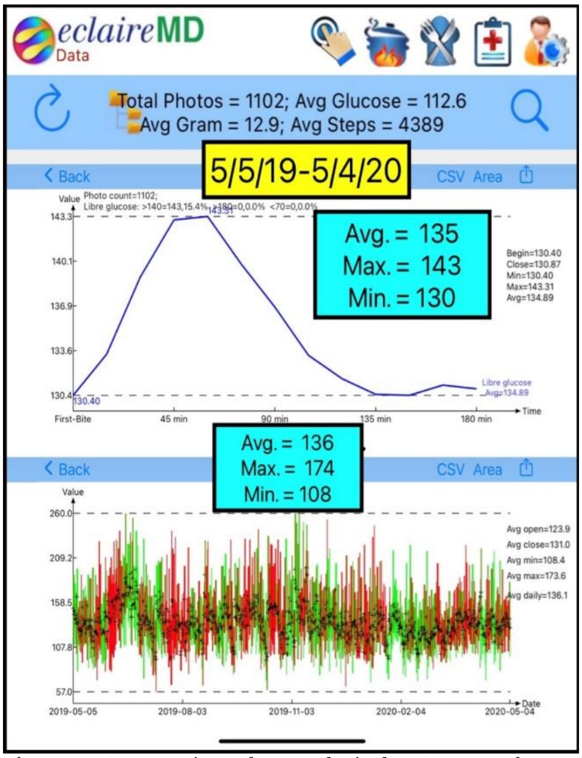

Figure 2: Summary input data, synthesized PPG TD waveform, and Candlestick K-line of Period B from 5/5/2019 to 5/4/2020.

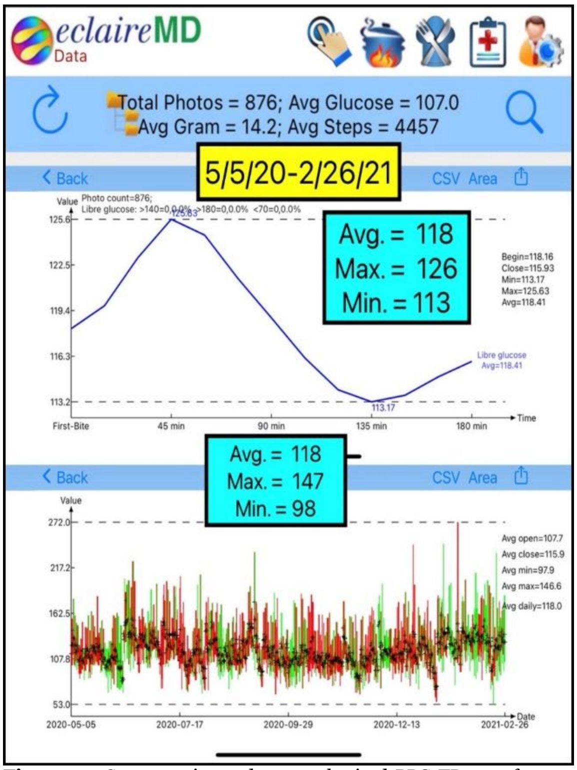

Figure 3: Summary input data, synthesized PPG TD waveform, and Candlestick K-line of Period C from 5/5/2020 to 2/26/2021.

First, from the middle-synthesized PPG waveform diagram, the average PPG values for Periods A and B are around 134-136 mg/dL, which is 14% higher than Period C with 118 mg/dL.

Second, from the Candlestick K-line diagram, the PPG fluctuation (i.e., max-min) value of Periods A and B is 66 mg/dL, which is 35% higher than the PPG fluctuation value of 49 mg/dL in Period C. In other words, both the average PPG values and PPG fluctuations of Periods A and B are numerically higher and have a more aggressive pattern than Period C.

It should be pointed out that the Candlestick K-line model can capture more realistic maximum and minimum PPG values which provide a better presentation via the synthesized PPG waveform model (i.e., the average PPG values at each 15-minute interval with hundred days of each time period).

Third, the top two influential factors which are carbs/sugar intake in grams and the post-meal walking steps are remarkably similar to each other in these three time periods. This means that the author has kept a very stringent lifestyle management program with an intake of less than 15 grams of carbs/sugar and walking more than 4,200 steps after each meal. However, there are still 17 third-tier or minor influential factors of the PPG formation. According to his previous research results, the contribution ratios are ~40 % from carbs/sugar, ~40% from exercise, and ~20% from the combination of all of the third-tier influential factors such as weather temperature, sleep, stress, mood, diseases, measuring timing, etc.

Figure 4 depicts the direct comparison of his TD analysis results among the three time periods.

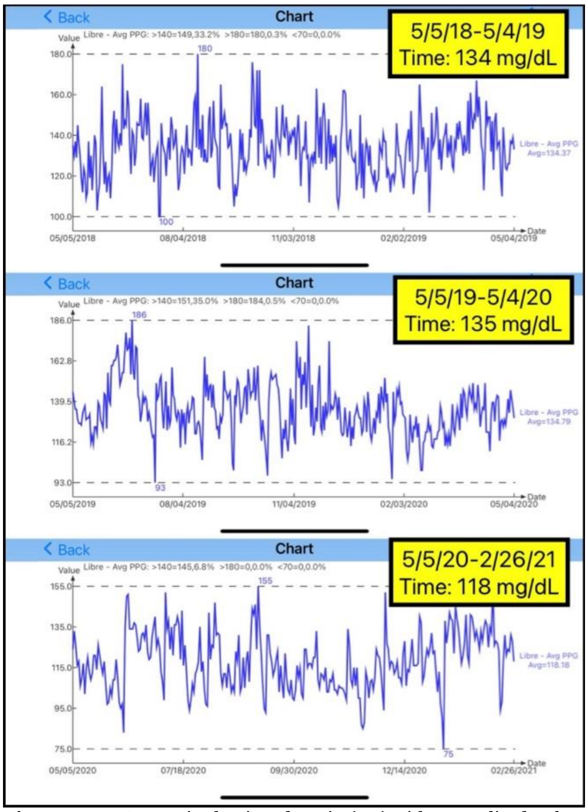

Figure 4: PPG wave in the time domain (TD) with Y-amplitude of average PPG value of 3 periods.

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.

The FD analysis provides two observations. First, in Figure 5, the relative energy associated with PPG, which is the frequency area of three frequency diagrams, reveals that the FD's Y-amplitudes for Period A (223) and Period B (226) are ~15% higher than the FD's Y-amplitude for Period C (196). This observed phenomenon is due to the higher amplitude (Y-value) result of the FD after the FFT operation that originates from the high Y-amplitude in TD, i.e., the PPG value. Furthermore, in Figure 6, the total frequency areas for Periods A and B are in the range of 81180 to 82303 which are ~42% higher than the total frequency area of Period C of 57555. It should be pointed out that the total frequency area equals the average Y-amplitude of FD by multiplying the frequency components (N).

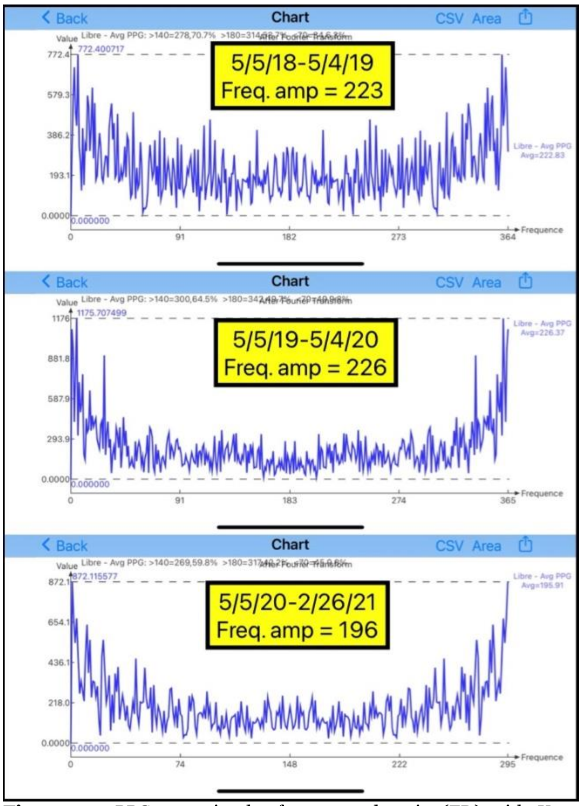

Figure 5: PPG wave in the frequency domain (FD) with Y-amplitude of relative energy of 3 periods.

Second, the three time periods with the corresponding three relative energies associated with PPG within three equal-component segments are low, medium, and high with 1/3 of total frequency components each. Where the low-frequency with high-amplitude has the largest amount of total energy area, medium range is next, and the segment of high-frequency with low-amplitude has the smallest total energy area. All of the three FD analyses for the time periods reveal a similar pattern. This phenomenon makes perfect biomedical sense to the author. The lower PPG values carry less energy but occupy 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 but occupy the least volume of the total frequency quantity (i.e., the lower-frequency with high-amplitude glucose happen the least times in a day) and cause the most damage to the internal organs.

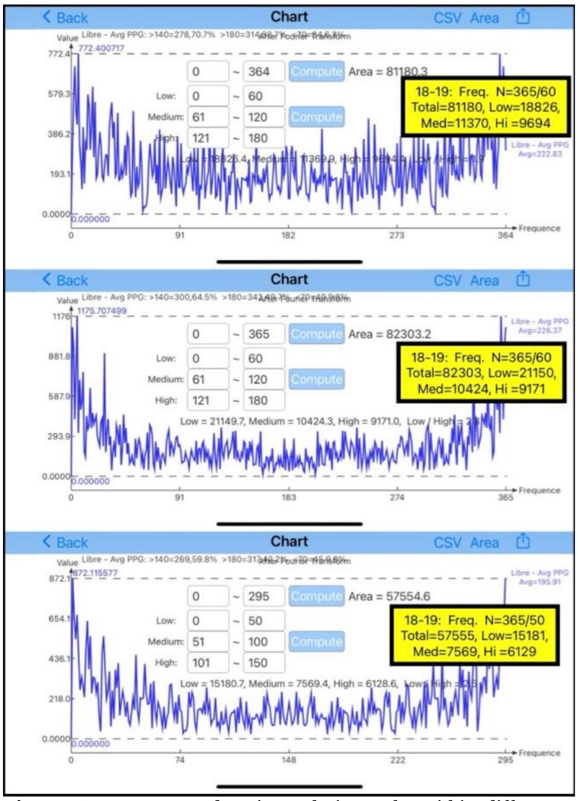

Figure 6: Frequency domain analysis results within different frequency ranges.

Figure 7 with a bar diagram illustrates the Y-amplitudes of TD and FD, along with the relative percentage of the frequency areas.

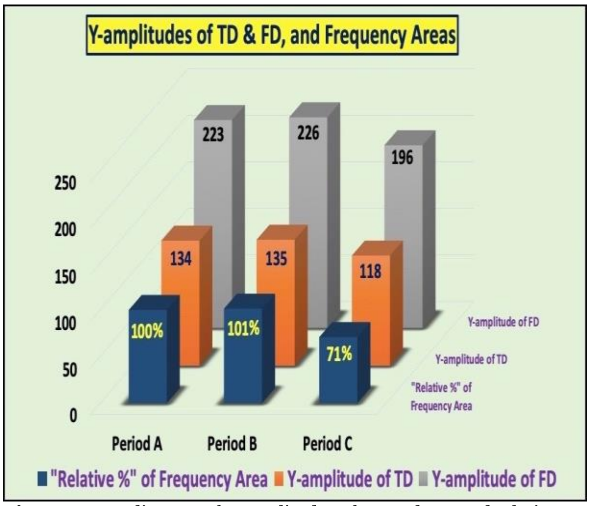

Figure 7: Bar diagram of Y-amplitudes of TD and FD, and relative % of frequency areas.

2.5 PPG fluctuation in TD and FD

The straightforward finding of the PPG fluctuation (i.e., max-min) value of Periods A and B is 66 mg/dL, which is 35% higher than the PPG fluctuation value of 49 mg/dL in Period C. These data indicate that the PPG fluctuations of Periods A and B are numerically higher and have a more aggressive pattern than Period C.

The author decided not to pursue the relevant FD analyses of the PPG fluctuations since it involves more tedious work in assembling 3 PPG wave fluctuations of breakfast, lunch, and dinner together. This paper focuses on the overall picture of PPG and its associated relative energy levels for these three time periods.

3. CONCLUSION

To summarize in a more detailed manner, there are three observations from the TD analysis of both synthesized waveform and the Candlestick K-line model.

First, the average PPG values for Periods A and B are ~14% higher than Period C; and the PPG fluctuation (i.e., max-min) value for Periods A and B is 35% higher than the PPG fluctuation value of Period C. In other words, both the average PPG and PPG fluctuation for Periods A and B are higher or more aggressive than the Period C[(11,12)].

Second, it should be pointed out that the Candlestick K-line model can capture more realistic maximum and minimum PPG values better than the synthesized PPG waveform model.

Third, the top two influential factors which are carbs/sugar intake in grams and the post-meal walking steps are remarkably similar to each other in these three time periods. This means that the author has kept a very stringent lifestyle management program with an intake of less than 15 grams of carbs/sugar and walking more than 4,200 steps after each meal.

The FD analysis provides two observations. First, the relative energy associated with the PPG wave reveals that the FD Y-amplitudes for Periods A and B are ~15% higher than Period C. The total frequency areas for Periods A and B are ~42% higher than the total frequency area of Period C[(13-15)].

Second, the three time periods with the corresponding three relative energies associated with PPG within three equal-component segments are low, medium, and high with 1/3 of total frequency components each. Where the low-frequency with high-amplitude has the largest amount of total energy area, medium range is next, and the segment of high-frequency with low-amplitude has the smallest total energy area. All of the three FD analyses for the time periods reveal a similar pattern. This phenomenon makes perfect biomedical sense to the author. The lower PPG values carry less energy but occupy 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 but occupy the least volume of the total frequency quantity (i.e., the lower-frequency with high-amplitude glucose happen the least times in a day) and cause the most damage to the internal organs[(16,17)].

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