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Viscoelastic and Viscoplastic Glucose Theory (VGT #123): Using 3 Energy Methods, Time-Domain, Space-Domain VGT, and Frequency-Domain FFT, to Study the Relationships of Postprandial Plasma Glucose Curve versus Food Contribution Curve and Temperature Contribution Curve with 8 Annual Data Based on Math-Physical Medicine Method (No. 714)

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Note: This article is an expanded version of Papers No. 712 and No.713.

Keywords: Viscoelastic; Viscoplastic; Food; Temperature; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: FFT: fast Fourier transform; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; FD: frequency domain; SD: space domain; TD: time domain; MPM: math-physical medicine

1. INTRODUCTION

For many years, by analyzing the influential factors of type 2 diabetes particularly glucose, the author has identified the most critical factor that forms the postprandial plasma glucose (PPG) level which is the insulin resistance resulting from damage to pancreatic beta cells. This can also be indicated by the level of fasting plasma glucose (FPG).

Other than this “insulin” baseline factor, carbohydrates and sugar intake amount is the next most critical contribution factor (~60% of carbs and exercise) and post-meal exercise intensity is another critical and effective contribution factor (~40% of carbs and exercise). In addition to these 3 primary factors, type and dosage of diabetes medication, body weight, anxiety, stress, traveling, illness, sleep quality and disturbance, and glucose measurement delay are secondary causes of glucose fluctuations. In summary, about 20 factors for PPG and 6 factors for FPG have been identified by the author. All of these elements are considered minor influential factors in glucose formation.

Although the contribution % from weather temperature on glucose is relatively smaller, it is still one of the higher contributed influential factors among the remaining minor factors of PPG and FPG.

Paper No. 002 written on 3/13/2019 was a rudimentary report because the author had just started his research work on weather temperature influences on glucose. Papers No. 712 and No.713 further discuss a more detailed and deeper relationship existing between colder temperature versus FPG and warmer temperature versus PPG using SD-VGT and FD-FFT methods.

This particular study utilized data from 3 curves and their related datasets, PPG curves, primary food (carbs/sugar) contribution curve, and secondary weather temperature contribution curve for a period of 7 years from 6/1/2015 to 8/5/2022. The following section describes his analysis methods.

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2. METHODS

2.1 TD, SD, and FD analysis tools

This section has brief descriptions of time-domain (TD) correlation analysis with other observational results, space-domain (SD) VGT analysis with hysteresis loop area's energy results, and frequency-domain (FD) analysis with frequency curve area's energy results.

First of all, using a TD analysis tool, we can examine the curves' moving trend and pattern visually along with their correlation numerically. We can also study those extremely high or low data values in the dataset. The visual observation or calculation-derived interpretations are a part of statistical analysis results which can indeed provide some useful hints or even derive some accurate conclusions. However, we must be aware of the limitations of the data we select and be cautious of the appropriate statistics tool we choose.

The author would like to describe the essence of his developed "hybrid model" that combines both space-domain (SD) viscoelastic/plastic VGT analysis method and frequency-domain (FD) fast Fourier transform (FFT) analysis method together with a comparison against the traditional time-domain statistical correlation analysis.

It is described in 10 steps in the English language instead of using mathematical equations to explain it. In this article, he has applied both the SD-VGT operations (steps 1-7) and the FD-FFT operations (steps 8-10). As a result, it is aimed at readers who do not have an extensive background in the academic subjects of engineering, physics & mathematics.

The first step is to collect the output data or symptom (strain or ε) on a time scale. The second step is to calculate the output change rate with time (dε/dt), i.e. the change rate of strain or symptom over each period. The third step is to gather the input data or cause (viscosity or η) on a time scale. The fourth step is to calculate the time-dependent input or cause (time-dependent stress or σ) by multiplying dε/dt and η together. The "time-dependent input or cause equation" of "stress σ = strain change rate of dε/dt * viscosity η" is the essential part of "time-dependency". The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a 2-dimensional space domain or SD (x-axis versus y-axis) with strain (output or symptom) on the x-axis and stresses (time-dependent inputs, causes, or stresses) on the y-axis. The sixth step is to calculate the total enclosed area within these stress-strain curves or input-output curves (i.e. the hysteresis loops), which is also an indicator of associated energies (either created energy or dissipated energy) of this input and output dataset. These energy values can also be considered as the degrees of influence on output by inputs. The seventh step is the assembly of the area values of the selected periods to compare the "progression and contribution of condition" over certain time periods.

For the frequency domain, the eighth step is to define a "hybrid input variable" by using "strain*stress" which yields another accurate estimation of energy ratio similar to the SD-VGT energy ratio associated with the hysteresis loop. The ninth step is to present these hybrid models' results of (strain*stress) in a time domain and then perform the fast Fourier transformation (FFT) operation to convert them into a frequency domain (FD). The enclosed area of the frequency curve (where the x-axis is the frequency and the y-axis is the amplitude of energy) can be used to estimate the total FD-FFT energy. The tenth step is to compare these FD energy results against the SD-VGT energy results, or even TD energy results.

After providing the above 10-step description, the author would still like to use the following set of VGT stress-strain mathematical equations in a two-dimensional SD to address the unique "time-dependency characteristics" of selected medical variables:

Strain
= ε
= individual strain value at the present time duration

Stress
= σ (based on the change rate of strain multiplying with a chosen viscosity factor η)
= η * (dε/dt)
= η * (d-strain/d-time)
= (viscosity factor η using individual viscosity factor at present time duration) * (strain at

present quarter - strain at previous time duration)

Some of these inputs (causes or viscosity factors) are further normalized by dividing them or being divided by a normalization factor using certain established health standards or medical pieces of knowledge. Some examples of normalization factors are 6.0 for HbA1C, 120 mg/dL for glucose, 25 for body mass index (BMI), 4,000 steps after each meal, 10,000 or 12,000 steps for daily walking exercise depending on time-period selection, 15 or 20 grams of carbs/sugar intake amount per meal depends on time-period selection. If using the originally collected data, i.e. the non-normalized data would distort the numerical comparison of the hysteresis loop areas. Using this "normalization process", we can remove the dependency of the individual unit or certain unique characteristics associated with each viscosity factor. This process allows us to convert the originally collected variables into a set of "dimensionless variables" for easier numerical comparison and result interpretation.

In this particular study, since the three calculated and plotted curves are based on the same unit, mg/dL, there is no need to apply any normalization factors to its two viscosities or input causes, the food contribution data, and the temperature contribution data. The selected strain or output symptom is PPG with the same unit of mg/dL as the food (carbs/sugar) contributed PPG component and the weather temperature contributed PPG component.

Note: For a more detailed description, please refer to the "consolidated method" section which is given at the beginning of the special issue.

3. RESULTS

Figure 1 shows his data table and the TD diagram.

Figure 2 displays his results using both SD-VGT strain-stress analysis and FD-FFT analysis.

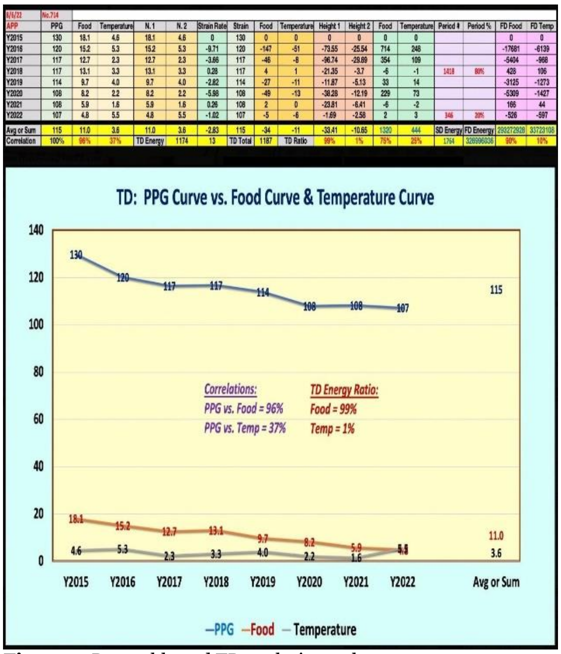

Figure 1: Data table and TD analysis results.

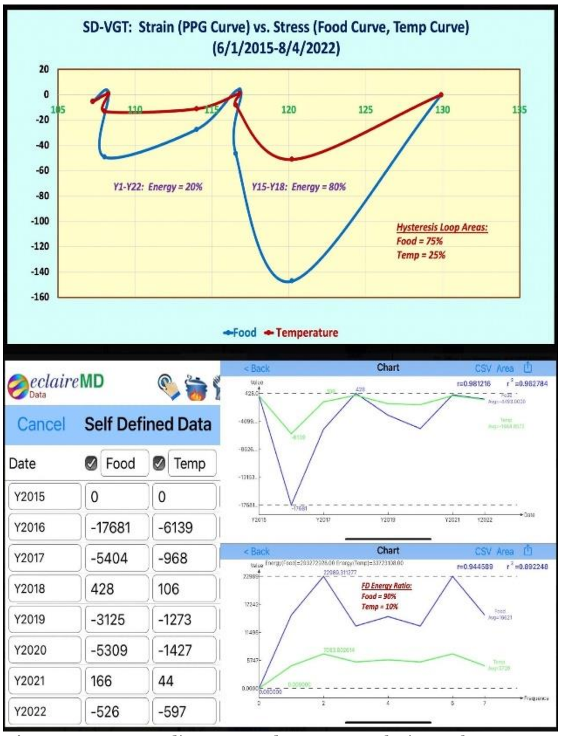

Figure 2: SD-VGT diagrams and FD-FFT analysis results.

4. CONCLUSION

There are 3 conclusions observed from this study:

(1) From the TD diagram, two correlations are: PPG vs. food = 96%; PPG vs. temperature = 37% which make sense. The TD squared-amplitude energy ratio of food vs. temperature is 99% : 1% which a little bit strange.

(2) From SD-VGT energy analysis results, the following ratios are observed: Food = 75%; Temp = 25%. Y15-Y18 Food & Temp = 80%; and Y19-Y22 Food & Temp = 20%. These percentages mean that Food has three times higher influences (i.e. larger energies from this primary factor) than temperature which is a secondary factor. For time-period energy percentages, we can see that the earlier 4-years (Y15-Y18) have four times higher influences on his overall glucose situation than the recent 4 years for both cases of FPG cold and PPG warm than the earlier period (Y15-Y18). Incidentally, more detailed calculations have shown the independent components, food or temperature, have almost identical time-period energy split ratios, i.e. 80% : 20%.

(3) From FD-FFT energy analysis results, the following ratios are observed: Food = 90%; Temp = 10%. These FD energy distribution ratio of 90% : 10% is also close to the SD energy distribution ratio of 75% : 25%. This finding has further proven both SD results and FD results are comparable.

This study has demonstrated that, other than insulin resistance, PPG values are mainly influenced (75%-99%) by food, i.e. carbs/sugar intake amount, and in a minor way (1% to 25%) from weather temperature. In the author's case, the contribution from both food and temperature to his PPG in the earlier period of Y16-Y18 has more prominent influence than the PPG in the recent period of Y19-Y22.

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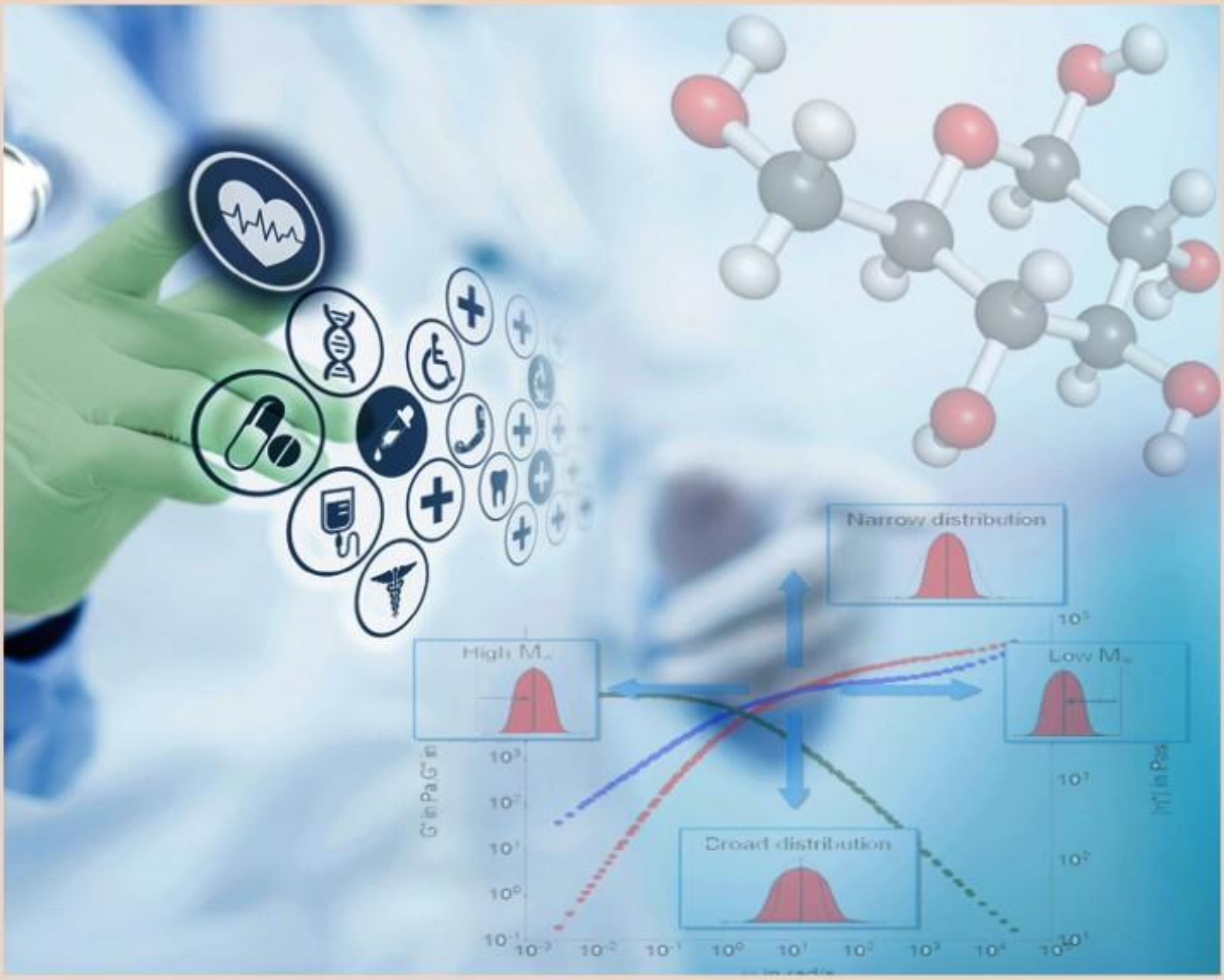

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