

The GH-Method

Viscoelastic and Viscoplastic Glucose Theory (VGT #122): Using Space-Domain VGT Energy Method and Frequency- Domain FFT Energy Method to Investigate the Relationships of Fasting Plasma Glucose versus Cold Weather Temperature and Postprandial Plasma Glucose versus Warm Weather Temperature (No. 713)

Gerald C. Hsu*

eclairMD Foundation, USA

Note: This article is an expanded version of Paper No. 712.

Keywords: Viscoelastic; Viscoplastic; Weather temperature; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: FFT: fast Fourier transform; T2D: type 2 diabetes; 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 significant 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/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.

Although Paper No. 002 written on 3/13/2019 was a rudimentary report, the author had just started his research work on weather temperature influences on glucose. This particular Paper No. 713 discusses more detailed and deeper relationship that existed between colder temperature versus FPG and warmer temperature versus PPG using both SD-VGT and FD-FFT methods.

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 the 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 tools 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 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 those 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 ($d\epsilon/dt$), 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 $d\epsilon/dt$ and η together. The "time-dependent input or cause equation" of "stress $\sigma = \text{strain change rate of } d\epsilon/dt * \text{viscosity } \eta$ " 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. 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)

= $\eta * (d\epsilon/dt)$

= $\eta * (d\text{-strain}/d\text{-time})$

= (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 his collected viscosity or input cause (weather temperature data) is located within the range of 57°F to 86°F, therefore, he has selected 72°F as the normalization factor. His two selected strains or output symptoms are FPG and PPG which are with the unit of mg/dL.

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 the collected weather temperature data from 6/1/2015 to 8/4/2022 and 3 segregated weather temperature groups using data mining tool.

Figure 2 displays two data tables, one for FPG versus cold temperature and the other for PPG versus warm temperature.

Figure 3 depicts two time-domain analysis results, FPG versus cold temperature and PPG versus warm temperature.

Figure 4 reflects three SD-VGT strain-stress diagrams together. The top and middle diagrams are FPG vs. cold temperature and PPG vs. warm temperature using the same scale for the strain, i.e. glucoses. The same strain scaled diagrams (between 90 mg/dL to 130 mg/dL) can show the relative comparison of hysteresis loop area sizes and curve patterns between FPG and PPG. The bottom diagram has a “fitted” but different strain scale (between 104 mg/dL to 124 mg/dL) for PPG case.

Figure 5 illustrates the FD-FFT analysis results.

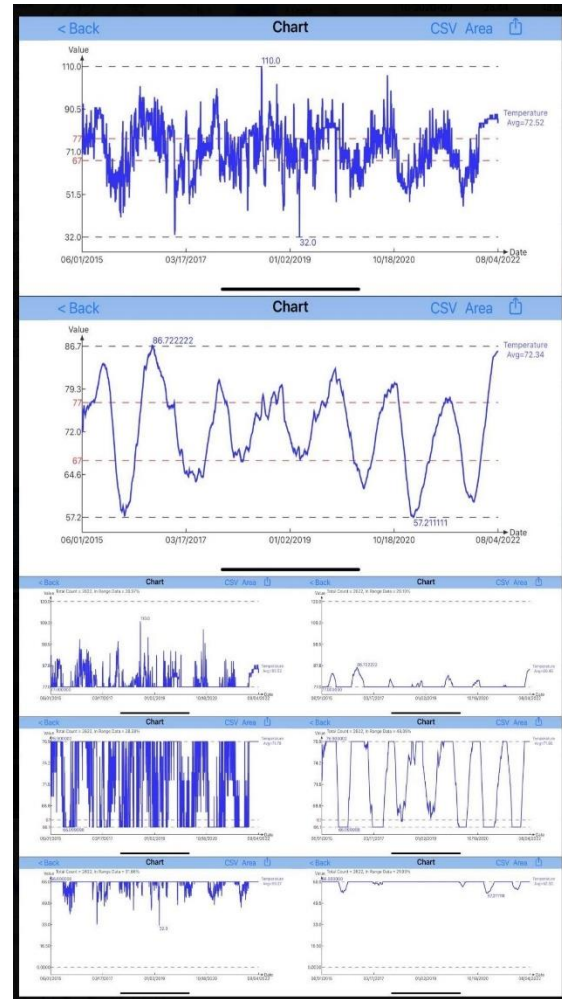


Figure 1: Weather temperature fluctuation and data-mining results.

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SD-VGT	Strain	Viscosity	NF = 72	Strain Rate	Strain	Stress	Height	Area	Period #	Period %	FPG vs. Temp	
	FPG	Lo. Temp	N. Temp	FPG Rate	PPG	Temp	Temp	Temp	Period #	Period %	Strain*Stress	
Y2015	123.5	58.5	0.81	0.00	123.5	0.00	0.00	0			0	
Y2016	111.6	57.2	0.79	-11.89	111.6	-9.44	-4.72	56			-1054	
Y2017	122.7	58.7	0.82	11.09	122.7	9.04	-0.20	-2	Y15-Y18		1110	
Y2018	115.9	58.7	0.82	-6.82	115.9	-5.56	1.74	-12	42	26%	-645	
Y2019	111.6	60.1	0.84	-4.35	111.6	-3.63	-4.60	20			-405	
Y2020	104.9	59.8	0.83	-6.69	104.9	-5.55	-4.59	31			-582	
Y2021	94.8	59.8	0.83	-10.11	94.8	-8.40	-6.98	71	Y15-Y22		-796	
Y2022	94.5	61.1	0.85	-0.26	94.5	-0.22	-4.31	1	122	74%	-21	
Avg	109.9	59.2	0.82	-3.63	109.9	-2.97	-2.96	164	Total Area		-259	
Correlation	-66%								164	FD Energy	3634333	68%

8/5/22	Strain	Viscosity	NF = 72	Strain Rate	Strain	Stress	Height	Area	Period #	Period %	PPG vs. Temp	
SD-VGT	PPG	Hi. Temp	N. Temp	PPG Rate	PPG	Temp	Temp	Temp	Period #	Period %	Strain*Stress	
Y2015	119.0	83.7	1.16	0.00	119.0	0.00	0.00	0			0	
Y2016	120.2	84.5	1.17	1.17	120.2	1.37	0.69	1			165	
Y2017	122.5	85.9	1.19	2.32	122.5	2.77	2.07	5	Y15-Y18		339	
Y2018	115.9	82.5	1.15	-6.59	115.9	-7.55	-2.39	16	21.37	30%	-875	
Y2019	112.8	83.2	1.16	-3.10	112.8	-3.58	-5.57	17			-404	
Y2020	106.4	82.1	1.14	-6.39	106.4	-7.28	-5.43	35			-775	
Y2021	108.3	80.9	1.12	-1.85	108.3	2.08	-2.60	-5	Y15-Y22		225	
Y2022	105.1	85.1	1.18	-3.20	105.1	-3.78	-0.85	3	49.88	70%	-897	
Avg	113.8	83.5	1.16	-1.74	113.8	-2.0	-1.76	71	Total Area		-215	
Correlation	48%								71	FD Energy	1724783	32%

SD Area Ratio	FPG / Temp	164	70%	PPG / Temp	71	30%	Total Area	236	100%	Total FD Energy	5359116	100%
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Figure 2: 2 data tables of FPG vs. cold temperature and PPG vs. warm temperature.

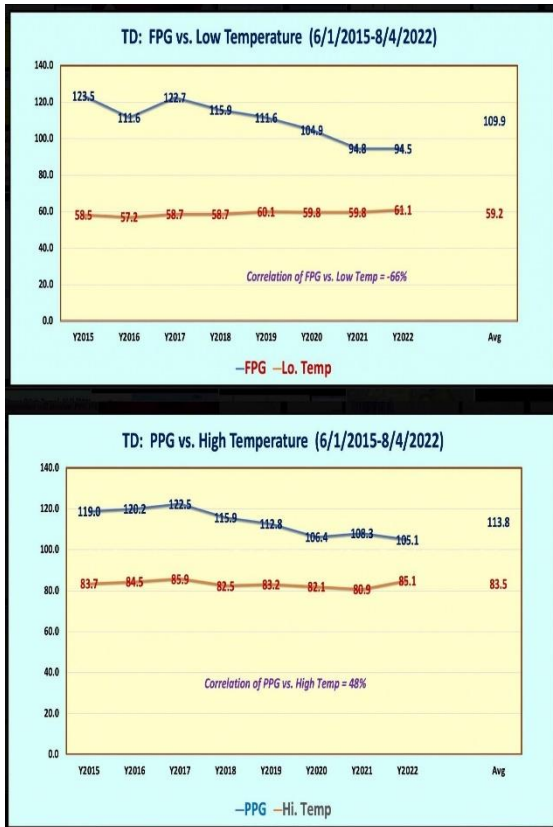


Figure 3: 2 Time-domain diagrams.

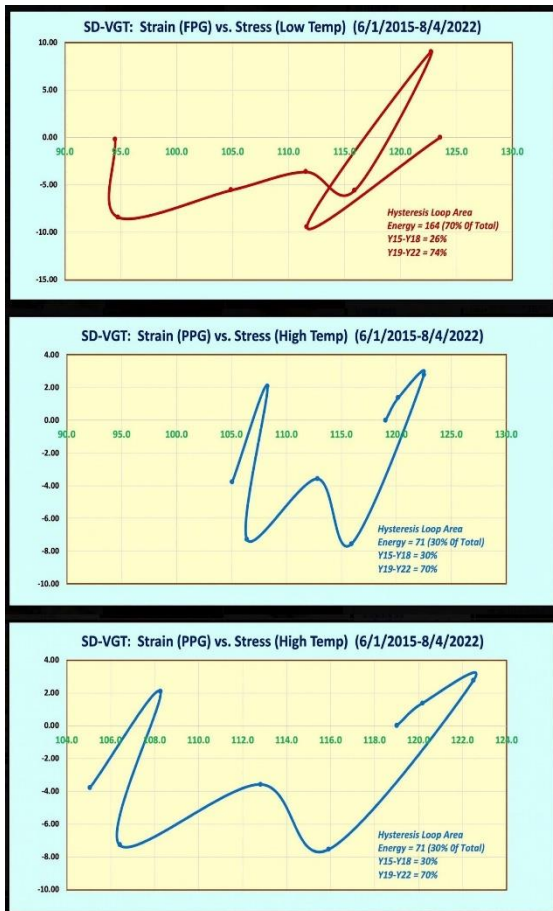


Figure 4: 3 SD-VGT diagrams.

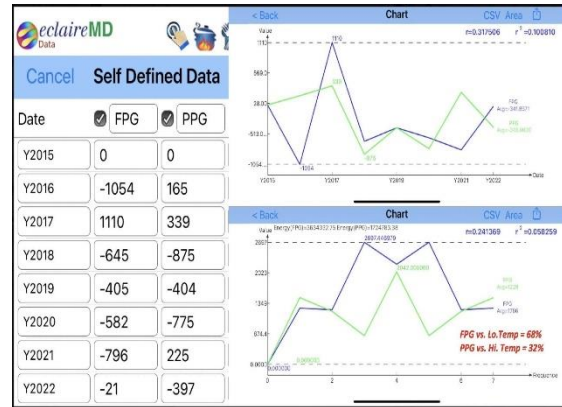


Figure 5: FD-FFT analysis results.

4. CONCLUSION

There are 3 conclusions observed from this study:

(1) From the TD diagram, for warm weather, the average PPG of 114 mg/dL is from those days with a corresponding average warm temperature of 84°F, while the average FPG of 110 mg/dL is from those days with a corresponding average cold temperature of 59°F. The correlations of -66% for FPG vs. cold temperature and 48% for PPG vs. warm temperature do not make much biophysical sense. This has shown the shortcomings of using statistics tool.

(2) From SD-VGT energy analysis results, the following ratios are observed: FPG cold energy = 70%; PPG warm energy = 30%. Y15-Y18 FPG cold energy = 26%; and Y19-Y22 FPG cold energy = 74%; but, Y15-Y18 PPG warm energy = 30%; Y19-Y22 PPG warm energy = 70%. These percentages mean that the case of FPG with cold temperature has more influences (i.e. larger energies) and therefore has a more prominent effect than the case of PPG with warm temperature. For time-period energy percentages, we can see that the later 4-years (Y19-Y22) have a more prominent effect on his overall glucose situation for both cases of FPG cold and PPG warm than the earlier 4-years (Y15-Y18).

(3) From FD-FFT energy analysis results, the following ratios are observed: FPG cold energy = 68%; PPG warm energy = 32%. These FD energy distribution ratio of 68% : 32% is very close the SD energy distribution ratio of 70% : 30%. This finding has further proven both SD results and FD results are comparable.

This study has demonstrated that glucoses are influenced by weather temperature even though the temperature factor is only a minor influential factor. It also seems that the cold temperature's influence on FPG is higher than the warm temperature's influence on

PPG. For the author's case, the weather temperature in the recent period of Y19-Y22 has a more prominent influence on his glucoses than in the earlier period of Y15-Y18.

Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

Gerald C. Hsu

