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Viscoelastic and Viscoplastic Glucose Theory (VGT #125): Using Three Different Energy Methods, Time Domain, Space Domain, and Frequency Domain, to Calculate Energies or Degrees of Influence on the Total Sensor PPG 1,920 Meals versus Intermittent Fasting PPG 506 Meals and Non-IF PPG 1,414 Meals During 11/1/2020 to 8/7/2022 Based on Math-Physical Medicine Method (No. 716)

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Note: This article is an expanded version of Papers No. 603 and No. 606.

Keywords: Viscoelastic; Viscoplastic; Intermittent fasting; Cardiovascular disease; Metabolism index; Exercise; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: IF: intermittent fasting; CVD: cardiovascular disease; 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

The author started to practice intermittent fasting (IF) on 11/8/2020. He selects one meal each day, usually breakfasts, to avoid eating any “solid or high-energy food” except for drinking tea or water and not coffee since it increases glucose. For the period of 721 days from 11/1/2020 to 8/7/2022, he utilized IF for 506 meals (26%) and non-IF for 1,414 meals (74%) out of the total 1,920 meals (100%).

An internet search of “IF” yielded real and fake information on the benefits and drawbacks of this lifestyle nutrition and health practice. The author decided to conduct his own experiment on the IF impact or influences on his postprandial plasma glucose (PPG). Out of curiosity, he also applied the stress-strain diagram in space domain (SD) with viscoelastic and viscoplastic theory from engineering along with wave theory in time domain (TD) through fast Fourier transform (FFT) operation into a frequency domain (FD). This is to estimate the relative energy associated with PPG for both IF and Non-IF cases to understand the energy impact or degree of influence distribution from each type of meal.

2. METHODS

2.1 Brief introduction of math-physical medicine (MPM) research

The author has collected 3+ million data regarding his health condition and lifestyle details over the past 13 years. He spent the entire year of 2014 developing a metabolism index (MI) model using a topology concept, nonlinear algebra, algebraic geometry, and finite element method. This MI model contains various measured biomarkers and recorded lifestyle details along with their induced new biomedical variables for an additional ~1.5 million data. Detailed data of his body weight, glucose, blood pressure, heart rate, blood lipids, body temperature, and blood oxygen level, along with important lifestyle details, including diet, exercise, sleep, stress, water intake, and daily life routines are included in the MI database. In addition, these lifestyle details also include some lifetime bad habits and environmental exposures. Fortunately, the author has none

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of these lifetime bad habits and an extremely low degree of exposure to environmental factors. The developed MI model has a total of 10 categories covering approximately 500 detailed elements that constitute his defined "metabolism index model" which are the building blocks or root causes for diabetes and other chronic disease complications, including but not limited to cardiovascular disease (CVD), chronic heart disease (CHD), stroke, chronic kidney disease (CKD), retinopathy, neuropathy, foot ulcer, hypothyroidism, dementia, and various cancers. The end result of the MI development work is a combined MI value within any selected period with 73.5% as its dividing line between a healthy and unhealthy state. The MI serves as the foundation for many of his follow-up medical research work.

During the period from 2015 to 2017, he focused his research on type 2 diabetes (T2D), especially glucose, including fasting plasma glucose (FPG), PPG, estimated average glucose (eAG), and hemoglobin A1C (HbA1C). During the following period from 2018 to 2022, he concentrated on researching medical complications resulting from diabetes, chronic diseases, and metabolic disorders which include heart problems, stroke, kidney problems, retinopathy, neuropathy, foot ulcer, diabetic skin fungal infection, hypothyroidism, diabetic constipation, dementia, and various cancers. He also developed a few mathematical risk models to calculate the probability percentages of developing various diabetic complications based on this MI model.

From his previous medical research work with 700+ published papers, he has identified and learned that the associated energy of hyperglycemic conditions is the primary source of causing many diabetic complications which lead to death. Therefore, a thorough knowledge of these energies is important for achieving a better understanding of the dangerous complications.

2.2 TD, SD, and FD analysis tools

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

First of all, by 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 tool we choose.

The author would like to describe the essence of his developed "hybrid model" that combines both the SD viscoelastic/plastic VGT analysis method and 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 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 (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. 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 the 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 * ($d\varepsilon/dt$)
= 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, it 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, he uses 120 mg/dL as the "normalization factors" for his two viscosities, IF PPG and Non-IF PPG.

2.3 Time-frequency analysis

In signal processing, the time-frequency analysis comprises the techniques that study a signal in both TD and FD simultaneously, using various time-frequency representations. Rather than viewing a 1-dimensional signal (a function, real or complex-valued, whose domain is the real line) and some transform (another function whose domain is the real line, obtained from the original via some transform, such as FTT), time-frequency analysis studies a two-dimensional signal – a function whose domain is the two-dimensional real plane, obtained from the signal via a time-frequency transform.

The mathematical motivation for this study is that functions and their transform representation are tightly connected, and they can be understood better by studying them jointly, as a two-dimensional object, rather than separately.

The practical motivation for time-frequency analysis is that classical Fourier analysis assumes that signals are infinite in time or periodic, while many signals in practice are of short duration, and change substantially over their duration."

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 TD analysis results.

8/8/22	No. 716																
IF	Strain	Viscosity 1	Viscosity 2	120	120	Strain Rate	Strain	Stress 1	Stress 2	Area 1	Area 2	IF	IF	Non-IF	Non-IF	FD 1	FD 2
Sensor PPG	Total PPG	IF PPG	Non-IF PPG	N. IF	N. Non-IF	Total Rate	Total PPG	IF	Non-IF	IF	Non-IF	Period #	Period %	Period #	Period %	IF	Non-IF
First-Bite	114	108	117	0.9	1.0	0.0	114	0.0	0.0	0	0					0	0
15 min	116	109	118	0.9	1.0	1.5	116	1.4	1.5	1	1					156	170
30 min	118	109	122	0.9	1.0	2.7	118	2.4	2.7	5	6					289	322
45 min	120	110	124	0.9	1.0	1.9	120	1.8	2.0	4	4	0-60 min		0-60 min		211	237
60 min	120	111	124	0.9	1.0	-0.1	120	-0.1	-0.1	0	0	10	27%	11	28%	-8	-9
75 min	118	110	121	0.9	1.0	-1.9	118	-1.8	-1.9	2	2					-209	-229
90 min	116	110	118	0.9	1.0	-2.5	116	-2.2	-2.4	5	5					-260	-279
105 min	113	109	114	0.9	1.0	-3.0	113	-2.7	-2.8	7	8	75-120 min		75-120 min		-303	-317
120 min	110	108	111	0.9	0.9	-3.1	110	-2.8	-2.8	8	9	22	60%	24	60%	-302	-310
135 min	110	109	110	0.9	0.9	-0.2	110	-0.1	-0.1	0	0					-16	-16
150 min	111	111	111	0.9	0.9	1.3	111	1.2	1.2	1	1					135	136
165 min	113	113	112	0.9	0.9	1.6	113	1.6	1.5	2	2	135-180 min		135-180 min		175	174
180 min	114	115	113	1.0	0.9	1.0	114	1.0	1.0	1	1	5	12%	5	12%	112	110
Avg. S. PPG	115	110	117	0.92	0.97	-0.04	115	0.0	0.0	37	39	37	100%	39	100%	-1.4	-0.9
Squared PPG	1920 meals	1	1	N.Vis. Ratio	0.95			Stress Ratio	1.13	Area Ratio	0.94				FD Energy	550718	624892
Eneregy Ratio	TD Eneregy	47%	53%						SD Energy	48%	52%				FD Energy	47%	53%
Correlation	100%	7%	99%														

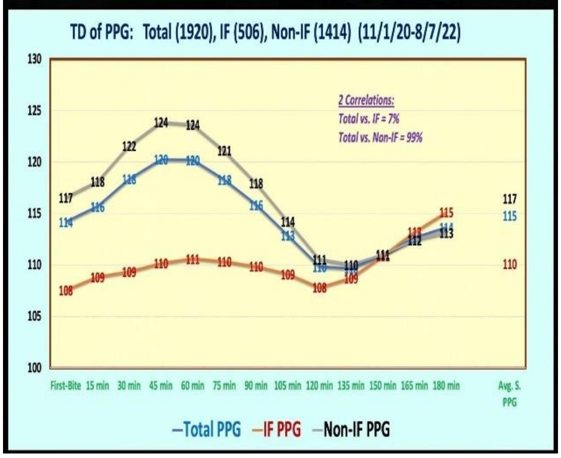

Figure 1: Data table and TD analysis results.

Figure 2 displays his SD and FD energy analysis results.

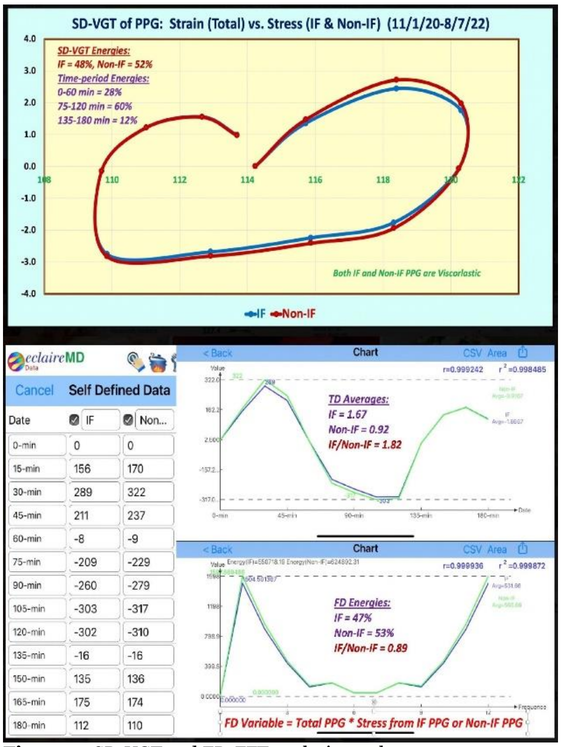

Figure 2: SD-VGT and FD-FFT analysis results.

4. CONCLUSION

In summary, there are 3 findings from this study:

(1) From the TD diagram, the IF PPG curve is almost a flat line, especially within 0-120 minutes (the author starts his post-meal walking exercise around 60 minutes and ceases his post-meal walking exercise after 120 minutes). The average PPG values are 117 mg/dL for non-IF meals and 110 mg/dL for IF meals with a PPG difference of 7 mg/dL. Two correlation coefficients are: Total vs. IF = 7%; Total vs. non-IF = 99%. The TD squared amplitude energy ratios are: IF = 47%; non-IF = 53%.

(2) From the SD-VGT analysis results, the stress-strain curve has a viscoelastic behavior. The energy ratios are: IF = 48%; non-IF = 52%. The energy distribution over 3 time-periods are: 1st hour = 28% (energy infusion), 2nd hour = 60% (energy dissipation), and 3rd hour = 12% (energy left-over). Although the meal number distributions are IF = 26% versus non-IF = 74%, their energy distribution ratios are IF =48% and non-IF = 52%. This means that IF indeed offers more influence on the total PPG. The 2nd hour's energy dissipation of 60% results from the non-IF occupies 74% of the total meals which has dissipated most of the energy via walking exercise within the 2nd hour.

(3) From the FD-FFT analysis results, the energy distribution ratios are: IF = 47%; non-IF = 53%. These FD energy ratios are very close to both SD energy ratios of IF = 48% & non-IF = 52% and TD energy ratios of IF = 475 & non-IF = 53%. In terms of energy analysis, these three different methods have yielded very similar results.

In conclusion, after practicing IF for nearly two years, the author has experienced a form of relief or relaxed feeling. In other words, he no longer has the burden of overeating his daily meals. An additional benefit of utilizing IF is that he no longer needs to walk additional steps. This is particularly welcome for his post-lunch exercises during the summertime. That is why he has decided to continue the practice of IF.

5. REFERENCES

For editing purposes, the majority of the references in this paper, which are self-references, have been removed for this article. Only references from other authors' published sources remain. The bibliography of the author's original self-references can be viewed at www.eclairemd.com.

Special Issue | Issue No. 5

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Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

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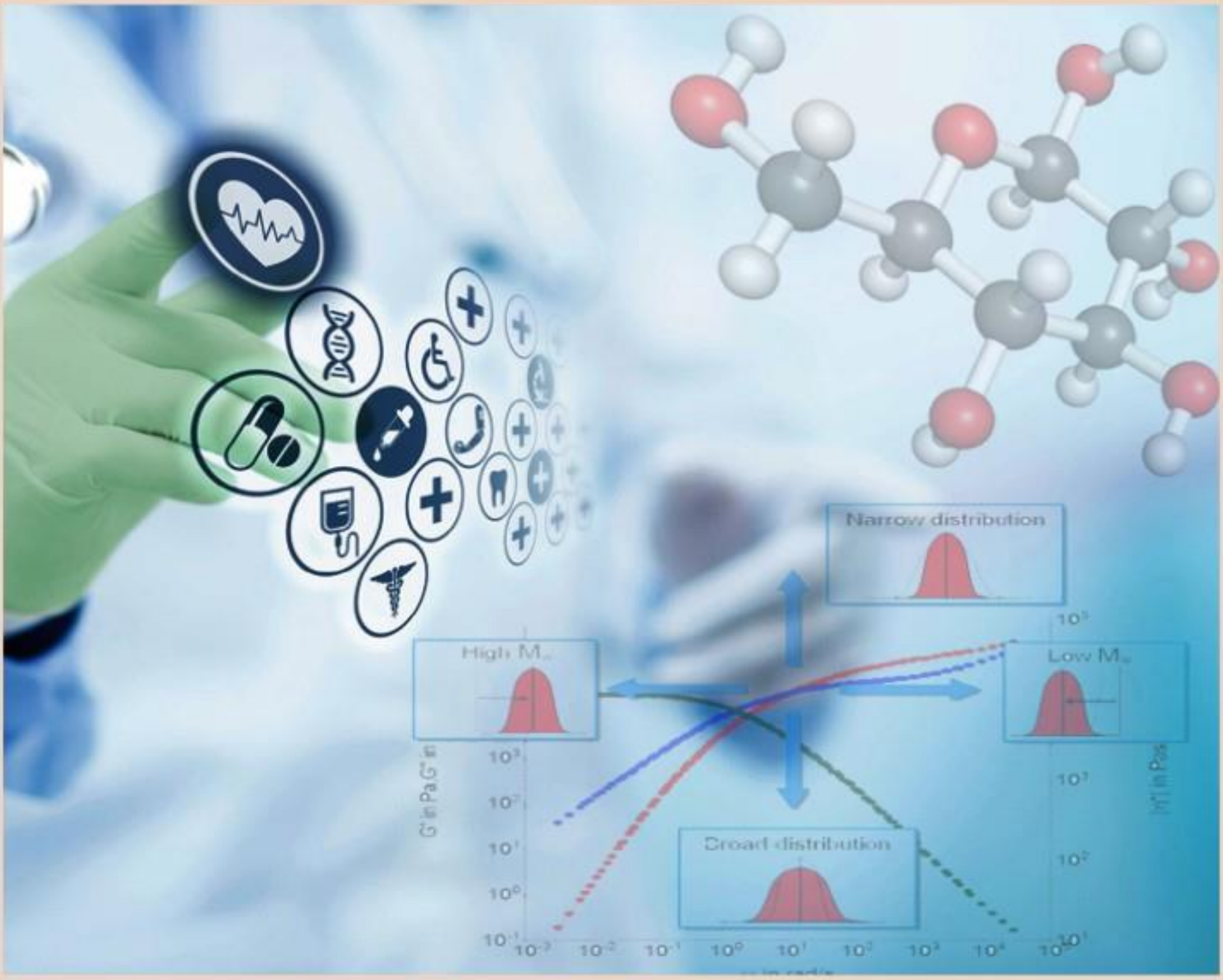

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2022