

The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #105): A Neuroscience Study on the Neural Communication Model Between the Brain and Gastrointestinal Organs, Stomach, Liver, and Pancreas of Postprandial Plasma Glucose Levels from a Total of 505 Egg Meals versus 257 Liquid and 248 Solid Egg Meals Over 4+ Years from 5/8/2018 to 6/29/2022 Based on TD-Squared PPG, SD-VGT, and FD-FFT Energy Tools of the GH-Method: Math-Physical Medicine (No. 695)

Gerald C. Hsu*

eclairMD Foundation, USA

Note: This article is an enhanced version of Paper No. 664 (VGT #74).

Keywords: Viscoelastic; Viscoplastic; Neuroscience; Brain; Gastrointestinal organs; Carbohydrates; Sugar; Walking k-steps; Body weight; Body temperature; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: BW: body weight; BT: body temperature; 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; eAG: estimated average glucose; HbA1C: hemoglobin A1C

1. INTRODUCTION

Over the past 2+ years of the COVID pandemic period, based on the collected data regarding postprandial plasma glucose (PPG) fluctuation, the author has conducted several medical research work regarding the neuroscientific relationship between the brain and the liver's glucose production, and the pancreatic beta cell's insulin secretion. For the past 13 years, he has collected and processed over 3 million data from his own body to conduct certain useful biomedical experiments and analysis work.

After consuming 505 experimental meals that include both soup-based meals (liquid egg) and solid food meals (pan-fried egg or hard-boiled egg), he noticed that there are differences in the peak and average PPG values by eating two different preparation types of egg meals. For example, there are 18 mg/dL of peak PPG difference and 12 mg/dL of average PPG difference between 257 liquid egg meals and 248 solid egg meals. These

observed glucose differences resulting from consuming different egg meal preparation methods (using ~4 grams of carbohydrates/sugar amount and ~4k post-meal walking exercise) extend beyond the knowledge domain in his past 13 years of dealing with "traditional branch studies" of diabetes and food nutrition. Incidentally, during the past 8 years, his normal lifestyle routines consist of consuming less than 15 grams of carbs/sugar for each meal and walking ~4,000 steps after each meal.

This article combines 257 PPG results from his meals with a liquid state of food, i.e. egg drop soup, known as "liquid egg" meals. The liquid meals have a carbs/sugar intake amount of 4.2 grams and post-meal walking exercise of 4,074 steps. In addition, he cooked 248 egg meals in a solid state. The solid egg meals consisted of pan-fried eggs and hard-boiled eggs known as "solid egg" meals that have a carbs/sugar intake of 4.4 grams and post-meal walking exercise of 4,395 steps.

Other than the PPG amplitude difference, he wondered what are the differences from the viewpoint of PPG-associated energies, particularly utilizing 3 different energy models? As a result, this discovery further presented probable proof to spend additional time and effort to delve deeper into the subject of neural communication. Applying his egg meals research findings, he can reduce his average PPG, daily estimated average glucose (eAG), and hemoglobin A1C (HbA1C) level in assisting his continuous effort for type 2 diabetes (T2D) control. More importantly, by knowing the PPG-associated energy quantitatively, he would know what degree of damage to his internal organs resulted from the situation of hyperglycemia, e.g. high PPG.

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 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 and 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 his MI database. In addition, these lifestyle details include some lifetime bad habits and environmental exposures which the author is not affected because he does not have any bad habits and has a low degree of exposure to environmental toxic factors. His developed MI model has a total of 10 categories covering approximately 500 detailed elements that constitute his defined “metabolism 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), diabetic retinopathy (DR), neuropathy, foot ulcer, and hypothyroidism. The 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, eAG, and 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, and diabetic constipation, cancer, dementia, and geriatrics (longevity). He has also developed a few mathematical risk models to calculate the probability percentages of developing various diabetic complications.

From his previous medical research work, he has identified and learned that those associated energy of hyperglycemia conditions are the primary source of causing many diabetic complications which lead to final death. Therefore, a thorough knowledge of these biophysical energies is very important for achieving a better understanding of dangerous medical complications.

In addition, he has identified his FPG level in the early morning which serves as a clear indicator of the overall health condition of pancreatic beta cells as well as functioning as the baseline for the predicted PPG value.

2.2 The author's diabetes case

The author has been a severe T2D patient since 1996. He weighed 220 lb. (100 kg, BMI 32.5) at that time. By 2010, he still weighed 198 lb. (BMI 29.2) with average daily glucose of 250 mg/dL (HbA1C of 10%). During that year, his triglycerides reached 1161 and 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. Other than the cerebrovascular disease (stroke), he has suffered most of the known diabetic

complications, including both macro-vascular and micro-vascular complications.

In 2010, he decided to launch his self-study on endocrinology, diabetes, and food nutrition to save his own life. During 2015 and 2016, he developed four prediction models related to diabetes conditions: weight, PPG, fasting plasma glucose (FPG), and A1C. As a result, from using his developed mathematical metabolism index (MI) model in 2014 and the four prediction tools, by end of 2016, his weight was reduced from 220 lbs. (100 kg, BMI 32.5) to 176 lbs. (89 kg, BMI 26.0), waistline from 44 inches (112 cm) to 33 inches (84 cm), average finger glucose reading from 250 mg/dL to 120 mg/dL, and lab-tested A1C from 10% to ~6.5%. One of his major accomplishments is that he no longer takes any diabetes medications as of 12/8/2015.

In 2017, he has 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 along with the overall metabolic impact due to his irregular life patterns through a busy travel schedule; therefore, his glucose control and overall metabolism state were somewhat affected during this two-year heavier traveling period.

Since 2020, living in a COVID-19 quarantined lifestyle, not only has he published 400+ medical papers in 100+ journals, but he has also reached his best health conditions in the past 26 years. By the beginning of 2022, his weight was further reduced to 168 lbs. (BMI 24.8) along with a 5.8% A1C value (beginning level of pre-diabetes), without having any medication interventions or insulin injections. These good results are due to his non-traveling, low-stress, and regular daily life routines. Of course, his knowledge of chronic diseases, practical lifestyle management experiences, and development of various high-tech tools contribute to his excellent health status since 1/19/2020, the beginning date of his self-quarantined life.

On 5/5/2018, he applied a continuous glucose monitoring (CGM) sensor device on his upper arm and checks his glucose measurements every 5 minutes for a total of ~288 times each day. He has maintained the same measurement pattern to the present day. In his research work, he uses his CGM sensor glucose at a time interval of 15 minutes (96 data per day). Incidentally, the difference in average sensor glucose between 5-minute intervals and 15-minute intervals is only 0.7% (average glucose of 112.15 mg/dL for 5 minutes and average glucose of 111.33 mg/dL for 15 minutes with a correlation of 96% between these two sensor glucose curves) during the period from 2/19/20 to 5/9/22.

Therefore, over the past 13 years, he could study and analyze the collected ~3 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 research is based on the aims of achieving both “high precision” with “quantitative proof” in the medical findings.

The following timetable provides a rough sketch of the emphasis in his medical research during each stage:

2000-2013: Self-study diabetes and food nutrition, developing a data collection and analysis software.

2014: Develop a mathematical model of metabolism, using engineering modeling and advanced mathematics.

2015: Weight & FPG prediction models, using neuroscience.

2016: PPG & HbA1C prediction models, using optical physics, artificial intelligence (AI), and neuroscience.

2017: Complications due to macro-vascular research, such as cardiovascular disease (CVD), coronary heart diseases (CHD), and stroke, using pattern analysis and segmentation analysis.

2018: Complications due to micro-vascular research such as kidney (CKD), bladder, foot, and eye issues (DR).

2019: CGM big data analysis, using wave theory, energy theory, frequency domain analysis, quantum mechanics, and AI.

2020: Cancer, dementia, longevity, geriatrics, DR, hypothyroidism, diabetic foot, diabetic fungal infection, and linkage between metabolism and immunity, learning about certain infectious diseases, such as COVID-19.

2021: Applications of linear elastic glucose theory (LEGT) and perturbation theory from quantum mechanics on medical research subjects, such as chronic diseases and their complications, cancer, and dementia.

2022: Applications of viscoelastic/viscoplastic glucose theory (LEGT) on 92 biomedical research cases and 4 economics research cases.

Again, to date, he has spent around 40,000 hours self-studying and researching medicine. He has collected and calculated more than three million pieces of data regarding his medical conditions and lifestyle details. In addition, he has written nearly 700 medical research notes and published 600+ papers in 100+ various medical and engineering journals. Moreover, he has also given ~120 presentations at ~65 international medical conferences. He has continuously dedicated his time (11-12 hours per day and work each day of a year, without rest) and efforts to his medical research work and shared his findings and learnings with other patients worldwide.

2.3 History of his neuroscience study

Since 1/1/2012, the author developed research-oriented and AI-based software on his iPhone to collect all of his diabetes-related medical data and lifestyle details. In addition, he started to collect his glucose data using a CGM sensor device on 5/5/2018. He accumulated approximately 96 glucose data per day with 13 glucose data per meal over 3 hours or 9 glucose data per meal over 2 hours.

In mid-2018, he noticed some differences in his PPG results from his variety of meals. Therefore, he started to use his own body to conduct the necessary experiments by eating certain meals with simple food ingredients with low carbs/sugar amounts and preparing them with different cooking methods. For

example, he started to eat a “pan-fried egg” meal with one single large egg on 5/11/2018, an “egg drop soup” meal with one single large egg on 12/30/2019, and a “hard-boiled egg” meal with one single large egg on 6/28/2020. As of 9/25/2019, he launched a special research project regarding various meal preparation methods or food cooking methods using one large egg as the major food nutritional ingredient, resulting in quite different PPG results. In the second half of 2020, he noticed the PPG waveform patterns and peak PPG values were fairly close to each other between the pan-fried egg and hard-boiled egg meals; therefore, he combined these two types of meals into one group of “solid egg” meals.

He described the results from Phase 1 of his research work, from 9/25/2019 to 2/11/2020, by utilizing the collected data from the 30 egg drop soup and 30 pan-fried egg meals.

For Phase 2 of his research work, from 9/25/2019 to 5/29/2020, he further collected an additional 39 liquid meals and 36 solid meals with identical food materials and cooking methods. During this phase, he accumulated a total of 69 liquid meals (egg drop soup) and 66 solid meals (pan-fried egg). He also enhanced his software program to present the collected glucose data using the Candlestick K-Line chart. The chart reflects five key PPG values at different time instants between liquid food and solid food.

For Phase 3, from 9/25/2019 through 8/13/2020, he accrued additional data from a total of 95 liquid egg meals (egg drop soup) and 110 solid egg meals (68 pan-fried eggs and 42 hardboiled eggs). In comparison to the Phase 2 data, he collected an additional 26 liquid meals and 44 solid meals over 76 days.

In Phase 4, from 8/14/2020 through 11/25/2020, he gathered more data to reach a total of 159 liquid egg and 126 solid egg meals. In comparison to the Phase 3 data, he collected an extra 64 liquid meals and 16 solid meals over 100 days. During Phase 4, he started to add in 17 tea-only meals to serve as the baseline for PPG comparison.

In Phase 5, from 11/26/2020 through 12/26/2020, he accumulated additional data to reach a total of 165 liquid egg meals, 133 solid egg meals, and 30 tea-only meals. In comparison to the Phase 4 data, he collected

an additional 6 liquid meals, 7 solid meals, and 13 tea-only meals.

During the five phases of the food and glucose experiments, he focused on investigating the relationships among different food inputs, such as meal nutritional contents, cooking methods, physical states of liquid vs. solid), peak and average PPG values, and PPG waveforms. When he observed the different physical phenomena of glucose waves from liquid and solid meals, he wondered why these two different cooking methods would end up with such large and obvious differences in the two PPG waveforms, regardless of having identical food nutritional ingredients and exercise input amounts. Most of his medical associates or colleagues, in the fields of internal medicine and food nutrition, have mentioned the important relationship between PPG level and food nutritional components, particularly carbohydrates and sugar intake amounts along with the intensity and duration of exercise influence PPG values. Therefore, he decided to experiment with eating the same food ingredients but with two different cooking or preparation methods. It should be noted that he has kept the intensity and duration of his post-meal walking at the same level of over 4,000 steps.

By 2/11/2020 with ~30 meals in each liquid and solid category, he already discovered the vast differences in PPG values existing between these two types of meals. At that moment, he came up with a preliminary neural communication hypothesis of his own regarding the brain and certain internal organs' communication via the nervous system. He then decided to extend his experiments to verify this neural communication model with the path of sending messages from the stomach to the brain and then forwarding the brain's feedback message, or marching order, to the liver and pancreas. This communication system carries the PPG production or release amount of information at different time instances. He also decided to use a larger experimental database with some mathematical tools for his follow-up analysis.

2.4 Neuroscience article

On May 27, 2020, David Templeton, a writer for the Pittsburgh Post-Gazette presented an excellent medical discovery report. On May

29, 2020, the author read this report regarding this specific research work performed at the University of Pittsburgh (Reference 5).

Here is an excerpt:

Published May 18th of 2020 in the Proceedings of the National Academy of Sciences, an important world first, a study co-authored by Dr. Levinthal and Dr. Peter Strick, both from the Pitt School of Medicine, has explained what parts of the brain's cerebral cortex influence stomach function and how it can impact health. Dr. Peter Strick is a world leader in establishing evidence that internal organs are strongly modulated at the highest levels by the cerebral cortex. It's been traditional in biology and medicine that the internal organs are self-regulatory through the autonomic nervous system, largely independent of higher brain regions. Dr. Strick's previous research, for instance, also showed that similar areas of the cerebral cortex also control kidney and adrenal function. That course of research now could extend to "the heart, liver, and pancreas to discover more about how the brain coordinates control of internal organs," said Mr. Sterling who holds a Ph.D. in neuroscience. When it comes to trusting your gut, it already is well-established that the stomach and gut send "ascending" signals to the brain in a way that influences brain function. But the study has found that the "central nervous system both influences and is influenced by the gastrointestinal system." What people haven't understood to date, Dr. Strick said, is that the brain also has "descending influences on the stomach" with various parts of the brain involved in that signaling, including those areas that control movement and emotions. Those areas control the stomach "as directly as cortical control of movement. These are not trivial influences."

This published report has described exactly what the author, for almost two years, guessed and felt about the neural communication model between the brain and other internal organs. Although by training, he is a mathematician, software expert, physicist, and mechanical/structural engineer, he is not a medical doctor, neuroscientist, biologist, or chemist. However, during his research work in this area since 9/15/2019, he discovered and

proven his “gut-feeling” or “hunch” regarding the existence of these “ascending” messages from the stomach to the brain regarding food entry, and “descending” messages from the brain to the liver and pancreas regarding glucose production or release amount. He also verified these physical observations through his carefully developed mathematical models and numerical examinations. Specifically speaking, his biomedical interpretation of certain physical phenomena would be verified through a few carefully established mathematical models, and then confirmed his hypothesis or theory using artificial intelligence (AI) techniques, big data analytics, or straightforward numerical analysis.

In 2019, he was cautious in using the words, such as hypotheses, guess, and might be, to describe his gut feelings generated from the observed findings, but now he has found supporting academic and biomedical proof from other neuroscientific experts in the medical field.

His friend, Dr. Nelson Hendler, a nerve pain specialist and a neuroscientist from Johns Hopkins University provided the following comments:

“Embryologically, the brain and gut arise from the same neuroectodermal tissue. This is why the gut has many of the same neurosynaptic transmitters as the brain does. In fact, many pharmaceutical houses use gut preparation to predict how a drug may work in the brain. Chief differences among these receptors are various types of serotonin.”

Since the author has already published a few articles on this subject in early 2020, by using various food and glucose data, he will forgo the detailed explanations and similar conclusions based on this relatively “larger” size of data from egg meals experiments, including the data from drinking tea only. Although there are plenty of tea-only or water-only meals included in this experiment, its results have demonstrated that the tea-only or water-only meals (actually, they are intermittent fasting) can serve as a useful baseline reference to support the relative positions of both solid and liquid egg waveforms in his 2+ year-long project on food and glucose neuroscientific experiment.

The reason he chose tea as his baseline is twofold. First, he hypothesizes that the stomach sends a food-arrival message and its associated physical state of either solid or liquid to the brain. The brain then considers the liquid egg drop soup as being “similar” to drinking water or tea. Second, he has conducted some experiments on drinking coffee only, both regular and decaffeinated. However, his exploration has found that regular coffee produces an extremely high level of PPG which would damage his health. The decaffeinated coffee provides somewhat better PPG results, but they are still much higher than liquid eggs may be due to the added cream.

Starting from 11/8/2020, he initiated his experiments by adding in “tea only”. Finally, by 8/15/2021, he feels that he has collected sufficient data on both soup meals and intermittent fasting (IF) for writing another report. In addition, he includes his study of the glucose gap in the morning which is also resulted from the brain and neural functions.

As of 5/10/2022, he has collected even more data and decided to conduct one additional study with the insertion of VGT analysis results regarding energies from liquid egg and solid egg meals, respectively.

2.5 Elasticity, plasticity, viscoelasticity, and viscoplasticity (LEGT & VGT)

The difference between elastic materials and viscoelastic materials (from “Soborthans, innovating shock and vibration solutions”).

What are elastic materials?

Elasticity is the tendency of solid materials to return to their original shape after forces are applied on them. When the forces are removed, the object will return to its initial shape and size if the material is elastic.

Medical analogy: The medical application is when cause or risk factors are reduced or removed, the symptoms of certain disease would be improved or ceased.

What are viscous materials?

Viscosity is a measure of a fluid’s resistance to flow. A fluid with large viscosity resists motion. A fluid with low viscosity flows. For example, water flows more easily than syrup

because it has a lower viscosity. High viscosity materials might include honey, syrups, or gels – generally things that resist flow. Water is a low viscosity material, as it flows readily. Viscous materials are thick or sticky or adhesive. Since heating reduces viscosity, these materials don't flow easily. For example, warm syrup flows more easily than cold.

What is viscoelastic?

Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Synthetic polymers, wood, and human tissue, as well as metals at high temperature, display significant viscoelastic effects. In some applications, even a small viscoelastic response can be significant.

Medical analogy: Viscoelastic behavior means material has “time-dependent” characters. Biomedical data, i.e. biomarkers, are time-dependent due to body cells are organic which changes with time constantly.

Elastic behavior versus viscoelastic behavior

The difference between elastic materials and viscoelastic materials is that viscoelastic materials have a viscosity factor and the elastic ones don't. Because viscoelastic materials have the viscosity factor, they have a strain rate dependent on time. Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed; however, a viscoelastic substance does.

Medical analogy: Most of the biomarkers display time-dependency; therefore, they have both change-rate of time and viscosity factor behaviors. Viscoelastic biomarkers do dissipate energy when a causing force is applied to it.

The following brief introductions are excerpts from Wikipedia:

“Elasticity (physics):

The physical property is when materials or objects return to their original shape after deformation.

In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and

shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remains in its deformed state.

Hooke's law states that the force required to deform elastic objects should be directly proportional to the distance of deformation, regardless of how large that distance becomes. This is known as perfect elasticity, in which a given object will return to its original shape no matter how strongly it is deformed. This is an ideal concept only; most materials that possess elasticity in practice remain purely elastic only up to very small deformations, after which plastic (permanent) deformation occurs.

In engineering, the elasticity of a material is quantified by the elastic modulus such as the Young's modulus, bulk modulus or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic limit or yield strength is the maximum stress that can arise before the onset of plastic deformation.

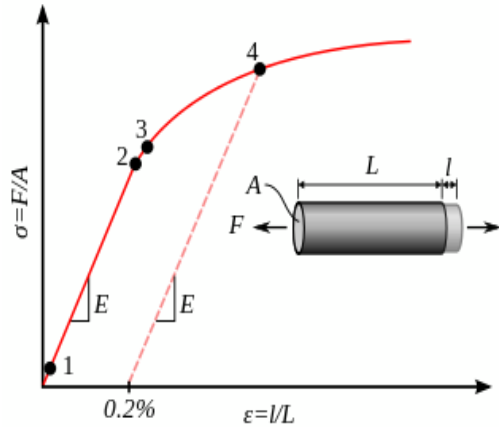
Medical analogy: The elastic behavior analogy in medicine can be expressed by the metal rod analogy for the postprandial plasma glucose (PPG). Consuming carbohydrates and/or sugar acts like a tensile force to stretch a metal rod longer, while post-meal exercise acts like a compressive force to suppress a metal rod shorter. If lacking food consumption and exercise, the metal rod (analogy of PPG) will remain its original length, for a non-diabetes or less severe type 2 diabetes (T2D) patient.

Plasticity (physics):

Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

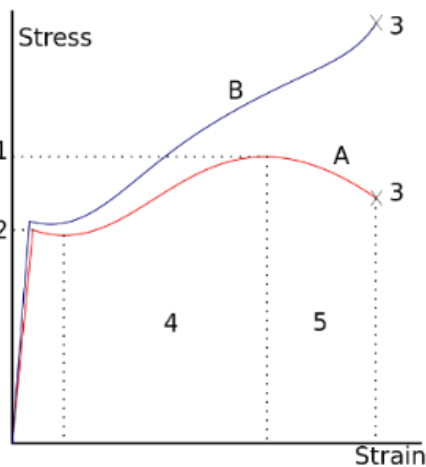
In physics and materials science, plasticity, also known as plastic deformation, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces. For example, a solid piece of metal being bent or pounded into a new shape displays

plasticity as permanent changes occur within the material itself. In engineering, the transition from elastic behavior to plastic behavior is known as yielding. Plastic deformation is observed in most materials, particularly metals, soils, rocks, concrete, and foams.



A stress-strain curve showing typical yield behavior for nonferrous alloys.

1. True elastic limit
2. Proportionality limit
3. Elastic limit
4. Offset yield strength



A stress-strain is typical of structural steel.

- 1: Ultimate strength
- 2: Yield strength (yield point)
- 3: Rupture
- 4: Strain hardening region
- 5: Necking region
- A: Apparent stress (F/A_0)
- B: Actual stress (F/A)

For many ductile metals, tensile loading applied to a sample will cause it to behave in an elastic manner. Each increment of load is accompanied by a proportional increment in extension. When the load is removed, the piece returns to its original size. However, once the load exceeds a threshold – the yield strength – the extension increases more rapidly than in the elastic region; now when the load is removed, some degree of extension will remain.

Medical analogy: A plastic behavior analogy in medicine is the PPG level of a severe T2D patient. Even consuming a smaller amount of carbs/sugar, the patient’s PPG will rise sharply which cannot be totally brought down to a healthy PPG level even with a significant amount of exercise. This means the PPG level has exceeded its “elastic limit” and entering into a “plastic range”.

Viscoelasticity:

Property of materials with both viscous and elastic characteristics under deformation.

In materials science and continuum mechanics, viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and immediately return to their original state once the stress is removed.

Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain. Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

In the nineteenth century, physicists such as Maxwell, Boltzmann, and Kelvin researched and experimented with creep and recovery of glasses, metals, and rubbers. Viscoelasticity was further examined in the late twentieth century when synthetic polymers were engineered and used in a variety of applications. Viscoelasticity calculations depend heavily on the viscosity variable, η . The inverse of η is also known as fluidity, ϕ . The value of either can be derived as a

function of temperature or as a given value (i.e. for a dashpot).

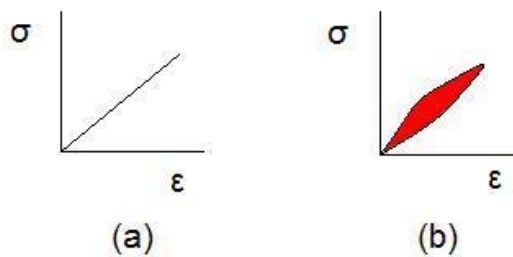
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit rubber-like behaviors explained by the thermodynamic theory of polymer elasticity.

Cracking occurs when the strain is applied quickly and outside of the elastic limit. Ligaments and tendons are viscoelastic, so the extent of the potential damage to them depends both on the rate of the change of their length as well as on the force applied.

A viscoelastic material has the following properties:

- hysteresis is seen in the stress-strain
- stress relaxation occurs: step constant strain causes decreasing stress
- creep occurs: step constant stress causes increasing strain
- its stiffness depends on the strain rate or the stress rate.

Elastic versus viscoelastic behavior:



Stress-strain curves for a purely elastic material (a) and a viscoelastic material (b). The red area is a hysteresis loop and shows the amount of energy lost (as heat) in a loading and unloading cycle. It is equal to $\oint \sigma d\epsilon$ where σ is stress and ϵ is strain. In other words, the hysteresis loop area represents the amount of energy during the loading and unloading process.

Unlike purely elastic substances, a viscoelastic substance has an elastic component and a viscous component. The viscosity of a viscoelastic substance gives the

substance a strain rate dependence on time. Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed. However, a viscoelastic substance dissipates energy when a load is applied, then removed. Hysteresis is observed in the stress-strain curve, with the area of the loop being equal to the energy lost during the loading cycle. Since viscosity is the resistance to thermally activated plastic deformation, a viscous material will lose energy through a loading cycle. Plastic deformation results in lost energy, which is uncharacteristic of a purely elastic material's reaction to a loading cycle.

Viscoplasticity:

Viscoplasticity is a theory in continuum mechanics that describes the rate-dependent inelastic behavior of solids. Rate-dependence in this context means that the deformation of the material depends on the rate at which loads are applied. The inelastic behavior that is the subject of viscoplasticity is plastic deformation which means that the material undergoes unrecoverable deformations when a load level is reached. Rate-dependent plasticity is important for transient plasticity calculations. The main difference between rate-independent plastic and viscoplastic material models is that the latter exhibit not only permanent deformations after the application of loads but continue to undergo a creep flow as a function of time under the influence of the applied load.

Medical analogy: In viscoelastic or viscoplastic analysis, the stress component equals the strain change rate of time multiplying with the viscosity factor, or

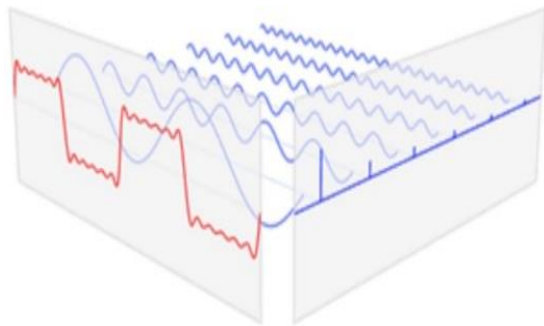
$$\begin{aligned} \text{Stress } (\sigma) &= \text{strain } (\epsilon) \text{ change rate} * \text{viscosity factor } (\eta) \\ &= d\epsilon/dt * \eta \end{aligned}$$

$$\begin{aligned} \text{The hysteresis loop area} &= \text{the integrated area of stress } (\sigma) \text{ and strain } (\epsilon) \text{ curve} \\ &= \oint \sigma d\epsilon \end{aligned}$$

2.6 From time-domain to frequency domain via Fourier transform

In physics, electronics, control systems engineering, and statistics, the frequency domain refers to the analysis of mathematical functions or signals concerning

frequency, rather than time.[1] Put simply, a time-domain graph shows how a signal changes over time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the phase shift that must be applied to each sinusoid to be able to recombine the frequency components to recover the original time signal.



The Fourier transform converts the function's time-domain representation, shown in red, to the function's frequency-domain representation, shown in blue. The component frequencies, spread across the frequency spectrum, are represented as peaks in the frequency domain.

A given function or signal can be converted between the time and frequency domains with a pair of mathematical operators called transforms. An example is the Fourier transform, which converts a time function into a complex-valued sum or integral of sine waves of different frequencies, with amplitudes and phases, each of which represents a frequency component. The "spectrum" of frequency components is the frequency-domain representation of the signal. The inverse Fourier transform converts the frequency-domain function back to the time-domain function. A spectrum analyzer is a tool commonly used to visualize electronic signals in the frequency domain.

Advantages

One of the main reasons for using a frequency-domain representation of a problem is to simplify the mathematical analysis. For mathematical systems governed by linear differential equations, a

very important class of systems with many real-world applications, converting the description of the system from the time domain to a frequency domain converts the differential equations to algebraic equations, which are much easier to solve.

In addition, looking at a system from the point of view of frequency can often give an intuitive understanding of the qualitative behavior of the system, and a revealing scientific nomenclature has grown up to describe it, characterizing the behavior of physical systems to time-varying inputs using terms such as bandwidth, frequency response, gain, phase shift, resonant frequencies, time constant, resonance width, damping factor, Q factor, harmonics, spectrum, power spectral density, eigenvalues, poles, and zeros.

An example of a field in which frequency-domain analysis gives a better understanding than the time domain is music; the theory of operation of musical instruments and the musical notation used to record and discuss pieces of music is implicitly based on the breaking down of complex sounds into their separate component frequencies (musical notes).

Magnitude and phase

In using the Laplace, Z-, or Fourier transforms, a signal is described by a complex function of frequency: the component of the signal at any given frequency is given by a complex number. The modulus of the number is the amplitude of that component, and the argument is the relative phase of the wave. For example, using the Fourier transform, a sound wave, such as human speech, can be broken down into its component tones of different frequencies, each represented by a sine wave of different amplitude and phase. The response of a system, as a function of frequency, can also be described by a complex function. In many applications, phase information is not important. By discarding the phase information, it is possible to simplify the information in a frequency-domain representation to generate a frequency spectrum or spectral density. A spectrum analyzer is a device that displays the spectrum, while the time-domain signal can be seen on an oscilloscope.

Types

Although "the" frequency domain is spoken of in the singular, there are several different mathematical transforms that are used to analyze time-domain functions and are referred to as "frequency domain" methods. These are the most common transforms and the fields in which they are used:

- Fourier series – periodic signals, oscillating systems.
- Fourier transform – aperiodic signals, transients.
- Laplace transform – electronic circuits and control systems.
- Z transform – discrete-time signals, digital signal processing.
- Wavelet transform — image analysis, data compression.

More generally, one can speak of the transform domain for any transform. The above transforms can be interpreted as capturing some form of frequency, and hence the transform domain is referred to as a frequency domain.

Discrete frequency domain

The Fourier transform of a periodic signal has energy only at a base frequency and its harmonics. Another way of saying this is that a periodic signal can be analyzed using a discrete frequency domain. Dually, a discrete-time signal gives rise to a periodic frequency spectrum. Combining these two, if we start with a time signal which is both discrete and periodic, we get a frequency spectrum which is also both discrete and periodic. This is the usual context for a discrete Fourier transform.

History of term

The use of the terms "frequency domain" and "time domain" arose in communication engineering in the 1950s and early 1960s, with "frequency domain" appearing in 1953. See time domain: the origin of the term for details.

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 data table of both TD-squared PPG and SD-VGT with the source data.

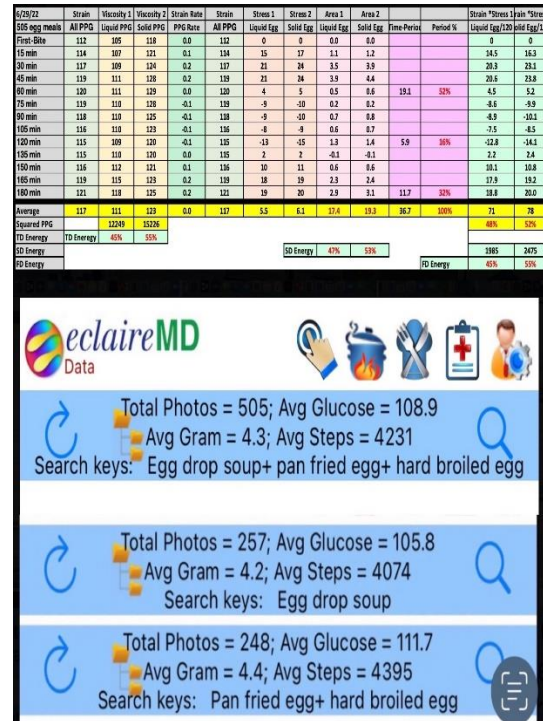


Figure 1: Data table of this study.

Figure 2 depicts three graphic results, three PPG waveforms in the time domain, and a stress-strain diagram of VGT analysis.

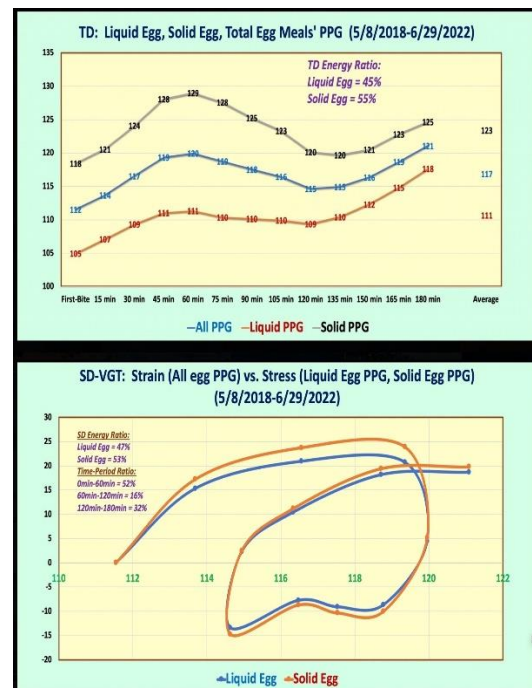


Figure 2: PPG in time-domain and SD-VGT stress-strain diagram.

Figure 3 depicts FD-FFT operations and FD energy results.

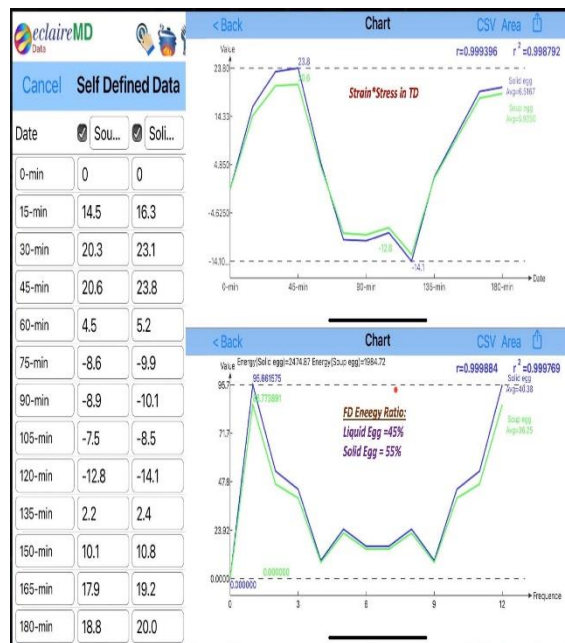


Figure 3: FD-FFT energy of egg meals.

4. CONCLUSION

In summary, there are 3 observations listed regarding different estimated PPG energy levels using 3 different tools of TD-squared PPG, SD-VGT of hysteresis loop area, and FD-FFT of (strain*stress) variable:

(1) From the three PPG waveforms in a time domain, the 3-hour solid egg PPG waveform shows a mountain shape. This solid egg meal PPG waveform has an average PPG of 123 mg/dL and peak PPG at 60-minutes of 129 mg/dL. On the other hand, the 3-hour liquid egg PPG waveform has a “pseudo-flatline” shape or more of a “rolling-hill” shape, but with an upward titled tail between the second and third hour after the first bite of his meal. This liquid egg meal PPG waveform has an average PPG of 111 mg/dL and peak PPG at 60-minutes of 111 mg/dL. Actually, from a research viewpoint, he should focus on the segment of 0-min to 120-min only while ignoring the segment of 120-min to 180-min since his post-meal exercise usually ends at around 120-min. In summary, between 248 solid and 257 liquid egg meals, the difference in average PPG is 12 mg/dL and peak PPG is 18 mg/dL. More importantly, his squared PPG energy ratio is 45% for liquid eggs and 55% for solid eggs with a 10% TD energy difference.

(2) Applying the space-domain viscoelastic or viscoplastic glucose (SD-VGT) energy tool, both of his two hysteresis loops’ moving paths look like a “bow-tie” shape and the ratio of two hysteresis loop areas associated with solid eggs versus liquid eggs is 53% versus 47% (similar results to each other with a 6% higher contribution from solid egg meals). This indicates both solid egg meal energy and liquid egg meal energy are making an almost equal amount of contribution (with a mere 6% difference) to the PPG of all egg meals despite solid egg meal’s average PPG being 11% higher than liquid egg meal’s average PPG. In addition, his 3 time-period energy ratios are 0-min to 60-min at 52%, 60-min to 120-min at 16%, and 120-min to 180-min at 32%. This reflects that, from the energy viewpoint, the period of 120-min to 180-min is important enough and cannot be ignored (~1/3).

(3) Applying the frequency-domain Fourier transform (FD-FFT) energy tool and using a new variable of (strain*stress) from SD, his FD energy ratio of solid eggs versus liquid eggs is 55% versus 45% (a 10% higher contribution from solid egg meals). This finding is quite similar to the TD’s average PPG amplitude comparison between meals in which solid eggs’ average PPG is 11% higher than liquid eggs’ average PPG.

From a neuroscientific viewpoint, the author could utilize the developed GH-Method: math-physical medicine methodology (MPM) and learned biomedical knowledge from his medical research work to “trick” or “trigger” the cerebral cortex of the brain into producing or releasing a “lesser” amount of PPG from the liver which is resulted in from liquid egg drop soup meals, without worrying about the important food nutritional balance. In other words, by changing the food cooking or preparation method to transform meals from a solid phase into a liquid phase (a fundamental concept from physics), it can help lower peak PPG value, average PPG level, and associated energy level without altering the required food nutritional balance. The brain actually considers liquid food similar to drinking tea or water from his research findings of nearly 500 intermittent fasting experiments.

This article offers some practical ideas and effective ways how to control a T2D patient’s daily glucose situation through the

biophysical findings and the energy analyses related to the food preparation method.

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.eclaircmd.com.

Readers may use this article as long as the work is properly cited, their use is educational and not for profit, and the author's original work is not altered.

To read additional published VGT and FD analysis results on medical research, please view them in the following three journals:

- (1) Special Issue. The GH-Method. (<https://www.theghmethod.com>)
- (2) Journal of Applied Material Science & Engineering Research (contact: Catherine)
- (3) Advances in Bioengineering and Biomedical Science Research (contact: Sonny Hazi).

An external source of referenced paper

- 1) Templeton D. Pitt study shows brain and stomach connections are a two-way street. Pittsburgh Post-Gazette.

Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

Gerald C. Hsu

