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The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #79): A Sensitivity Analysis on Selecting Normalization Baselines for 3 Viscosity Factors, Fasting Plasma Glucose, Sleep Scores, and Sleep Hours to Study a Single Symptom of HbA1C versus 3 Measured Causes Using 3 Domain Analyses of Time, Space, and Frequency Based on GH-Method: Math-Physical Medicine (No. 669)

Gerald C. Hsu*

eclaireMD Foundation, USA

Abstract

The author applied viscoelastic and viscoplastic theories (VGT) to conduct 78 sets of studies regarding single or multiple symptoms (strains ε) versus multiple causes (stresses σ) in the biomedical field with paper No. 578 beginning on 1/8/2022. In this article, he used 5,864 data of daily HbA1C (A1C), daily fasting plasma glucose (FPG), daily sleep scores, and daily seeping hours collected from a continuous glucose monitoring (CGM) sensor device and other health measuring devices, such as a Fitbit watch, Oura ring, and eclaireMD chronic software over ~7.5 years from 1/1/2015 to 5/15/2022. The reason FPG was chosen first as the major cause of A1C is that it reflects the health status of pancreatic beta cells that produce and release insulin to control glucose levels. Although PPG numerically contributes the bulk of daily average glucose, PPG's biggest contribution is also from the quality and quantity of insulin. His daily sleep score is based on the following 16 different types of input items: • sleeping hours • wakeup times during sleep • annoying issues • degree of freshness & restfulness • degree of wake-up headache • degree of night dreams • comfortable room temperature • degree of physical sickness • sleep pattern disturbance • itchy skin • numbness of hands or feet • hungry feeling during sleep • feeling sleepy at wakeup • leg muscle cramp • cold feeling of legs or feet • snoring during sleep. In the above-mentioned 16 items in the author's case, the most important items with a higher degree of variance are sleeping hours (for rejuvenating energy of general health concerns) and the number of wake-up times at night (due to his bladder damage caused by diabetes). His software-based and "subjective" sleep measurement methods are different from the hardware-based "objective" measurement methods via heart rate, body temperature, REM, deep sleep versus light sleep, etc. The defined dividing lines between healthy and unhealthy conditions are: Sleep score = 6.0; Sleep hours = 7 hours; FPG = 99 mg/dL; HbA1C = 5.6% (unused baseline). The defined equations for estimated daily finger-glucose average (eGA) and daily estimated finger-based HbA1C (A1C) are: eGA = FPG * 0.25 + PPG * 0.75; A1C = eGA /17. Initially, he compares his FPG, sleep scores, and sleep hours against A1C via a time-domain analysis to verify their corresponding correlation coefficients to develop a "biophysical sense of connectivity" of these biomarkers. Secondly, he used the following defined VGT equation from engineering and physics to address the unique "time-dependency characteristic" of biomedical symptoms and causes to establish several stress-strain diagrams (i.e. cause-symptom diagrams) in a space domain (SD): Strain = ε (A1C) = individual A1C value at the present time. Stress = σ (based on the change rate of strain, A1C rate, multiplying with a chosen viscosity factor η, FPG, sleep score, or sleep hours) = η * (dε/dt) = η * (d-strain/d-time) = (viscosity factor η using individual FPG, sleep score, or sleep hours at present time) * (A1C at present time - A1C at a previous time), where the causes or viscosity factors are further grouped into two different categories in this study. First category: non-modified original data from various measurements. FPG = a measured finger-piercing glucose value in the early morning, Sleep score = calculated daily sleep score based on 16 items, Sleep hours = recorded sleeping hours each night via Fitbit watch and Oura ring. Second category: normalized data based on dividing lines between healthy vs. unhealthy. Normalized FPG = FPG / 99 (99 mg/dL is the dividing line between normal and diabetes), Normalized sleep score = daily sleep

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*Corresponding author: Gerald C. Hsu, eclaireMD Foundation, USA

score / 6.0 (6.0 is the target for maintaining his healthy sleep conditions), Normalized sleep hours = 7.0 / sleep hours (7 hours is his target of minimum sleeping hours). Thirdly, he applies the Fourier Transform operation to convert the biomarker data, i.e. FPG, sleep score, sleep hours, from a time domain or TD (x-axis is the time component and y-xis is the biomarker's amplitude) into a frequency domain of FD (x-axis is frequency component and the y-axis is biomarker's energy amplitude). The total area underneath the frequency curve is the total energy associated with each biomarker. In summary, there are 5 key findings from this comparison study: (1) From the TD analysis results, the correlations are: FPG vs. A1C = 92% (highest); sleep score vs. A1C = 73%; and sleep hours vs. A1C = - 62%. This finding has proven the usefulness of statistical correlation studies for developing a "biophysical instincts" of connectivity among these biomarkers. (2) Utilizing the VGT energy tool to investigate A1C (strain ε) versus 3 viscosity factors (3 η, i.e. 3 causes of FPG, sleep score, and sleep hours), using measured data to calculate their associated energies (or degree of influences on A1C). From the x-axis (A1C, strain ε) values of the stress-strain diagram, A1C values are varying within the range of 6.0% to 7.7% over the past ~7.5 years. The ranking of both stress values and hysteresis loop areas are FPG (94%), sleep scores (1%), and sleep hours (5%). These value distributions are based on non-modified originally measured data of FPG, sleep scores, and sleep hours. This shows that FPG is the most significant contribution (94%) to A1C formation, contribution from sleep hours is higher than the contribution from sleep scores (5:1 ratio). These results proved that the contribution from the quality and quantity of insulin secreted by pancreatic beta cells is far more important to A1C than the contribution from the sleep category. These findings from nonlinear dynamic VGT in SD are quite similar to the findings from the correlation study in TD. (3) Utilizing the same VGT tool to investigate the same A1C (strain ε) versus 3 viscosity factors (η), i.e. FPG, sleep score, and sleep hours, except these 3 causes (viscosity factors η) using the normalized data to calculate their associated energies (or degree of influences on A1C). From the x-axis (A1C, strain ε) values of the stress-strain diagram, A1C values are varying within the range of 6.0% to 7.7% over the past ~7.5 years. However, the ranking of both stress values and hysteresis loop areas are in a very different pattern of FPG (34%), sleep scores (31%), and sleep hours (35%). It should be pointed out that an energy split of 33%: 33%: 33% (1/3 each) is the perfect healthy situation. These value distributions are based on normalized data of FPG, sleep score, and sleep hours. This indicates that FPG, sleep score, and sleep hours based on "normalized healthy/unhealthy standards" have almost equal amounts of contributions to A1C formation. This interesting finding of equal contribution from 3 causes resulted from the normalization process with the average cause results being FPG (1.1), carbs (1.0), and steps (1.1). (4) These two VGT analyses using both 3 measured causes versus 3 normalized causes are particularly interesting to him. The TD analysis utilizing statistical correlation reflects the degree of connectivity between 3 causes versus A1C. However, the VGT analysis results can provide a quantitative sense regarding the different contribution levels from these 3 causes. The VGT results using measured data have also reflected the measured energy split of (FPG insulin = 94% : Sleep score = 1% : Sleep hours = 5%). On the contrary, the VGT results using normalized data have indicated a different influence contribution map through the normalized energy split of (FPG insulin = 34% : Sleep score = 31% : Sleep hours = 35%). These dimensionless variables, i.e. normalization process, actually offer a clear picture regarding the division between healthy versus unhealthy conditions. (5) From the FD energy analysis results (FPG insulin = 99.8%, Sleep score = 0.002%, Sleep hours = 0.2%), it is evident that FPG insulin almost occupies the entire energy contribution. Although FD results are highly similar to SD results, they do show small numerical differences. The summary statement from the analysis findings is that pancreatic beta cells insulin (via FPG) is the primary contributor to A1C formation while supplemented by sleep conditions. For the period from Y2021 to Y2022, all of its 3 causes have contributed very small percentages (FPG 16%, sleep score 14%, sleep hours 18%) to A1C formation. This is a result of his healthier conditions of FPG < 99 mg/dL, sleep score <6.0, sleep hours >6.4 hours, and near 7 hours).

Keywords: Viscoelastic; Viscoplastic; Postprandial plasma glucose; Sleep score; Sleep hours; Type 2 diabetes; Glucose; Fasting plasma glucose; HbA1C

Abbreviations: TD: time-domain; SD: space domain; CGM: continuous glucose monitoring; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; MPM: math-physical medicine

1. INTRODUCTION

The author applied viscoelastic and viscoplastic theories (VGT) to conduct 78 sets of studies regarding single or multiple symptoms (strains ε) versus multiple causes (stresses σ) in the biomedical field with paper No. 578 beginning on 1/8/2022.

In this article, he used 5,864 data of daily HbA1C (A1C), daily fasting plasma glucose (FPG), daily sleep scores, and daily seeping hours collected from a continuous glucose monitoring (CGM) sensor device and other health measuring devices, such as a Fitbit watch, Oura ring, and eclaireMD chronic software over ~7.5 years from 1/1/2015 to 5/15/2022.

The reason FPG was chosen first as the major cause of A1C is that it reflects the health status of pancreatic beta cells that produce and release insulin to control glucose levels. Although PPG numerically contributes the bulk of daily average glucose, PPG's biggest contribution is also from the quality and quantity of insulin.

His daily sleep score is based on the following 16 different types of input items:

- sleeping hours
- wakeup times during sleep
- annoying issues
- degree of freshness & restfulness
- degree of wake-up headache
- degree of night dreams
- comfortable room temperature
- degree of physical sickness
- sleep pattern disturbance
- itchy skin
- numbness of hands or feet
- hungry feeling during sleep
- feeling sleepy at wakeup
- leg muscle cramp
- cold feeling of legs or feet
- snoring during sleep

In the above-mentioned 16 items in the author's case, the most important items with a higher degree of variance are sleeping hours (for rejuvenating energy of general health concerns) and the number of wake-up times at night (due to his bladder damage caused by diabetes). His software-based and "subjective" sleep measurement methods are different from the hardware-based "objective" measurement methods via heart rate, body temperature, REM, deep sleep versus light sleep, etc.

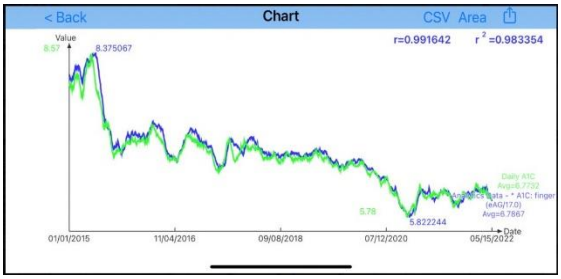
The defined dividing lines between healthy and unhealthy conditions are

Sleep score = 6.0
Sleep hours = 7 hours
FPG = 99 mg/dL
HbA1C = 5.6% (unused baseline)

The defined equations for estimated daily finger-glucose average (eGA) and daily estimated finger-based HbA1C (A1C) are:

eGA = FPG * 0.25 + PPG * 0.75

A1C = eGA /17 (see diagram below)



Initially, he compares his FPG, sleep scores, and sleep hours against A1C via a time-domain analysis to verify their corresponding correlation coefficients to develop a "biophysical sense of connectivity" of these biomarkers.

Secondly, he used the following defined VGT equation from engineering and physics to address the unique "time-dependency characteristic" of biomedical symptoms and causes to establish several stress-strain diagrams (i.e. cause-symptom diagrams) in a space domain (SD):

Strain
= ε (A1C)
= individual A1C value at the present time

Stress
= σ (based on the change rate of strain, A1C rate, multiplying with a chosen viscosity factor η, FPG, sleep score, or sleep hours)
= η * (dε/dt)
= η * (d-strain/d-time)

= (viscosity factor η using individual FPG, sleep score, or sleep hours at present time) * (A1C at present time - A1C at a previous time)

Where the causes or viscosity factors are further grouped into two different categories in this study.

First category:
Non-modified original data from various measurements

FPG = a measured finger-piercing glucose value in the early morning

Sleep score = calculated daily sleep score based on 16 items

Sleep hours = recorded sleeping hours each night via Fitbit watch and Oura ring

Second category:
Normalized data based on dividing lines between healthy vs. unhealthy

Normalized FPG = FPG / 99 (99 mg/dL is the dividing line between normal and diabetes)

Normalized sleep score = daily sleep score / 6.0 (6.0 is the target for maintaining his healthy sleep conditions)

Normalized sleep hours = 7.0 / sleep hours (7 hours is his target of minimum sleeping hours)

Thirdly, he applies the Fourier Transform operation to convert the biomarker data, i.e. FPG, sleep score, sleep hours, from a time domain or TD (x-axis is the time component and y-xis is the biomarker's amplitude) into a frequency domain of FD (x-axis is frequency component and the y-axis is biomarker's energy amplitude). The total area underneath the frequency curve is the total energy associated with each biomarker.

2. METHODS

2.1 MPM background

To learn more about his developed GH-Method: math-physical medicine or MPM methodology, readers can select the following three articles from the 400+ published medical papers.

The first paper, No. 386, describes his MPM methodology in a general conceptual format. 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 versus the MPM approach. The third paper, No. 397, depicts a general flow diagram containing ~10 key MPM research methods and different tools.

All of the listed papers in the Reference section are his written and published medical research papers.

2.2 The author's case of diabetes

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.

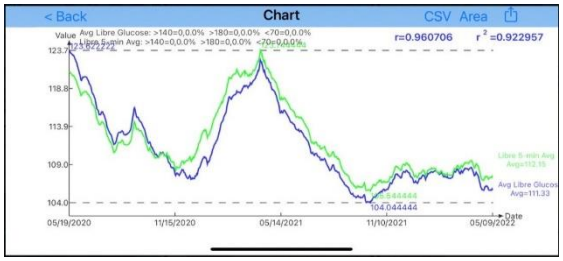
In 2010, he decided to launch his self-study on endocrinology, diabetes, and food nutrition to save his own life. During 2015 and 2016, he developed four prediction models related to diabetes conditions: weight, PPG, fasting plasma glucose (FPG), and A1C. As a result, from using his developed mathematical 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 glucoses 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 5/9/212.



Therefore, over the past 12 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 73 biomedical research cases.

Again, to date, he has spent around 40,000 hours studying and researching medicine. He has collected more than three million pieces of data regarding his medical conditions and lifestyle details. In addition, he has written 663 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 and efforts to his medical research work and shared his findings and learnings with other patients worldwide.

2.3 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 cause force is applied on 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.

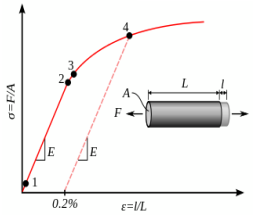
In engineering, the elasticity of a material is quantified by the elastic modulus such as the Young's modulus, bulk modulus or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic 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):

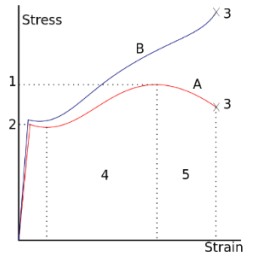
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

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/A0)
- 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).

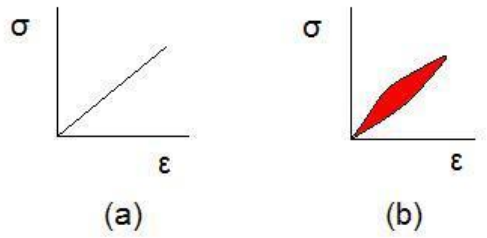
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit 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 $\oint \sigma d\varepsilon$ 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

Stress (σ)
= strain (ε) change rate * viscosity factor (η)
= dε/dt * η

The hysteresis loop area
= the integrated area of stress (σ) and strain (ε) curve
= $\oint \sigma d\varepsilon$

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 TD analysis of FPG, sleep score, and sleep hours.

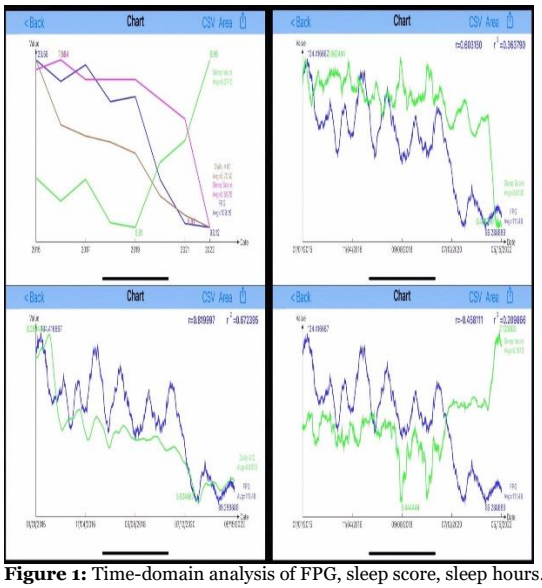


Figure 1: Time-domain analysis of FPG, sleep score, sleep hours.

Figure 2 reflects the data table of the source data and the VGT operations.

Figure 3 depicts two stress-strain diagrams of VGT energy analysis using both measured causes and normalized causes.

5/16/22	Strain	Stress 1	Stress 2	Stress 3						Height	Height	Height	Area	Area	Area
1/1/15-5/15/22	A1C	FPG	Sleep Score	Sleep hours	A1C Rate	Strain (A1C)	Stress (FPG)	Stress (Sleep #)	Stress (Sleep hrs)	FPG	Sleep score	Sleep hrs	FPG	Sleep score	Sleep hrs
Y2015	7.7	120.58	0.63	6.23	0.0	7.7	0.00	0.00	0.00	0	0	0	0	0.00	0
Y2016	7.0	117.04	0.64	6.08	-0.6	7.0	-74.91	-0.41	-3.89	-37	-0.2	-2	24	0.13	1
Y2017	6.9	116.76	0.62	6.22	-0.1	6.9	-13.17	-0.07	-0.68	-44	-0.2	-2	5	0.03	0
Y2018	6.9	113.73	0.62	5.94	-0.1	6.9	-6.82	-0.04	-0.36	-10	-0.1	-1	1	0.00	0
Y2019	6.7	114.55	0.62	5.91	-0.1	6.7	-12.60	-0.07	-0.65	-10	-0.1	-1	1	0.01	0
Y2020	6.3	100.97	0.60	6.33	-0.4	6.3	-42.41	-0.25	-2.66	-28	-0.2	-2	12	0.07	1
Y2021	6.1	99.76	0.58	6.47	-0.2	6.1	-17.81	-0.11	-1.23	-30	-0.2	-2	6	0.03	0
Y2022	6.0	99.12	0.47	6.99	-0.1	6.0	-11.17	-0.06	-0.84	-14	-0.1	-1	2	0.01	0
Average / Sum	6.7	109.2	0.6	6.3	-0.2	6.7	-22.36	-0.13	-1.29	-21.66	-0.12	-1.24	49	0.28	3
Correl & contri %	100%	91%	73%	-42%			94%	1%	5%				94%	1%	5%

5/16/22	Measured	/ 99	/ 0.6	7 /						Height	Height	Height	Area	Area	Area
1/1/15-5/15/22	A1C	Norm. FPG	Norm. Sleep Score	Norm. Sleep hours	A1C Rate	Strain (A1C)	Stress (FPG)	Stress (Sleep #)	Stress (Sleep hrs)	FPG	Sleep score	Sleep hrs	FPG	Sleep score	Sleep hrs
Y2015	7.7	1.22	1.05	1.12	0.0	7.7	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00	0.00
Y2016	7.0	1.18	1.07	1.15	-0.6	7.0	-0.76	-0.68	-0.74	-0.4	-0.4	-0.4	0.28	0.25	0.28
Y2017	6.9	1.21	1.05	1.13	-0.1	6.9	-0.13	-0.11	-0.12	-0.1	-0.1	-0.1	0.01	0.01	0.01
Y2018	6.9	1.15	1.05	1.18	-0.1	6.9	-0.07	-0.06	-0.07	-0.1	-0.1	-0.1	0.01	0.01	0.01
Y2019	6.7	1.16	1.05	1.18	-0.1	6.7	-0.13	-0.11	-0.13	-0.3	-0.3	-0.3	0.03	0.03	0.03
Y2020	6.3	1.02	1.00	1.11	-0.4	6.3	-0.43	-0.42	-0.46	-0.3	-0.3	-0.3	0.13	0.13	0.14
Y2021	6.1	0.95	0.97	1.08	-0.2	6.1	-0.18	-0.18	-0.21	-0.1	-0.1	-0.2	0.03	0.03	0.03
Y2022	6.0	0.94	0.78	1.00	-0.1	6.0	-0.11	-0.09	-0.12	-0.1	0.0	-0.1	0.01	0.01	0.01
Average	6.7	1.1	1.0	1.1	-0.2	6.7	-0.23	-0.21	-0.23	-0.2	-0.2	-0.2	0.49	0.46	0.50
Correl & contri %	100%	91%	73%	61%			34%	31%	35%				34%	31%	35%

Figure 2: Data table of this study.

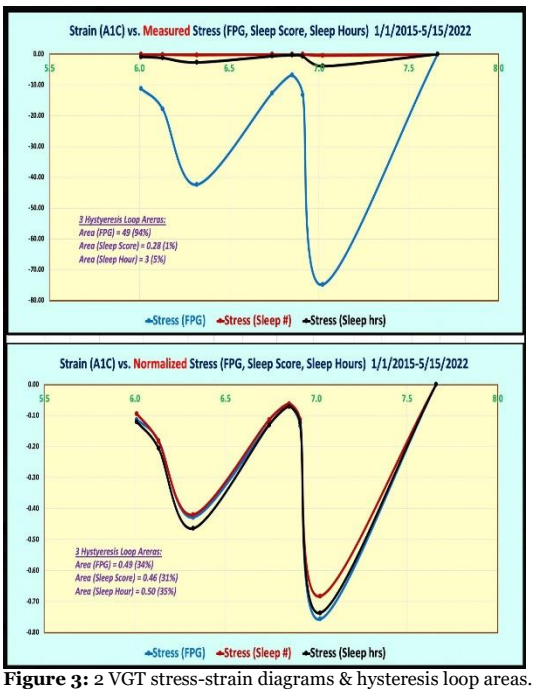


Figure 3: 2 VGT stress-strain diagrams & hysteresis loop areas.

Figure 4 illustrates the FD analysis results.

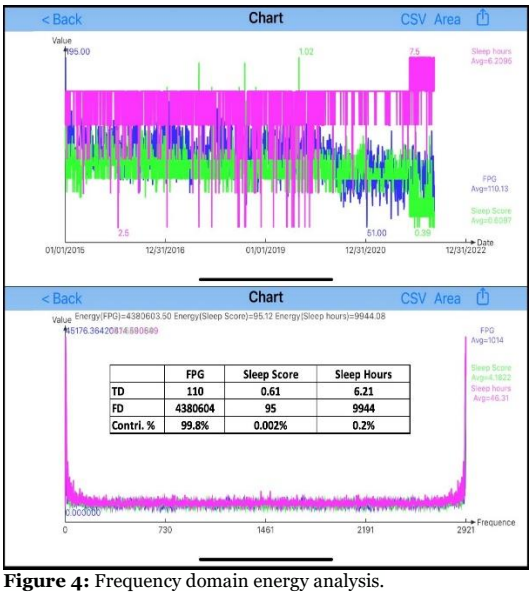


Figure 4: Frequency domain energy analysis.

4. CONCLUSION

In summary, there are 5 key findings from this comparison study:

(1) From the TD analysis results, the correlations are: FPG vs. A1C = 92% (highest); sleep score vs. A1C = 73%; and sleep hours vs. A1C = - 62%. This finding has proven the usefulness of statistical correlation studies for developing a "biophysical instinct" of connectivity among these biomarkers.

(2) Utilizing the VGT energy tool to investigate A1C (strain ε) versus 3 viscosity factors (3 η, i.e. 3 causes of FPG, sleep score, and sleep hours), using measured data to calculate their associated energies (or degree of influences on A1C). From the x-axis (A1C, strain ε) values of the stress-strain diagram, A1C values are varying within the range of 6.0% to 7.7% over the past ~7.5 years. The ranking of both stress values and hysteresis loop areas are FPG (94%), sleep scores (1%), and sleep hours (5%). These value distributions are based on non-modified originally measured data of FPG, sleep scores, and sleep hours. This shows that FPG is the most significant contribution (94%) to A1C formation, contribution from sleep hours is higher than the contribution from sleep scores (5:1 ratio). These results proved that the contribution from the quality and quantity of insulin secreted by pancreatic beta cells is far more important to A1C than the contribution from the sleep category. These findings from nonlinear dynamic VGT in SD are quite similar to the findings from the correlation study in TD.

(3) Utilizing the same VGT tool to investigate the same A1C (strain ε) versus 3 viscosity factors (η), i.e. FPG, sleep score, and sleep hours, except these 3 causes (viscosity factors η) using the normalized data to calculate their associated energies (or degree of influences on A1C). From the x-axis (A1C, strain ε) values of the stress-strain diagram, A1C values are varying within the range of 6.0% to 7.7% over the past ~7.5 years. However, the ranking of both stress values and hysteresis loop areas are in a very different pattern of FPG (34%), sleep scores (31%), and sleep hours (35%). It should be pointed out that an energy split of 33%: 33%: 33% (1/3 each) is the perfect healthy situation. These value distributions are based on normalized data of FPG, sleep score, and sleep hours. This indicates that FPG, sleep score, and sleep hours based on "normalized healthy/unhealthy standards" have almost equal amounts of contributions to A1C formation. This interesting finding of equal contribution from 3 causes resulted from the normalization process with the average cause results being FPG (1.1), carbs (1.0), and steps (1.1).

(4) These two VGT analyses using both 3 measured causes versus 3 normalized causes are particularly interesting to him. The TD analysis utilizing statistical correlation reflects the degree of connectivity between 3 causes versus A1C. However, the VGT analysis results can provide a quantitative sense regarding the different contribution levels from these 3 causes. The VGT results using measured data have also reflected the measured energy split of (FPG insulin = 94% : Sleep score = 1% : Sleep hours = 5%). On the contrary, the VGT results using normalized data have indicated a different influence contribution map through the normalized energy split of (FPG insulin = 34% : Sleep score = 31% : Sleep hours = 35%). These dimensionless variables, i.e. normalization process, actually offer a clear picture regarding the division between healthy versus unhealthy conditions.

(5) From the FD energy analysis results (FPG insulin = 99.8%, Sleep score = 0.002%, Sleep hours = 0.2%), it is evident that FPG insulin almost occupies the entire energy contribution. Although FD results are highly similar to SD results, they do show small numerical differences.

The summary statement from the analysis findings is that pancreatic beta cells insulin (via FPG) is the primary contributor to A1C formation while supplemented by sleep conditions. For the period from Y2021 to Y2022, all of its 3 causes have contributed very small percentages (FPG 16%, sleep score 14%, sleep hours 18%) to A1C formation. This has resulted from his healthier conditions of FPG < 99 mg/dL, sleep score <6.0, sleep hours >6.4 hours, and near 7 hours).

5. REFERENCES

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

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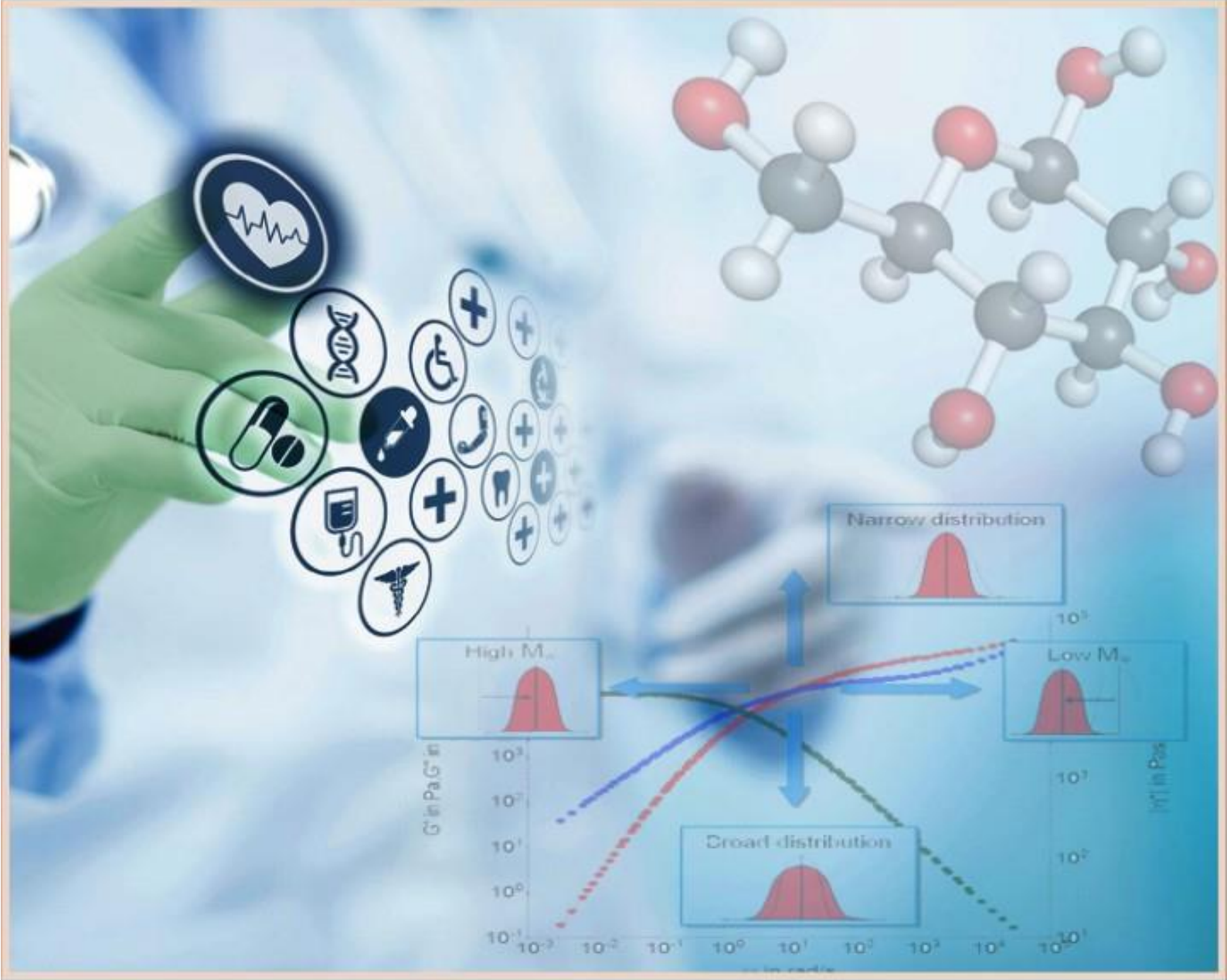
Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

Gerald C. Hsu



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