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The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #94): Using a VGT Energy Tool to Study Pancreatic Beta-Cell Insulin Resistance and Non-Alcohol Fatty Liver Disease via Triglyceride and Glucose Index Biomarker of TyG for a Type 2 Diabetes Patient over 10 Years from Y2013 to Y2022 Based on GH-Method: Math-Physical Medicine (No. 684)

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Abstract

The primary purpose of this report is to study the role of triglyceride and glucose index biomarker (TyG) in diabetes and chronic disease control. The author utilized his collected 26 data sets of lab-tested triglyceride (TG) and finger-pierced fasting plasma glucose (FPG) over the past 10 years from 1/4/2013 through 4/21/2022. On average, the data has an averaged time interval of ~130 days between testing for TG and hemoglobin A1C (HbA1C) from clinical laboratories or hospitals. Furthermore, he has utilized 90-days or 130-days of moving average finger-pierced FPG data in this study. In this study, he has used his collected data from the past 10 years to examine his TyG levels. Diabetes conditions contend with glucose production amount along with the storage of glucose in the liver, and insulin secretion (quantity) or insulin resistance (quality) from the pancreatic beta cells. The additional TyG biomarker and triglycerides (TG) biomarker are also utilized in evaluating the situation of insulin resistance. This demonstrates the connectivity of diabetes with both glucose and lipids in blood vessels and their relationships with the health conditions of the liver and pancreas. The author has self-studied and researched his diabetes and its related complications during the past 13 years (see Methods section); therefore, he understands the linkage of glucose biophysical characteristics and their mathematical interpretations along with the actual development of his diabetic complications. For example, he explores and comprehends the precise mathematical relationships between glucose fluctuations with changes in weight/food/exercise/others and how difficult diet control along with persistent exercise can be for most type 2 diabetes patients. In addition, he has also proven that the glucose reduction rate relates to the self-repair rate of his pancreatic beta cells. Since the FPG level indicates the health conditions of pancreatic beta cells and it is served as the baseline of postprandial plasma glucose (PPG) and daily estimated average glucose (eAG). The additional knowledge of lowering his risk of having nonalcoholic fatty liver disease (NAFLD) as well as various cardiovascular disease (CVD) via lowering his TyG level is extraordinarily beneficial. That is why in this study, he has established a "binary health target" for himself to accomplish: "either 80 TG and 100 FPG, or 90 TG and 90 FPG". By Y2020, after 8-years of persistent lifestyle management efforts, he had finally achieved his goal of lowering his FPG below 100 mg/dL level. His plan for 2021 and beyond is to accomplish his target of ~4.5 TyG level by having combined achievements of either 80 TG and 100 FPG (TyG at 4.49) or 90 TG and 90 FPG (TyG at 4.50). This strategy provides a practical guideline on how to reduce his insulin resistance via lowering the combined TG and FPG level to a numerical value lower than 180. However, based on his experience, he can probably reduce his FPG level further to 90 mg/dL, but at the same time, the target of decreasing his TG level to 90 mg/dL is much more difficult to accomplish. In conclusion, he has 3 key observations as follows: (1) From the time-domain (TD) analysis, his FPG curve is relatively smooth and trending downward from 135 mg/dL in 2013 to 91 mg/dL in 2022. However, his TG curve has a bigger wave fluctuation between 39 mg/dL and 176 mg/dL. An important observation is that the correlation coefficient between FPG and TG is a mere 27%, which means no correlation. (2) From the VGT analysis in the space-domain (SD), the area ratio of its two hysteresis loops where TG contributes 0.19 (33%) of energy to TyG while FPG contributes 0.40 (67%) of energy to TyG. This means that FPG contributes 2/3 of the total energy to TyG and TG only contributes 1/3 of the total

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energy to TyG. (3) His average TyG over the past 10 years is 4.74 with values around 4.6 in Y2021 & Y2022 (average FPG level around 96). If the past data can shed some light on his future performance, the target of bringing his TG level below 90 mg/dL would require a large effort to achieve this goal. Overall, his pancreatic beta cells have been self-repaired by around 30% over the past 8 years. His average TyG value of 4.74 (slightly greater than 4.49) has also provided good news. About the possibility of having NAFLD, his TyG of 4.74 is much lower than 8.5; therefore, he does not have it.

Keywords: Viscoelastic; Viscoplastic; Pancreatic beta-cell; Insulin resistance; Liver disease; Triglyceride; Cardiovascular disease; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes

Abbreviations: eAG: estimated average glucose; CVD: cardiovascular disease; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; SD: space domain; TD: time domain; MPM: math-physical medicine

1. INTRODUCTION

The primary purpose of this report is to study the role of triglyceride and glucose index biomarker (TyG) in diabetes and chronic disease control. The author utilized his collected 26 data sets of lab-tested triglyceride (TG) and finger-pierced fasting plasma glucose (FPG) over the past 10 years from 1/4/2013 through 4/21/2022. On average, the data has an averaged time interval of ~130 days between testing for TG and hemoglobin A1C (HbA1C) from clinical laboratories or hospitals. Furthermore, he has utilized 90-days or 130-days of moving average finger-pierced FPG data in this study. In this study, he has used his collected data from the past 10 years to examine his TyG levels.

Diabetes conditions contend with glucose production amount along with the storage of glucose in the liver, and insulin secretion (quantity) or insulin resistance (quality) from the pancreatic beta cells. The additional TyG biomarker and triglycerides (TG) biomarker are also utilized in evaluating the situation of insulin resistance. This demonstrates the connectivity of diabetes with both glucose and lipids in blood vessels and their relationships with the health conditions of the liver and pancreas.

The author has self-studied and researched his diabetes and its related complications during the past 13 years (see Methods section); therefore, he understands the linkage of glucose biophysical characteristics and their mathematical interpretations along with the actual development of his diabetic complications. For example, he explores and comprehends the precise mathematical relationships between glucose fluctuations with changes in weight/food/exercise/others and how difficult diet control along with persistent exercise can be for most type 2 diabetes patients. In addition, he has also proven that the glucose reduction rate relates to the self-repair rate of his pancreatic beta cells. Since the FPG level indicates the health conditions of pancreatic beta cells and it is served as the baseline of postprandial plasma glucose (PPG) and daily estimated average glucose (eAG). The additional knowledge of lowering his risk of having nonalcoholic fatty liver disease (NAFLD) as well as various cardiovascular disease (CVD) via lowering his TyG level is extraordinarily beneficial.

That is why in this study, he has established a "binary health target" for himself to accomplish: "either 80 TG and 100 FPG, or 90 TG and 90 FPG". By Y2020, after 8-years of persistent lifestyle management efforts, he had finally achieved his goal of lowering his FPG below 100 mg/dL level. His plan for 2021 and beyond is to accomplish his target of ~4.5 TyG level by having combined achievements of either 80 TG and 100 FPG (TyG at 4.49) or 90 TG and 90 FPG (TyG at 4.50). This strategy provides a practical guideline on how to reduce his insulin resistance via lowering the combined TG and FPG level to a numerical value lower than 180. However, based on his experience, he can probably reduce his FPG level further to 90 mg/dL, but at the same time, the target of decreasing his TG level to 90 mg/dL is much more difficult to accomplish.

2. METHODS

2.1 Input data

The author has had 40 blood draws at medical laboratories or hospitals in the past 10 years. Approximately 90% of them were performed at the same location; therefore, the consistency and reliability of the test results are not serious concerns. He has removed 14 test results from this study that include HbA1C only but without triglyceride data. Therefore, the dataset he has used in this study contains 26 datasets of TG and FPG for the calculation of TyG.

During the past 13 years, his major concerns center around his diabetes conditions and their induced various complications. Since 1/1/2012, he has collected FPG data once daily and postprandial plasma glucose (PPG) data 4 times daily via finger-piercing and test-strip method. In summary, he utilized his own 26 lab-tested TG data and finger-pierced FPG data for over 10 years with an average time interval of ~130 days between two adjacent health examinations of FPG and HbA1C at medical laboratories or hospitals.

2.2 TyG index

The "triglyceride and glucose index" is a screening method for insulin resistance,

which is simple to use, and only requires two laboratory determinations: serum triglycerides and serum glucose. According to a study by Salazar et al., the insulin resistance cut-off is placed at the TyG index value of 4.49, with a sensitivity of 82.6% and specificity of 82.1% (AUC=0.889, 95% CI: 0.854-0.924). Subjects with an index of 4.49 or greater are likely to suffer from insulin resistance (References 1, 2, 3, 4, and 5).

The TyG equation is:

TyG = ln [Fasting triglyceride (mg / dl) * Fasting glucose (mg / dl)] / 2

or,

TyG = (ln[Fasting triglyceride (mg / dl)] + ln[Fasting glucose (mg / dl)]) / 2

Furthermore, let us re-express it with an abbreviated format as follows:

TyG = (ln(TG) + ln(FPG)) / 2

The TyG is considered a screening tool for large-scale medical studies. Its accuracy and simplicity can be calculated with data obtained from medical records.

According to Fedchuk et al., the TyG values above 8.38 indicates a positive predictive value (PPV) of 99% in predicting steatosis equal to or greater than 5%. A recent cross-sectional study by Zhang et al. aimed to determine whether TyG has any predictive value for non-alcoholic fatty liver disease (NAFLD) by comparing the predictive value of TyG with the determinations of ALT (alanine aminotransferase) in a cohort of 10,761 patients.

The association between a screening method using triglycerides and glucose should not come as a surprise as NAFLD is considered the liver manifestation of metabolic syndrome, while triglycerides and serum glucose are key components of this process.

The following table summarizes the two cut-off points identified for insulin resistance and NAFLD positive diagnosis likelihood:

Condition	Cut-off value	Values below cut-off	Values above cut-off
Insulin resistance	4.49	Insulin resistance unlikely	Suggestive insulin resistance
Nonalcoholic fatty liver disease	8.5	NAFLD diagnosis is unlikely	High likelihood of NAFLD

2.3 New TyG index (TyG-B)

To develop any mathematical equation for describing an observed biophysical phenomenon, scientists should not only demand high accuracy of biophysical description via mathematical equation in reflecting the background physical concept or mathematical theory, but the equation must also be practical for real-life applications. The author is an engineer with a mathematics background and a long-term severe type 2 diabetes (T2D) patient. To date, he has collected and processed ~3 million data on his overall health conditions and lifestyle details and he understands his data very well. He wants to develop an easier way to interpret his complex pancreatic beta cells status regarding insulin resistance and to find a quicker path to achieving the goal of his diabetes control. Therefore, he made some simple modifications to the above-defined TyG equation and developed an alternative New TyG or TyG-B equation as follows:

TyG-B = ln(TG+FPG) - ln (2)

Or

TyG-B = ln((TG+FPG) / 2)

2.4 Sensitivity analysis

The most common blood test used to check triglyceride levels is called a lipid panel. A standard lipid panel will test for the following:

- Total cholesterol
- LDL (bad) cholesterol
- HDL (good) cholesterol
- Triglycerides
- Cholesterol/HDL ratio
- Non-HDL cholesterol

Normal triglyceride levels are < 150 mg/dL. Triglyceride levels between 150 and 199 mg/dL are borderline high. High triglyceride

levels occur at 200–499 mg/dL. Anything over 500 mg/dL is considered extremely high. (Note: The author had a triglyceride value of 1,161 mg/ dL and an FPG value of 280 mg/dL in 2010 with a TyG level of 6.58). Currently, the author cannot find a defined range for low triglyceride levels. However, if someone's triglyceride levels are exceptionally low, this may indicate an underlying condition or disease.

The author's TG record during the past 10 years (2013-2022) shows a data range covering from the lowest at 39 to the highest at 176, with an average value of 120 mg/dL. His 90-days to 130-days moving average data of FPG during the same period shows a data range from the lowest 91 mg/dL to the highest 135 mg/dL with an average value of 115 mg/dL. However, the extremely high or low values for both TG and FPG occurred only a few times.

2.5 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 5/9/22.

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 81 biomedical 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 676 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.

2.6 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.

2.7 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.

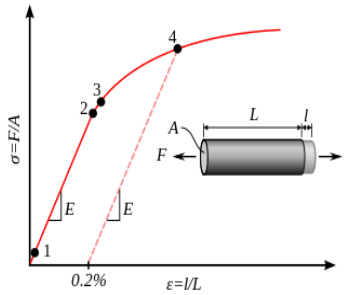
In engineering, the elasticity of a material is quantified by the elastic modulus such as the Young's modulus, bulk modulus or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic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

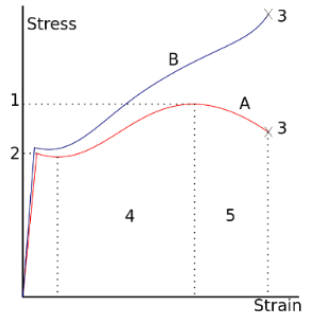
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

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).

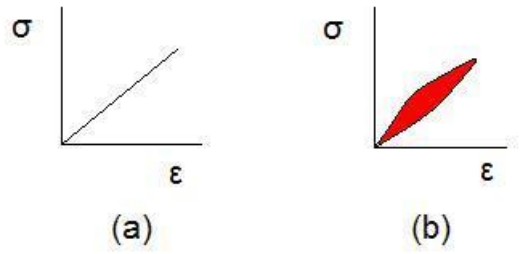
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit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

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 author's raw data of the lab-tested TG, finger-pierced average FPG, and calculated TyG. It also includes his calculated data of VGT energy analysis.

TyG Study			ln(a*b)/2	(ln(a)+ln(b))/2		TG/150	FPG/100	Strain Rate	Strain	Stress 1	Stress 2	Area 1	Area 2
Date	Lab TG	Finger-FPG	TyG	TyG	TyG% > 4.49	N.TG	N.FPG	TyG Rate	TyG	TG	FPG	TG	FPG
1/4/13	168	135	5.01	5.01	12%	1.12	1.35	0.00	5.01	0.00	0.00	0.00	0.00
3/8/13	131	128	4.86	4.86	8%	0.87	1.28	-0.15	4.86	-0.13	-0.19	0.01	0.01
2/5/14	119	129	4.82	4.82	7%	0.79	1.292	-0.04	4.82	-0.03	-0.06	0.00	0.01
8/20/14	156	130	4.96	4.96	10%	1.04	1.304	0.14	4.96	0.15	0.18	0.01	0.01
12/30/14	125	127	4.83	4.83	8%	0.83	1.266	-0.13	4.83	-0.10	-0.16	0.00	0.00
4/16/15	145	133	4.93	4.93	10%	0.97	1.325	0.10	4.93	0.09	0.13	0.00	0.00
8/6/15	122	117	4.78	4.78	6%	0.81	1.166	-0.15	4.78	-0.12	-0.18	0.00	0.00
10/15/15	173	116	4.96	4.96	10%	1.15	1.164	0.17	4.96	0.20	0.20	0.01	0.00
3/4/16	116	117	4.76	4.76	6%	0.77	1.171	-0.20	4.76	-0.15	-0.23	0.00	0.00
9/1/16	67	119	4.49	4.49	0%	0.45	1.193	-0.27	4.49	-0.12	-0.32	0.04	0.07
6/1/17	115	126	4.79	4.79	7%	0.77	1.261	0.30	4.79	0.23	0.38	0.02	0.01
9/12/17	95	112	4.63	4.63	3%	0.63	1.116	-0.16	4.63	-0.10	-0.17	-0.01	-0.02
12/20/17	125	118	4.80	4.80	7%	0.83	1.179	0.16	4.80	0.14	0.19	0.00	0.00
1/26/18	85	123	4.63	4.63	3%	0.57	1.226	-0.17	4.63	-0.10	-0.21	0.00	0.00
10/22/18	140	108	4.81	4.81	7%	0.93	1.081	0.19	4.81	0.17	0.20	0.01	0.00
1/18/19	149	113	4.86	4.86	8%	0.99	1.126	0.05	4.86	0.05	0.06	0.01	0.01
2/12/19	39	114	4.20	4.20	-6%	0.26	1.141	-0.66	4.20	-0.17	-0.76	0.04	0.23
4/4/19	86	116	4.61	4.61	3%	0.57	1.163	0.40	4.61	0.23	0.47	0.01	-0.06
7/11/19	107	111	4.69	4.69	5%	0.71	1.112	0.09	4.69	0.06	0.10	0.01	0.02
9/25/19	105	110	4.68	4.68	4%	0.70	1.098	-0.02	4.68	-0.01	-0.02	0.00	0.00
12/20/19	176	118	4.97	4.97	11%	1.17	1.176	0.29	4.97	0.34	0.34	0.05	0.05
10/21/20	88	95	4.52	4.52	1%	0.59	0.952	-0.45	4.52	-0.27	-0.43	-0.02	0.02
4/27/21	98	94	4.56	4.56	2%	0.65	0.94	0.05	4.56	0.03	0.04	-0.01	-0.01
7/21/21	161	99	4.84	4.84	8%	1.07	0.99	0.27	4.84	0.29	0.27	0.04	0.04
2/8/22	101	95	4.58	4.58	2%	0.67	0.95	-0.25	4.58	-0.17	-0.24	-0.02	0.00
4/21/22	116	91	4.63	4.63	3%	0.77	0.91	0.05	4.63	0.04	0.04	0.00	0.00
Average	120	115	4.7	4.7	0.1	0.80	1.15	-0.01	4.74	0.02	-0.01	0.19	0.40
Correlation	27%										Area %	33%	67%

Figure 1: Data table of TyG calculation and calculated data of VGT analysis.

Figure 2 depicts the time-domain correlation analysis results.

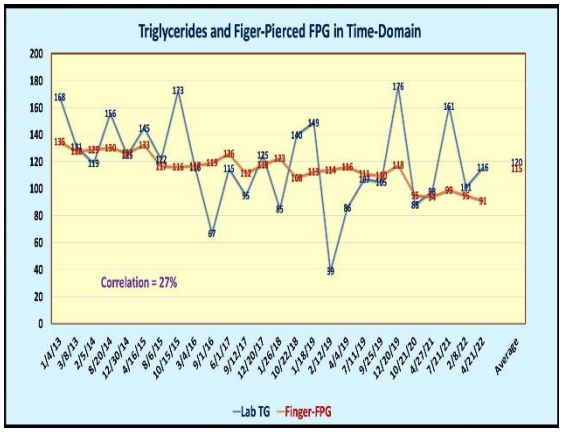


Figure 2: Time-domain correlation analysis result.

Figure 3 displays the space-domain VGT analysis results.

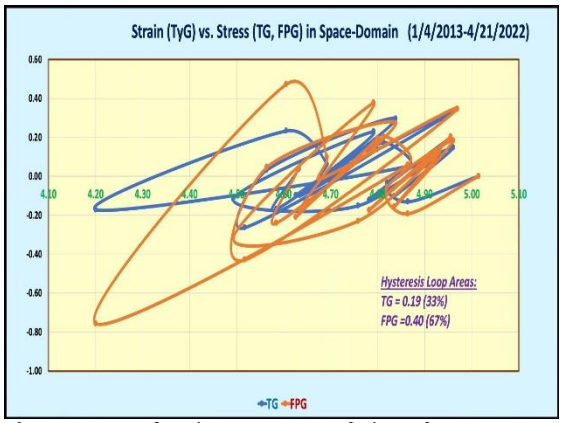


Figure 3: Space-domain VGT energy analysis result.

4. CONCLUSION

In conclusion, he has 3 key observations as follows:

(1) From the time-domain (TD) analysis, his FPG curve is relatively smooth and trending downward from 135 mg/dL in 2013 to 91 mg/dL in 2022. However, his TG curve has a bigger wave fluctuation between 39 mg/dL and 176 mg/dL. An important observation is that the correlation coefficient between FPG and TG is a mere 27%, which means no correlation.

(2) From the VGT analysis in the space-domain (SD), the area ratio of its two hysteresis loops where TG contributes 0.19 (33%) of energy to TyG while FPG contributes 0.40 (67%) of energy to TyG. This means that FPG contributes 2/3 of the total energy to TyG and TG only contributes 1/3 of the total energy to TyG.

(3) His average TyG over the past 10 years is 4.74 with values around 4.6 in Y2021 & Y2022 (average FPG level around 96). If the past data can shed some light on his future performance, the target of bringing his TG level below 90 mg/dL would require a large effort to achieve this goal. Overall, his pancreatic beta cells have been self-repaired by around 30% over the past 8 years. His average TyG value of 4.74 (slightly greater than 4.49) has also provided good news. About the possibility of having NAFLD, his TyG of 4.74 is much lower than 8.5; therefore, he does not have it.

5. REFERENCES

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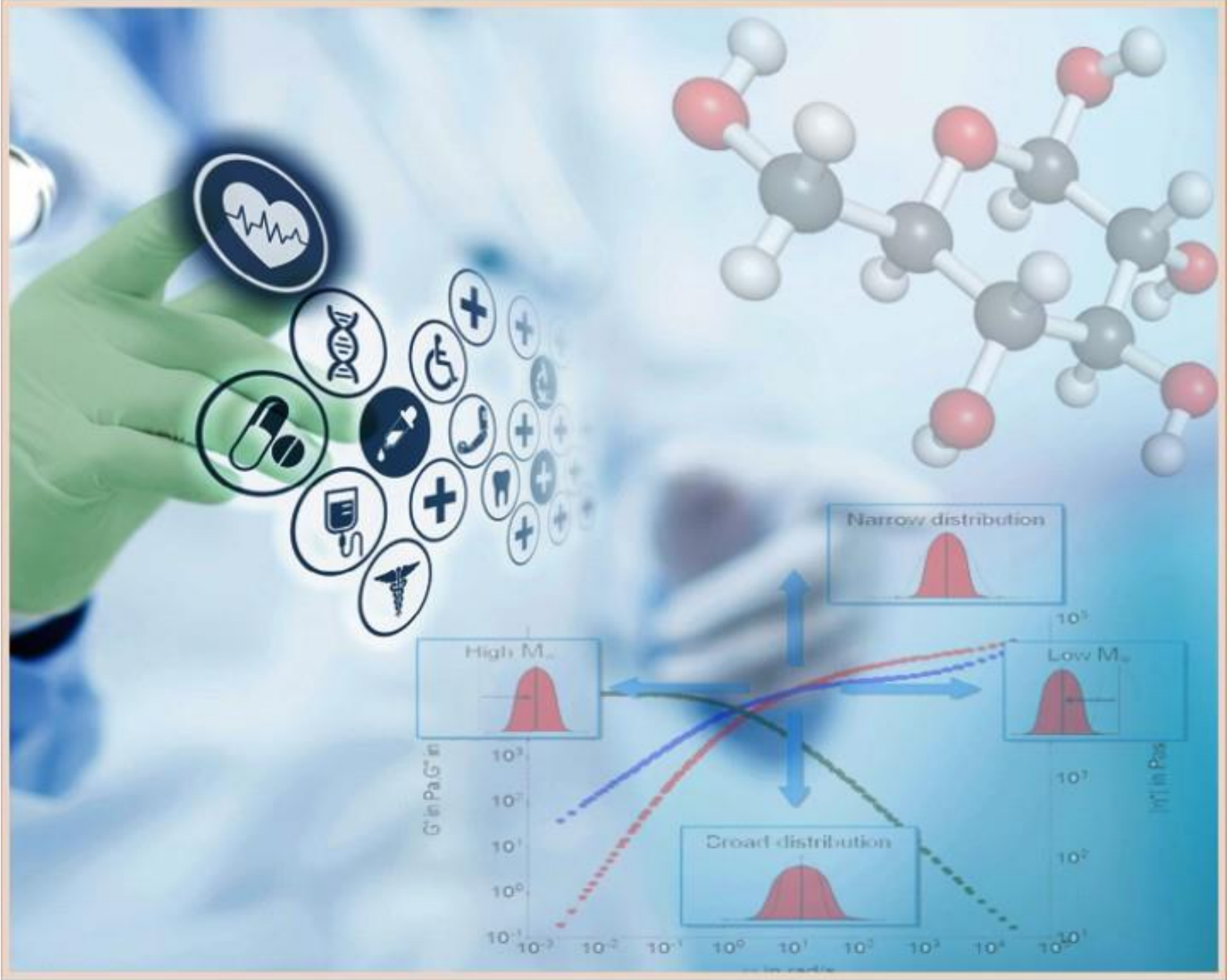

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