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# *Viscoelastic or Viscoplastic Glucose Theory (VGT #72):* Risk of Developing Complications, Such as CVD, CKD, and Cancers, resulting from Different Distribution Percentages between Normal PPG Meals Versus Hyperglycemic PPG Meals for a Type 2 Diabetes Patient using a Customized Software Program and VGT Energy Tool Based on GH-Method: Math-Physical Medicine (No. 661)

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## Introduction

The author has been a type 2 diabetes (T2D) patient since 1995. Beginning in 2012, he started to collect his body weight and finger-piercing glucose data every day. In addition, since 2015, he accumulates other medical condition-related biomarker data, including a combination of blood pressure (BP), heart rate (HR), and blood lipid data along with important lifestyle details. Using collected big data, he further organized them into two main groups. The first is the medical conditions group (MC) with 4 chronic disease-related categories: weight, glucose, BP, and blood lipids. The second is the lifestyle details group (LD) with 6 root-cause and lifestyle-related categories: food & diet, exercise, water intake, sleep, stress, and daily life routine. He then use these 2 groups, 10 categories, and 500+ elements to build a metabolism index (MI) model for his follow-up medical research work.

Starting from 5/1/2015, he has collected meal photos three times each day with its associated data of carbs/sugar grams (carbs), post-meal walking steps (steps), and finger-pierced post-prandial plasma glucose (PPG). On 5/8/2018, he applied a continuous glucose monitoring (CGM) sensor device on his upper arm and collected the sensor PPG every 15 minutes throughout the day. For 4 years from 5/1/2018 to 5/1/2022, he has collected 4,432 meals along with their associated data of biomarkers and lifestyle details. For this study, he utilized his developed software to extract a range of >180 mg/dL and <400 mg/dL of hyperglycemic PPG (hi-PPG) data from his database. As a result, he has extracted 27 hyperglycemic meals (0.6%) from a total of 4,432 meals (100%).

In this study, both his average Hi-PPG of 186 mg/dL and the average Normal-PPG of 125 mg/dL fit in the category of "***symptoms***" resulting from "***root causes***" from poor lifestyle and unhealthy habits. His carbs/sugar of 91.2 grams and post-meal walking of 3,558 steps for Hi-PPG case or carbs/sugar of 13.2 grams and post-meal walking of 4,259 steps for Normal-PPG case then belong to the category of "causes" of these observed symptoms. With these available input data, his remaining challenge is determining the energies associated with both the Hi-PPG case and the Normal-PPG case. The energy estimations are vital to his future studies of diabetic complications, including cardiovascular disease (CVD), chronic diet diseases (CKD), and various types of cancer (cancers).

Since December of 2021, the author has written and published ~70 medical research articles using the established viscoelasticity and viscoplasticity theories (VGT) from physics and engineering disciplines on a variety of medical subjects. This particular paper aims to explore some hidden biophysical behaviors which provide a quantitative sense of the inter-relationships between hyperglycemia (out of control) and normal glucose level (under control) versus two selected major influential factors or risk factors of carbs and steps. *Both glucose and the two selected risk factors, carbs and steps, are "time-dependent" which means that all of these variables are changing from time to time (or from meal to meal). This is why he utilizes VGT from physics and engineering to conduct his medical research work.*

The following defined VGT equations are used to establish a generic stress-strain diagram in a space domain (SD):

***strain***
***= ε (PPG)***
***= individual PPG value at the present time***

***Stress***
***= σ (based on the change rate of strain, PPG rate, multiplying***

***with a chosen viscosity factor, carbs, or steps)***
***= η * (dε/dt)***
***= η * (d-strain/d-time)***
***= (viscosity factor η using individual carbs or steps at present time) * (PPG at present time - PPG at a previous time)***

Where
*Normalized carbs = average carbs / 15 (15 grams of carbs/sugar is his target)*
*Normalized steps = 40 / k-steps (4,000 post-meal walking steps is his target)*

Initially, he calculates the respective hysteresis loop areas corresponding to each component of stress (or viscosity factor) and then computes the respective hysteresis loop areas corresponding to each sub-period in the time domain (TD), to judge the energy levels associated with each viscosity factor and each sub-period in time.

*After calculating the total hysteresis loop areas from both carbs and stress, he has observed that* ***the Hi-PPG case (from 1% of total meals) has a 5% contribution and the normal case (from 99% of total meals) has a 95% contribution on the combined energies of both Hi-PPG case and Normal-PPG case.*** *He then takes the 3 calculated average complication risks for CVD, CKD, and cancers (based on the MI model) over 11 years to conduct a* ***"what-if" analysis, i.e. what would happen to those complications risk % if he altered the contribution ratio between the Hi-PPG meals and Normal-PPG meals.***

*In this study, he has tried the following 6 cases of combinations for his "what-if" analysis:*

***Hi-PPG meals contributions:***
***1%, 10%, 20%, 30%, 40%, 50%***
***Corresponding normal-PPG meals:***
***99%, 90%, 80%, 70%, 60%, 50%***

Using the above-mentioned VGT analysis results for ***the combination of 1% and 99% as the baseline,*** he conducts numerical operations to calculate the three complications (i.e. CVD, CKD, and Cancers) risk % corresponding to the other five hypothetical combinations which can then present a clear ***diagram of complication risk changes versus percentages of hyperglycemia meals.***

At this point, it is necessary to briefly describe his health history. The author was diagnosed with T2D in 1997 with a random glucose check at a 300 mg/dL level; however, his T2D condition most likely began earlier (he guesses in 1995). He suffered his first two chest pain episodes in 1993-1994 and three more heart episodes until 2007. His primary physician informed him that he had diabetic kidney issues in 2010. He then consulted with two more clinical doctors who advised him to immediately start insulin injections and kidney dialysis. This was his wake-up call. He then decided to save his own life by conducting his self-study and research on food nutrition and chronic diseases that same year. His health profile in 2010 was: body weight at 220 lbs. (BMI 32, indicating ***obesity***), average glucose at 280 mg/dL (>140 mg/dL, signifying ***diabetes***), fasting plasma glucose (FPG) in the early morning at 180 mg/dL (>125 mg/dL, depicting ***hyperinsulinemia***), lab-tested HbA1C at 10% which means ***severe diabetes,*** triglycerides at 1160 mg/dL reflecting hyperlipidemia (target: <150 mg/dL), and his ACR at 116 which indicates ***kidney damage*** (target: <30). In summary, by 2010, he has also suffered a total of five heart episodes, chronic kidney disease (CKD), hypothyroidism, diabetic retinopathy, foot ulcer, neuropathy, diabetic constipation, diabetic skin fungal infection, etc.

Over the past ~13 years, he has made significant lifestyle changes. For example, ***he consumes less than 15 grams of carbohydrates and sugar per meal (his target is below 15 to 20 grams of carbs/sugar intake amount)***, avoids processed food, reduces his food quantity by 50%, walks 6-7 miles or 10-11 kilometers daily ***(his target is 9,000 to 12,000 steps each day), sleeps 7-8 hours each night, and reduces stress as much as possible.*** In addition, he has never drunk alcohol, smoked cigarettes, or used any illicit drugs in his life.

As of April 25, 2022, his health profile for the first 4 months of 2022 was: body weight at 169 lbs. (BMI 24.95 which is ***normal weight***), daily average glucose at 106 mg/dL, FPG in the early morning at 94 mg/dL, lab-tested A1C at 5.8% which is the ***beginning level of pre-diabetes,*** triglycerides at 108, and ACR at 16. Another significant accomplishment is that he has discontinued taking 3 different kinds of diabetes medications since 12/8/2015.

Recently, the author has modified his developed software for the iPhone by inserting a customized module that has the capability of calculating the strain (ε) change rate, i.e. ***dε/dt,*** and then being able to multiply with a selected viscosity factor (***η***) automatically. With this enhanced feature embedded in his AI-based software program, he can then avoid using the Excel program on a PC to conduct his needed VGT analysis. Now, he can administer multiple VGT analysis cases based on thousands of daily data stored on his iPhone and cloud server, instead of under the restriction of using "sub-period data", such as annual, quarterly, or monthly, via Excel program on a PC which requires significant manual data preparation time and easier making mistakes during data transfer.

Most of the author's medical papers are based on his collected biomarker data from his own body over the past 12+ years. His research work is based on quantitative analysis of the collected data using a math-physical medicine methodology, not using the traditional biochemical and statistical research approach in the current medical or psychological research fields. In other words, he mainly describes his observed biophysical phenomena using 10 numerical digits and then uses English words to depict or interpret some supporting phenomena. This is different from the traditional medical research papers or psychological behaviors reports which mainly utilize 26 English alphabet letters to describe most of their findings. Of course, this is rather a direct result of the author's educational shortcomings in both biology and chemistry fields. Based on his past 13-year of self-study and intensive research on internal medicine and food nutrition, he has observed that most biomedical phenomena do follow the basic law of physics. As a result, certain analysis principles and modeling techniques of engineering can also be applied easily in medical research. In this situation, a medical subject can then be easily analyzed and interpreted using various mathematical tools from the lower foundation level, while applying applicable physics laws and principles from the middle level, and utilizing various engineering modeling techniques from the upper application level.

If other medical research scientists utilize the math-physical medicine method such as a VGT tool based on multiple patients' biomarker data, they can then assemble his analysis results with other patients' VGT results as their first steps. After that step, they can conduct statistical analyses to summarize those VGT results into a much wider-viewed conclusion with a more rigorous math-physical background information as the underneath support.

## Methods

To offer a simple explanation to readers who do not have a physics or engineering background, the author includes a brief excerpt from Wikipedia regarding the description of basic concepts for elasticity and plasticity theories, viscoelasticity, and viscoplasticity theories from the disciplines of engineering and physics in this Method section.

### *Relationships Between Biomedical Causes and Biomedical Symptoms*

As a mathematician/engineer for over 40 years and now conducting his medical research work for the past 13 years, the author has discovered that people frequently seek answers, illustrations, or explanations for the relationships between the input variable (force applied on a structure or cause of a disease) and output variable (deformation of a structure or symptom of a disease). However, the multiple relationships between input and output could be expressed with many different matrix formats of 1 x 1, 1 x n, m x 1, or m x n (m or n means different multiple variables). In addition to these described mathematical complications, the output resulting from one or more inputs can also become an input of another output, which is a symptom of certain causes that can become a cause of another different symptom. This phenomenon is indeed a complex scenario with "chain effects". In fact, both engineering and biomedical complications are fundamentally mathematical problems that correlate or conform with many inherent physical laws or principles. In his medical research work, he has encountered more than 100 different sets of biomarkers with almost equal or more amounts of causes (or input variables) and symptoms (or output variables).

Since December of 2021, the author applied theories of viscoelasticity and viscoplasticity (VGT) from physics and engineering disciplines to investigate more than 60 sets of input/output biomarkers, including nearly 10 sets of cancer cases. The purpose is to identify certain hidden relationships between certain output biomarkers, such as cancer risk, and its corresponding multiple inputs, such as glucose, blood pressure, blood lipids, obesity or overweight, and metabolism index of 6 lifestyle details and 4 chronic diseases. In this study, the hidden biophysical behaviors and possible inter-relationships among the output symptom and multiple input causes are ***"time-dependent"*** and change from time to time. These important time-dependency characteristics provide insight into the cancer risk's moving pattern. It also controls the cancer risk curve shape, the associated energy created, stored, or burned inside during the process of stress up-loading (moving upward or increasing) and stress down-loading (moving downward or decreasing) of the input biomarkers with the output biomarker of cancer risk %. This VGT application emphasizes the ***time-dependency*** characteristics of involved variables. In the medical field, most biomarkers are time-dependent since body organ cells are organic in nature and change all of the time. Incidentally, VGT can generate a stress-strain curve or cause-symptom curve, known as a ***"hysteresis loop"*** in physics, in which area size can also be used to estimate the relative energy created, stored, or burned during the process of uploading (e.g., increasing glucose) and unloading (e.g., decreasing body weight) over the timespan of the cancer risk %. ***He calls this relative energy the "VGT energy".***

*It should be emphasized here that* ***both cancer risk % and its associated VGT energy are estimated relative values, not "absolute" values.***

*The following defined stress and strain equations are used to establish the VGT stress-strain diagram in a space domain (SD):*

***VGT strain***
***= ε (symptom)***
***= individual symptom at the present time***

***VGT Stress***
***= σ (based on the change rate of strain, symptom, multiplying with one or more viscosity factors or influential factors)***
***= η * (dε/dt)***
***= η * (d-strain/d-time)***
***= (viscosity factor η using normalized factor at present time) * (symptom at present time - symptom at a previous time)***

*Where the strain is the cancer risk percentage and the stress is his cancer risk change rate multiplied by several chosen input biomarkers as the individual viscosity factor. In his VGT studies, sometimes, he carefully selects certain normalization factors for each input biomarker, respectively. The normalization factors are the dividing lines between a healthy state and an unhealthy state. For example, 170 lbs. for body weight, 6.0 for HbA1C, 120 mg/dL for glucose, 180 mg/dL for hyperglycemia, 73.5% for overall MI score, and 10,000 steps for daily walking exercise, etc.*

### *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 counterpart is "when cause or risk factors are reduced or removed, the symptoms of a 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 the material has "time-dependent" characters.  Biomedical data, i.e. biomarkers, are time-dependent due to body cells being organic and changing 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 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.

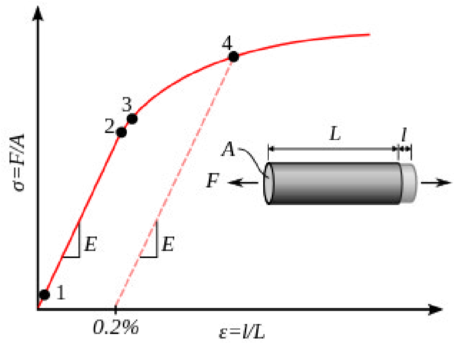
In engineering, the elasticity of a material is quantified by the elastic modulus such as Young's modulus, bulk modulus, or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic limit 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 in its original length, similar to a non-diabetes person or less-severed type 2 diabetes (T2D) patient.*

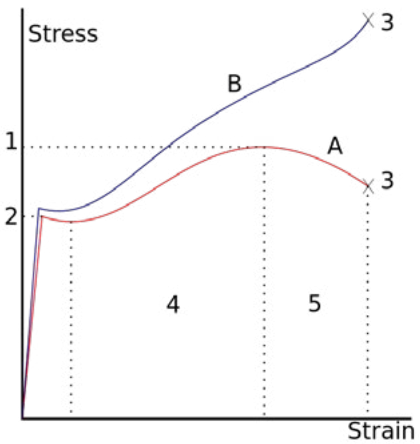
### Plasticity (Physics):

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 level of PPG even with a significant amount of exercise. This means that 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).**

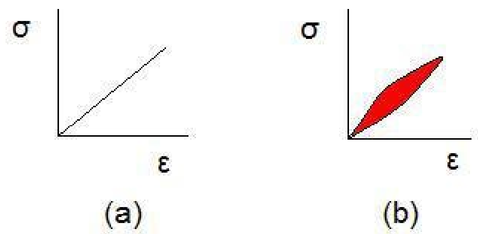
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit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

## Results & Conclusions

Figure 1 shows background data tables and a comparison of two time-domain PPG curves, Hi-PPG versus normal PPG. It is obvious that the hyperglycemic PPG case (average 186 mg/dL) is much higher than the normal PPG case (average 125 mg/dL). Furthermore, the correlation between these two waveforms is -15% which means no correlation at all.

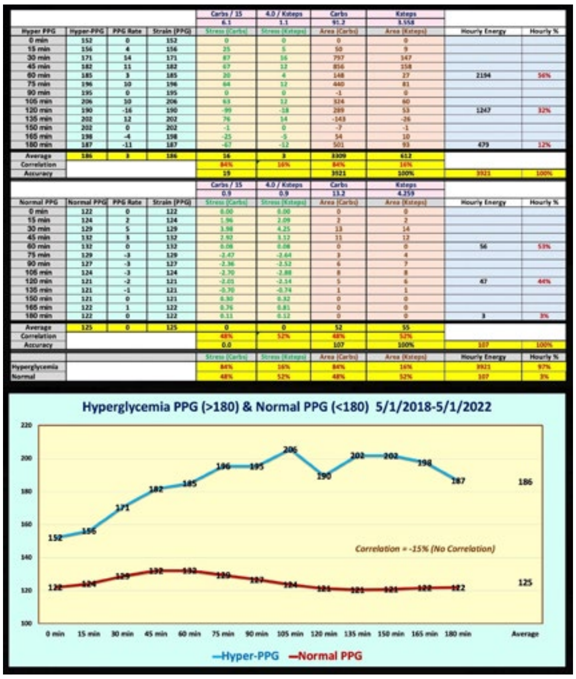



**Figure 1:** Background data tables and comparison of 2 time-domain PPG curves, hi-PPG & normal PPG

Figure 2 illustrates two stress-strain diagrams of both hyperglycemic PPG versus normal PPG based on the VGT energy model with two selected risk factors: carbs and steps.

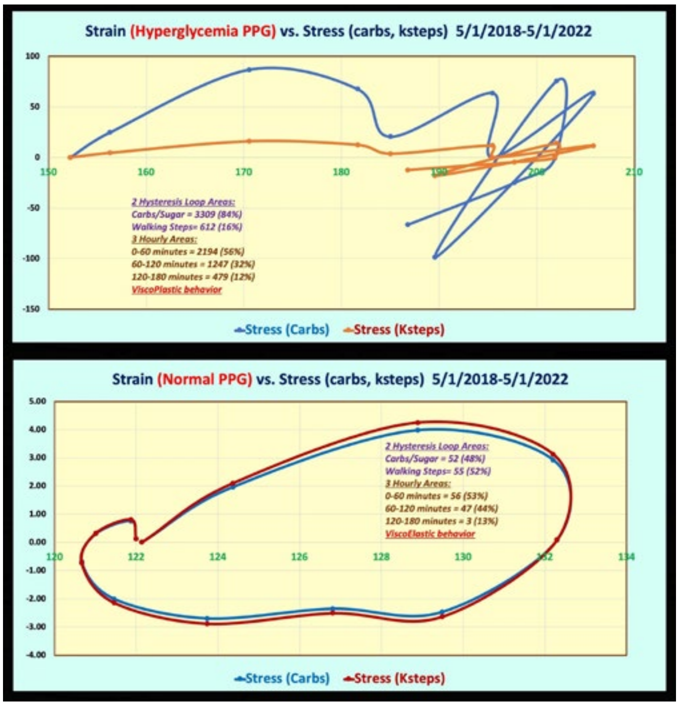



**Figure 2:** Stress-strain diagram of both hi-PPG & normal PPG based on the VGT energy model with two risk factors (carbs and steps)

The following 5 medical phenomena and biophysical interpretations have demonstrated certain unique behaviors of the two PPG cases under the influence of two chosen risk factors of carbs and steps (***a 2x1 model***):

(1) The hyperglycemic PPG case covers the range of 152 mg/dL at 0-minute through 206 mg/dL at 105-minutes to 187 mg/dL at 180-minutes with an average PPG of 186 mg/dL and a "left-over" PPG of 35 mg/dL ***(the hyperglycemic PPG case is a plastic case)***. But the normal PPG case covers the range of 122 mg/dL at 0-minute through 132 mg/dL at 60-minutes to 122 mg/dL at 180-minutes with an average PG of 125 mg/dL and a zero left-over PPG ***(the normal PPG case is an elastic case).***

(2) From two stress-strain diagrams, ***for the hyperglycemic case, the carbs loop area is about 5 times larger than the steps loop area which*** means that carbs contribute more to PPG (generate about 84% energy) and steps were not sufficient enough to dissipate the carb's input energy (dissipate about 16% energy). On the contrary, ***for the normal PPG case, the carbs loop area (48%) is almost the same as the steps loop area (52%).*** This means that, for a normal PPG case which is 99% of his total meals, his exercise has been completely capable to burn off the energy generated through carbs and it makes the normal PPG case an elastic case (i.e. the initial PPG almost equal to the ending PPG).

(3) From the stress-strain diagrams, it is evident that ***these two loop shapes in the space domain are completely different from each other. This phenomenon is resulted from the PPG change rate over time-varying from each other,*** not only their PPG curves are different in TD.

(4) Observing closely the sub-time period energy difference, the hyperlipidemia PPG case has 88% of the energy associated with the period from 0-minute to 120-minutes and only 12% of left-over energy for the sub-period from 120-minutes to 180-minutes. T***he sub-time period energy % for the normal PPG case is extremely similar to the Hi-PPG*** case that it has 87% of the energy associated with the period from 0-minute to 120-minutes, and only has 13% of left-over energy for the sub-period from 120-minutes to 180-minutes. This means that ***most of the energies (87%-88%) are created via carbs and dissipated via steps within the first 2 hours after the first bite of food. Therefore, the most important period to control diabetes conditions is the first 2 hours after eating meals.***

(5) From both TD PPG curves and SD PPG curves, we see the obvious difference in curve shapes, ***the Hi-PPG case has more fluctuation in TD and more curls in SD***. On the contrary, t***he normal PPG case is a smoother wave in TD and also possesses a smooth egg shape in SD. These curve shapes depict the internal strain rate situations, i.e. PPG's ups and downs over time with different magnitudes of carbs and steps.*** The higher values of carbs and lower values of steps of the Hi-PPG case further amplify or shrink the magnitude of stresses.

Figure 3 reflects the hyperglycemic PPG's impact on the risks of developing CVD, CKD, and cancers, respectively. It is clear that ***when the percentage of Hi-PPG meals increases, all of these three complication risks of CVD, CKD, and cancers are increasing accordingly.*** Of course, this is a type of "conclusion matched with common knowledge" in the medical field. However, this article illustrates the results obtained from using the engineering VGT research methodology which ***are expressed in a "quantitative" manner and provided a much clearer picture to the readers.***

In summary, this particular report on two PPG cases of stress-strain relationships via two distinctive hysteresis loop areas is extremely interesting to the author because of its ability to clearly demonstrate these two different loop areas (for energy) and curve shapes (for complication variance) over time scale***. More importantly, the linkage between 3 separated complication risks and a common cause of hyperglycemia is revealed.*** From this study, the author has developed more insights into VGT theory through these numerical detailed findings.

## 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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