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The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #106): Applying the Tools of Viscoelasticity and Viscoplasticity Theory to the Space Domain, Wave Theory in the Time Domain, and Fourier Transform in the Frequency Domain to Investigate the Combined Postprandial Plasma Glucose of 755 Meals vs. Two PPG Datasets Resulting from 619 Cabbage Meals and 136 High-Carb Meals Over 4+ Years from 5/8/2018 to 7/5/2022 Compared Against a Business Case Study Analogy Based on GH-Method: Math-Physical Medicine (No. 696)

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Keywords: Viscoelastic; Viscoplastic; Carbohydrates; Sugar; Walking k-steps; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: FFT: fast Fourier transform; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; FD: frequency domain; SD: space domain; TD: time domain; MPM: math-physical medicine

1. INTRODUCTION

This article presents an investigation regarding the associated energies related to the combined postprandial plasma glucose (PPG) dataset versus two individual PPG datasets resulting from two types of main food ingredients where cabbage is the first main ingredient and high carbohydrates and sugar (hi-carbs) as the second main ingredients. Since 5/8/2018, the author has collected +4,560 meal information with food contents, nutritional ingredients, carbs/sugar grams, post-meal walking steps as exercise, and their correlated PPG data with 13 data for each meal (data collected at 15-minute intervals).

The author applies various theories and tools, including linear elasticity, nonlinear plasticity, wave theory in the time domain (TD) with fast Fourier transform into a frequency domain (FD), viscoelasticity, and viscoplasticity from physics and engineering disciplines to investigate selected various medical research subjects. In this article, he conducts biomedical and food nutrition research regarding the relationship between a single symptom biomarker of the combined 755 PPG waveforms versus two PPG waveforms resulting from 619 cabbage meals and 136 hi-carbs meals.

The 619 cabbage meals contain cabbage with a smaller amount of other vegetables and some high-quality proteins, such as fish, tofu, and/or cheese with an average carbs/sugar amount of 14.2 grams per meal. The 136 hi-carbs meals contain rice, flour, noodle, mochi (Japanese sweet cake), lasagna (Italian flat noodle), and pho (Vietnamese rice noodle) as the main ingredient with an average carbs/sugar amount of 32.1 grams per meal.

The "elastic" waveform of PPG produced by the 619 cabbage meals has the following key PPG data points:

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Start @ 0-minute: 123 mg/dL
Max @ 60-min.: 132 mg/dL
At 120-minutes: 115 mg/dL
Close @ 180-min.: 115 mg/dL
Average PPG: 122 mg/dL

The "plastic" waveform of PPG produced by the 136 hi-carbs meals has the following key PPG data points:

Start @ 0-minute: 125 mg/dL
Max @ 60-min.: 142 mg/dL
At 120-minutes: 134 mg/dL
Close @ 180-min.: 132 mg/dL
Average PPG: 134 mg/dL

Therefore, the "elastic" waveform for the total PPG waveform produced by the combined 755 meals has the following key PPG data points:

Start @ 0-minute: 124 mg/dL
Max @ 60-min.: 132 mg/dL
At 120-minutes: 118 mg/dL
Close @ 180-min.: 118 mg/dL
Averaged PPG: 124 mg/dL

The combined 755 meals' PPG values are extremely close to the 619 cabbage meals' PPG values due to the cabbage meals being the majority (82%) of the total meals.

Here is a brief explanation of the three distinctive energy analysis approaches used in this study:

The first approach is to estimate the TD energy associated with waveforms of both cabbage meals PPG and hi-carbs meals PPG (2 inputs or 2 causes) to make a comparison between the two input meals. The TD energy is calculated with two squared amplitudes of the average inputs (or causes). Basic physics has taught us that "the energy carried by a wave is directly proportional to the square of this wave's amplitude". Here, the main purpose is to compare the two energies associated with 2 inputs, cabbage PPG, and hi-carbs PPG.

The second approach is to apply the viscoelastic or viscoplastic glucose theory (VGT) to construct a set of space-domain (SD) diagrams with stress-strain curves and then by calculating the enclosed area of the SD strain-stress curve or hysteresis loop to obtain its SD-VGT energy. The SD-VGT method is useful for investigating the "time-dependent" biomarker behaviors which can be applied to the majority of subjects in the fields of medicine, economics, psychology, and others. The SD-VGT energy is the hysteresis loop area size. The following 2 defined equations from viscoelasticity or viscoplasticity are utilized to study the stress-strain relationship in this case. Here, he wants to use the strain rate multiplied with the viscosity (input) as the stress component:

Strain
= ε
= individual output symptom value, at the present time

Stress
= σ
= $\eta * (d\varepsilon/dt)$
= η * (d-strain/d-time)
= (viscosity factor η, i.e. stimulator) / normalization factor) * (output symptom value at present time - output symptom value at a previous time)

In the VGT study, we must carefully choose appropriate "normalization factors", i.e. a factor associated with the "break-even line's value between healthy condition vs. unhealthy condition". The break-even line for glucose is 120 mg/dL. However, in this study, the chosen normalization factor is 1.0 because both viscosities are PPG with the same unit; therefore, the normalization process is not needed.

The third approach is to develop a newly-defined variable of (strain * stress) from SD as the new wave amplitude in a TD and then go through a fast Fourier transform (FTT) operation to calculate the enclosed area of this new variable created frequency curve in a frequency-domain (FD) as the FD energy. The FD-FFT energy is the enclosed area of this frequency curve.

2. METHODS

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

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

What are elastic materials?

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

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

What are viscous materials?

Viscosity is a measure of a fluid's resistance to flow. A fluid with large viscosity resists motion. A fluid with low viscosity flows. For example, water flows more easily than syrup because it has a lower viscosity. High viscosity materials might include honey, syrups, or gels – generally things that resist flow. Water is a low viscosity material, as it flows readily. Viscous materials are thick or sticky or adhesive. Since heating reduces viscosity, these materials don't flow easily. For example, warm syrup flows more easily than cold.

What is viscoelastic?

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

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

Elastic behavior versus viscoelastic behavior

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

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

The following brief introductions are excerpts from Wikipedia:

"Elasticity (physics):

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

In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remains in its deformed state.

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

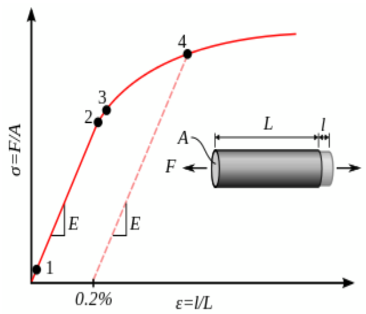
In engineering, the elasticity of a material is quantified by the elastic modulus such as the Young's modulus, bulk modulus or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic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

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

Plasticity (physics):

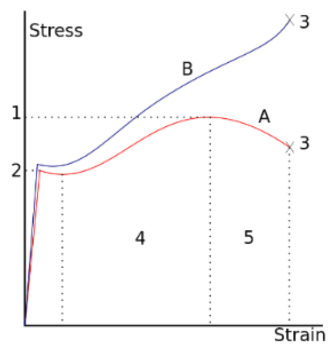
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

In physics and materials science, plasticity, also known as plastic deformation, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces. For example, a solid piece of metal being bent or pounded into a new shape displays plasticity as permanent changes occur within the material itself. In engineering, the transition from elastic behavior to plastic behavior is known as yielding. Plastic deformation is observed in most materials, particularly metals, soils, rocks, concrete, and foams.



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

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



A stress-strain is typical of structural steel.

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

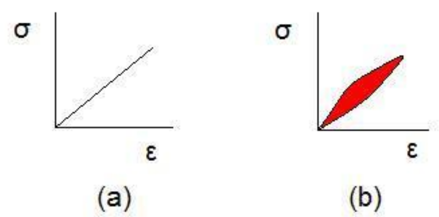
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit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

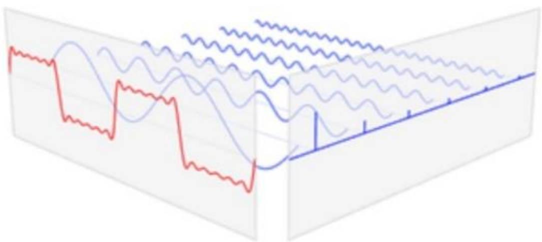
Medical analogy: In viscoelastic or viscoplastic analysis, the stress component equals the strain change rate of time multiplying with the viscosity factor, or

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
= $\oint \sigma d\varepsilon$

2.2 From time-domain to frequency domain via Fourier transform

In physics, electronics, control systems engineering, and statistics, the frequency domain refers to the analysis of mathematical functions or signals concerning frequency, rather than time.[1] Put simply, a time-domain graph shows how a signal changes over time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the phase shift that must be applied to each sinusoid to be able to recombine the frequency components to recover the original time signal.



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

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

Advantages

One of the main reasons for using a frequency-domain representation of a problem is to simplify the mathematical analysis. For mathematical systems governed by linear differential equations, a very important class of systems with many real-world applications, converting the description of the system from the time domain to a frequency domain converts the differential equations to algebraic equations, which are much easier to solve.

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

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

Magnitude and phase

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

Types

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

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

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

Discrete frequency domain

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

History of term

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

Note: For a more detailed description, please refer to the "consolidated method" section which is given at the beginning of the special issue.

3. RESULTS

Figure 1 shows the inputs and outputs of the biomedical study of PPG energy.

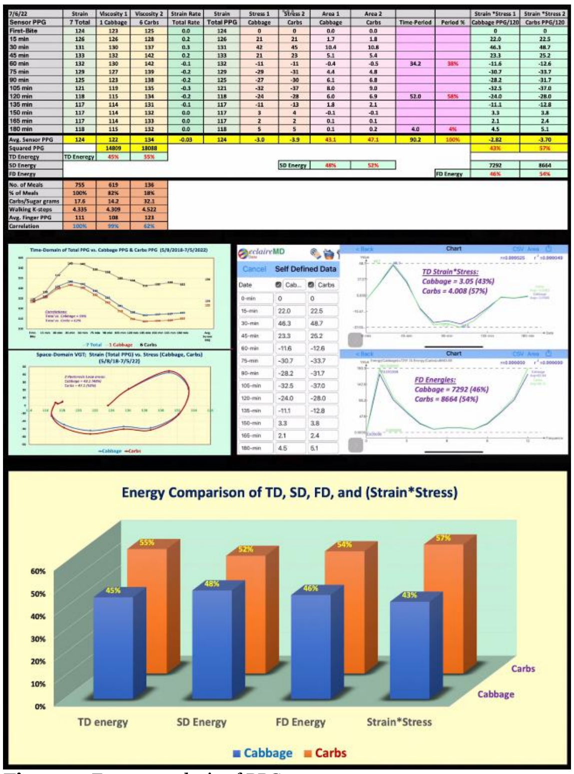


Figure 1: Energy analysis of PPG.

Figure 2 depicts the data and bar chart comparison of a business analogy.

Division Financial Record	Hardware Div.	Software Div.	Total
Employee No.	619	136	755
Cost ($K)/Person = Carbs	14.2	32.1	17.4
Total Cost ($M)	88	44	132
Revenue ($M) = Avg. PPG	122	134	124
Revenue / Employee	0.20	0.99	1.18
Profit ($M)	34	90	-8
Profif / Person	0.06	0.66	0.72
Division Financial Record	Hardware Div.	Software Div.	Total
Div. Employee %	82%	18%	100%
Div. Revenue %	17%	83%	100%
Div. Profit %	8%	92%	100%

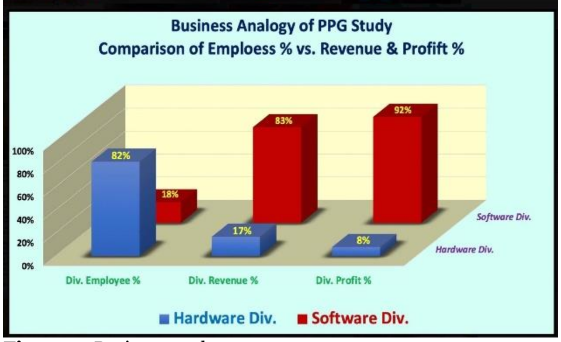


Figure 2: Business analogy.

4. CONCLUSION

In summary, there are 4 observations described as follows:

(1) In TD, both the cabbage PPG curve and the combined PPG curve behave as "elastic", but the hi-carbs PPG curve behaves as "plastic". The difference of average PPG is 12 mg/dL (hi-carbs is 134 mg/dL and cabbage is 122 mg/dL). From the TD energy analysis, its results using the squared PPG values as an indication of their respective energy levels, show that the TD energies for cabbage versus hi-carbs are cabbage = 45% versus hi-carbs = 55%. The TD energy ratio is 1.22:1.

(2) From the SD energy analysis, its results using the hysteresis loop area as an indication of energy level, show that the SD energies for cabbage versus hi-carbs are cabbage = 48% versus hi-carbs = 52%. The SD energy ratio is 1.08:1. Both hysteresis loops for the cabbage meals and the hi-carbs meals have shown the same curve patterns due to utilizing the same combined PPG change rates (strain rate). In addition, they have demonstrated viscoelastic behavior due to the same strain rate used, e.g. time-dependency and convergence between the initial-period data and ending-period data. Again, this observation is due to the cabbage meals being the majority of the combined meals (82%) which acts viscoelastic.

(3) From the FD energy analysis, its results using the frequency curve area as an indication of energy level, indicate that the FD energies for cabbage versus hi-carbs are cabbage = 46% versus hi-carbs = 54%. The SD energy ratio is 1.17:1.

(4) An interesting finding from the additional 2 analyses using two newly defined variables of (strain from total PPG * stress from cabbage PPG or hi-carbs PPG) has demonstrated that the FD energies for cabbage versus hi-carbs are cabbage = 43% versus hi-carbs = 57%. The SD energy ratio is 1.33:1.

In conclusion, whichever the energy analysis tool is utilized, the cabbage meals' energy is almost the same as the hi-carbs meals' energy with insignificant lower values of 8% to 33%. However, the most important fact is that the hi-carbs meal count versus cabbage meals count is 82%: 18% or 4.55: 1.0. In other words, 18% of the total meals (hi-carbs) have already generated 52% to 57% of total energy, while 82% of total meals (cabbage) have generated the remaining 43% to 48% of total energy.

Most clinical doctors review the glucose levels which are "linear" situations without any amplification effect. They should possess the physics knowledge of energy associated with glucose as an "amplified" variable. It is the energy associated with glucose causing damage to the internal organs, such as the heart, brain, and kidney, along with nerves, blood vessels, etc. From the perspective of physics, mathematics, and engineering, the energy is generated from the input variable multiplying with the consequent effect on the output variable; therefore, this "double amplification effect" would cause a larger value than the original biomarker's linear characteristics of either input variable (cause) or output variable (symptom) alone.

After reaching this stage of his research, the author suddenly recalls his personal experiences as a CEO for nearly 10 years to managing a publicly traded semiconductor company in Silicon Valley. Therefore, he utilized these biomedical data to "simulate" a business analogy case study.

First, he defines his average carbs/sugar intake amount as the unit cost figures for managing two separate divisions: hardware division (similar to cabbage meals) and software division (similar to hi-carbs meals). The hardware division has 619 factory workers with an average cost of $14.2 per worker (maybe hourly, monthly, or annually), and the software division has 136 programmers with an average cost of $32.1 per programmer (same unit as the hardware division which may be hourly, monthly, or annually). The revenue for the hardware division is $122 million and the revenue for the software division is $134 million. A profit of $34 million is generated for the hardware division and $90 million for the software division.

The author did not go through those 3 energy analysis processes for this business analogy case, but instead, he lists the results of "3 business ratios per person" as follows:

Division Employee %
= hardware 82% : software 18%

Division Revenue %
= hardware 17% : software 83%

Division Profit %
= hardware 8% : software 92%

The hardware division is not effectively managed in comparison with the software division, i.e. lots of hardware people have produced an almost equal amount of revenue with less profit than software people. It should be pointed out that the business analogy does not entirely match with the biomedical glucose case, since the higher revenue and profit in a business is better, whereas the lower the glucose level is preferred. However, as business executives, we cannot watch the revenue numbers only, we must also focus on profit numbers as well as employee productivity concerns. Similarly, it is not sufficient enough for a medical doctor to view a few biomarkers. Total knowledge of glucose, including the glucose energy causing the organ damage, is required which should be deeper and more thorough regarding "the source of diseases for preventive medicine", e.g. organ damages resulting from the energy associated with hyperglycemia, or a low percentage (12%) of hi-carbs meals creating a high percentage (52%) of "permanent deformation" of certain organs. In other words, medical doctors should not only know how to treat a disease using certain medications but their knowledge domain should be widened to include preventive medicine. Treatments are necessary actions for reducing some external symptoms of a disease, but not sufficient for the overall concerns of diseases, including both prevention and cure, if possible.

5. ACKNOWLEDGMENT

Without Professor Norman Jones at MIT as his academic advisor, the author would not be able to conduct this particular research work and published 700 medical research papers. The author has never forgotten his advice to him that he should always focus on and enhance his basic strength in foundations, such as mathematics and physics, to make further improvements and advancements. Professor Jones has also provided him with a personal example of doing outstanding teaching and research job with an excellent work attitude, extreme focus and dedication, and ultimate commitment to advancing both science and engineering.

6. REFERENCES

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

To read additional published VGT analyses on medical research, please view them in the following three journals:

(1) Special Issue. The GH-Method. (https://www.theghmethod.com)

(2) Journal of Applied Material Science & Engineering Research (contact: Catherine)

(3) Advances in Bioengineering and Biomedical Science Research (contact: Sonny Hazi).

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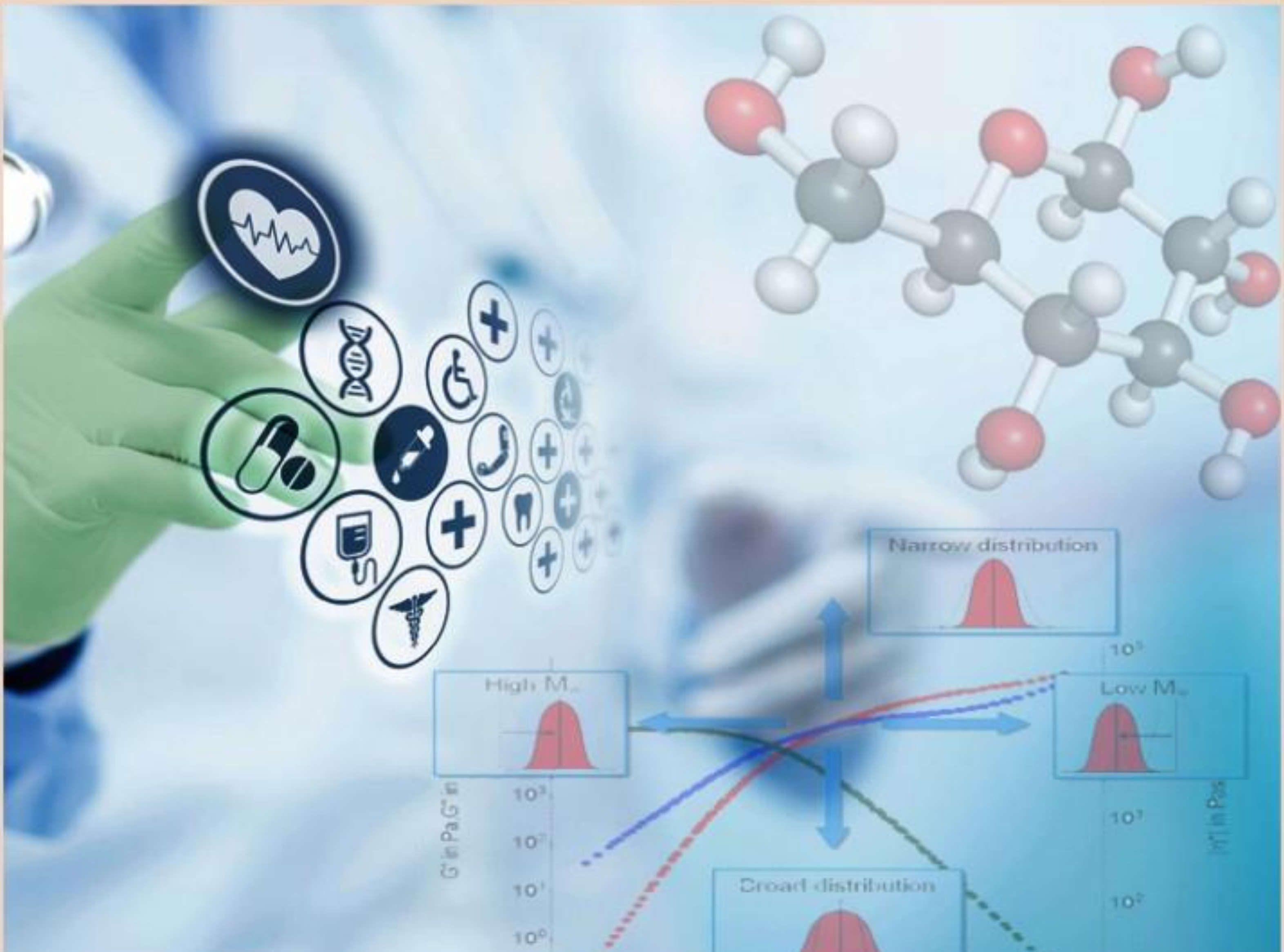

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