

The GH-Method

Viscoelastic and Viscoplastic Glucose Theory (VGT #117): Using Three Different Tools of Time-Domain Statistical Correlation, Space-Domain VGT Energy, and Frequency-Domain Fast Fourier Transform Energy to Study Body Weight versus Food Quantity %, Sleep Hours, and Daily Walking Steps Using a Type 2 Diabetes Patient Collected Data Over the Past 8 Annual Data from 7/25/2015 to 7/25/2022 Based on GH-Method: Math-Physical Medicine (No. 707)

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Note: This article is another version of both No. 618 (VGT #37) and No. 688 (VGT #98).

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

Abbreviations: CVD: cardiovascular disease; 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

The purpose of this article is to investigate the close relationship between the health output of body weight in the early morning (weight) versus three lifestyle inputs, food quantity % (food or m9a), sleeping hours at night (sleep), and daily walking steps (steps). The data used in this research are 8 annual data from 7/25/2015 to 7/25/2022.

The three inputs have gone through a “normalization process” by using the following 3 normalization factors:

- (1) The annual food portion % divided by the average food portion % of 8 annual periods.
- (2) Using 6 hours divided by each one of the annual sleep hours.
- (3) Using 14,000 steps divided by each one of the annual walking steps.

By applying the normalization process, he can remove the dependency of the individual unit or certain unique characteristics associated with each viscosity factor. In this way, these three input datasets can be compared “apples to apples” as a fair comparison.

The author is an engineer who has conducted medical research over the past 13 years in endocrinology, metabolic disorder-induced chronic diseases (especially diabetes), and their resulting various medical complications using math-physical medicine methodology (MPM) since 2010.

Beginning with paper No. 578 dated 1/8/2022, he has written 111 medical papers and 5 economics papers using viscoelasticity and viscoplasticity theories (VGT) tools from physics and engineering disciplines. These papers aim to explore some hidden physical behaviors and provide a deeper quantitative understanding of the inter-relationships of a selected output (symptom) versus singular

input or multiple inputs (root causes, risk factors, or influential factors).

In the field of medical research, the hidden biophysical behaviors and possible inter-relationships exist among lifestyle details, medical conditions, chronic diseases, and certain medical complications, such as heart attacks, stroke, kidney failure, cancers, dementia, and even longevity concerns. He has noticed that most medical subjects with their associated data, symptoms, and influential factors are “time-dependent” which means that all biomedical variables change from time to time because body living cells are organic and dynamically changing. This is what Professor Norman Jones, the author’s adviser at MIT, suggested to him in December of 2021 and why he utilizes the VGT tools from physics and engineering to conduct his 100+ medical research tasks since then.

The author is developing a software APP tool on his iPhone. After completion, he would be able to extract his collected health and medical data stored in a remote cloud server and then process them on his iPhone. Therefore, he can conduct all necessary numerical calculations using his VGT software tool which is similar to the establishment of an engineering laboratory. Of course, one of the major challenges of VGT analysis is always related to data mining, data selection, and data preparation which are similar to the setup tasks of a laboratory before conducting the actual engineering experiments.

This particular paper No. 707 discusses inter-relationship findings regarding his body weight in the early morning versus food portion, sleep hours, and walking steps. After having sound and sufficient sleep at night, his weight usually drops (in his case, around -2.4 lbs). After consuming food during the day, his weight usually increases (in his case, around +2.4 lbs). The bedtime weight minus the early morning weight is the weight gain amount of that particular day. The bedtime weight minus the early morning weight of the next day is the weight loss over that sleep.

His previous paper No. 618 (VGT #37) focused on body weight vs. food and sleep, without exercise for 13 half-year periods from Y15H2 to Y21H2. His other paper No.688 (VGT # 98) dealt with weight gain vs. food

and sleep, without exercise for 6 annual data from Y2017 to Y2022.

1.1 Specific medical information

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 his albumin-creatinine ratio (ACR) at 116. He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him about his need for kidney dialysis treatment and his future 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 & micro-vascular complications as well as nerve damage.

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 heavy traveling period.

Since early 2020, living in a COVID-19 quarantined lifestyle, not only has he written and published ~500 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 the 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 average sensor glucoses between 5-minute intervals and 15-minute intervals has only 0.6% difference (average glucose of 111.86 mg/dL for 5-minutes and average glucose of 111.18 mg/dL for 15-minutes with a correlation of 94% between these two sensor glucose curves) during the period from 2/19/20 to 7/22/22.

Therefore, over the past 13 years, he could study and analyze his 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 work has a goal of achieving both “high precision” and “quantitative proof” in the medical findings for the ultimate objectives of “preventive medicine”.

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 111 biomedical research cases and 5 economics research cases.

Again, to date, he has spent around 40,000 hours self-studying and researching medicine and he has read around 3,000 published medical papers online. He has collected and calculated more than three million pieces of data regarding his own medical conditions and lifestyle details. In addition, he has written 700+ medical research notes and published 650+ 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. METHODS

2.1 TD, SD, and FD analysis tools

This section has brief descriptions of time-domain (TD) correlation analysis with other observational results, space-domain (SD) VGT analysis with hysteresis loop area's energy results, and frequency-domain (FD) analysis with frequency curve area's energy results.

First of all, using a TD analysis tool, we can examine the curves' moving trend and pattern visually, and also the curves' correlation numerically. We can also study those extremely high or low data values in the dataset. The visual observation or calculation-derived interpretations are a part of statistical analysis which can indeed provide some useful hints or even derive some accurate conclusions. However, we must be aware of the limitation of the data we select and be cautious of the appropriate statistics tool we choose.

The author would like to describe the essence of his developed "hybrid model" that combines both space-domain (SD) viscoelastic/plastic VGT analysis method and frequency-domain (FD) fast Fourier transform (FFT) analysis method together with a comparison against the traditional time-domain statistical correlation analysis.

It is described in 9 steps instead of using mathematical equations to explain it. In this article, he has applied both the SD-VGT operations (steps 1-6) and the FD-FFT operations (steps 7-9). As a result, it is aimed at readers who do not have an extensive background in those academic subjects of engineering, physics & mathematics - several excerpts from Wikipedia are included in the Method section of this full-text article.

The first step is to collect the output data or symptom (strain or ϵ) on a time scale. The second step is to calculate the output change rate with time ($d\epsilon/dt$), i.e. the change rate of

strain or symptom over each period. The third step is to gather the input data or cause (viscosity or η) on a time scale. The fourth step is to calculate the time-dependent input or cause (time-dependent stress or σ) by multiplying $d\epsilon/dt$ and η together. The "time-dependent input or cause equation" of "stress $\sigma = \text{strain change rate of } d\epsilon/dt * \text{viscosity } \eta$ " is the essential part of "time-dependency". The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a 2-dimensional space domain or SD (x-axis versus y-axis) with strain (output or symptom) on the x-axis and stresses (time-dependent inputs, causes, or stresses) on the y-axis. The sixth step is to calculate the total enclosed area within these stress-strain curves or input-output curves (i.e. the hysteresis loops), which is also an indicator of associated energies (either created energy or dissipated energy) of this input and output dataset. These energy values can also be considered as the degrees of influence on output by inputs.

For the frequency domain, the seventh step is to define a "hybrid input variable" by using "strain*stress" which yields another accurate estimation of energy ratio similar to the SD-VGT energy ratio associated with the hysteresis loop. The eighth step is to present these hybrid models' results of both (strain*stress) and (strain*viscosity) in a TD and then perform the FFT operation to convert them into an FD. The enclosed area of the frequency curve (where the x-axis is the frequency and the y-axis is the amplitude of energy) can be used to estimate the total FD-FFT energy. The ninth step is to compare these FD energy results against the SD-VGT energy results.

After providing the above 9-step description, the author would still like to use the following set of VGT stress-strain mathematical equations in a two-dimensional SD to address the unique "time-dependency characteristics" of selected medical variables:

Strain
 $= \epsilon$
 $=$ individual strain value at the present time duration

Stress
 $= \sigma$ (based on the change rate of strain multiplying with a chosen viscosity factor η)
 $= \eta * (d\epsilon/dt)$

$= \eta * (d\text{-strain}/d\text{-time})$
 $= (\text{viscosity factor } \eta \text{ using individual viscosity factor at present time duration}) * (\text{strain at present quarter} - \text{strain at previous time duration})$

Some of these inputs (causes or viscosity factors) are further normalized by dividing them or being divided by a normalization factor using certain established health standards, such as 1.0 for metabolism index where m_i , $i=1,10$ for both 4 medical conditions and 6 lifestyle details since m_i values have already been normalized in their original calculations. Other examples of normalization factors are 6.0 for HbA1C, 6 or 7 hours for night-time sleep hours, 120 mg/dL for glucose, 25 for body mass index (BMI), 4,000 steps after each meal, 10,000 or 12,000 steps for daily walking exercise depends on time-period selection, 15 or 20 grams of carbs/sugar intake amount per meal depends on time-period selection. If using the originally collected data, i.e. the non-normalized data would distort the numerical comparison of the hysteresis loop areas. Using this “normalization process”, we can remove the dependency of the individual unit or certain unique characteristics associated with each viscosity factor. This process allows us to convert the originally collected variables into a set of “dimensionless variables” for easier numerical comparison and result interpretation.

2.2 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 them.

The following brief introductions are excerpts from Wikipedia:

“Elasticity (physics):

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

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

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

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

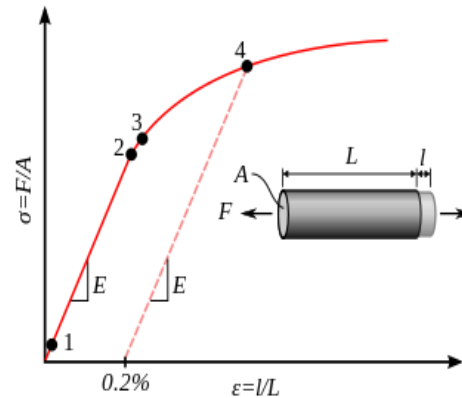
Medical analogy: The elastic behavior analogy in medicine can be expressed by the metal rod analogy for the postprandial plasma glucose (PPG). Consuming carbohydrates and/or sugar acts like a tensile force to stretch a metal rod longer, while post-meal exercise acts like a compressive force to suppress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

Plasticity (physics):

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

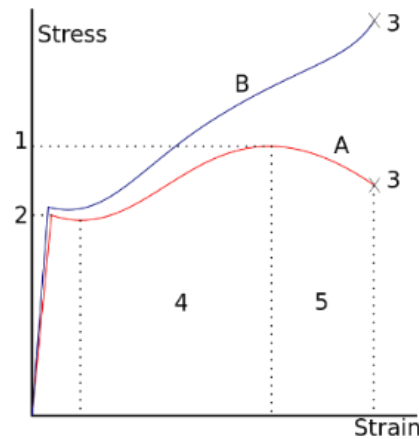
In physics and materials science, plasticity, also known as plastic deformation, is the ability of a solid material to undergo permanent deformation, a non-reversible

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



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

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



A stress-strain is typical of structural steel.

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

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

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

Viscoelasticity:

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

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

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

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

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

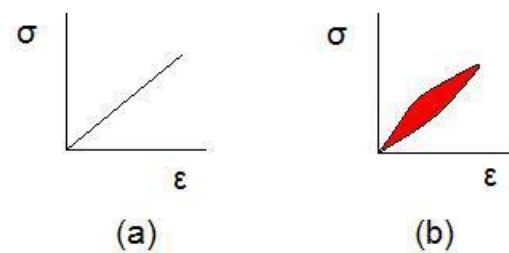
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit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

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

A viscoelastic material has the following properties:

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

Elastic versus viscoelastic behavior:



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

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

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

Viscoplasticity:

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

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

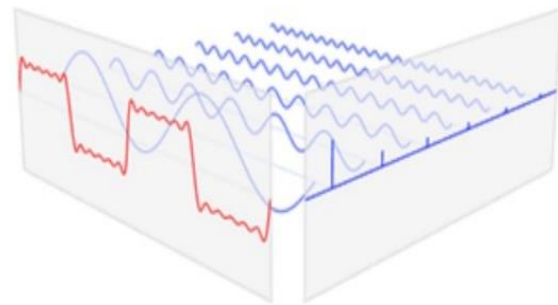
$$\begin{aligned} \text{Stress } (\sigma) & \\ &= \text{strain } (\epsilon) \text{ change rate} * \text{viscosity factor } (\eta) \\ &= d\epsilon/dt * \eta \end{aligned}$$

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

2.3 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 function 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 TD-correlation statistical analysis results.

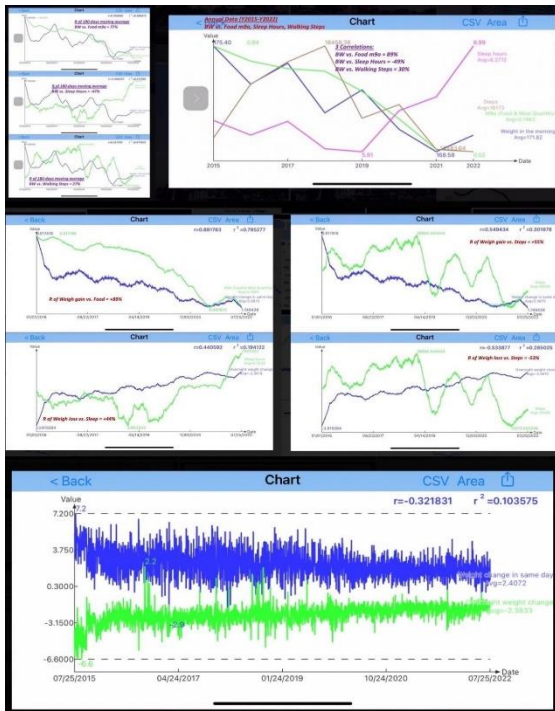


Figure 1: TD-correlation statistical analysis results.

Figure 2 displays the SD-VGT analysis and FD-FFT analysis results, as well as the data table.

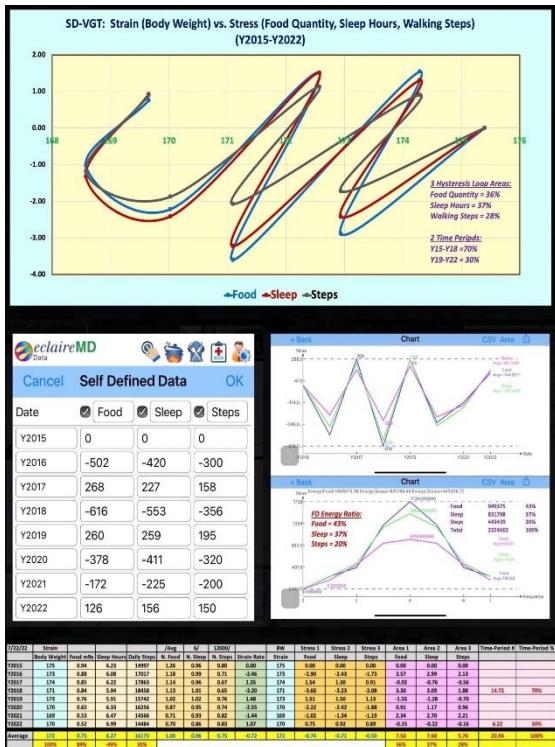


Figure 2: Results from SD-VGT and FD-FFT energy analyses with data table.

4. CONCLUSION

In summary, there are 3 observations and results from using the TD-correlation, SD-VGT energy, and FD-FFT energy analyses for investigating body weight versus food portion (food), sleep hours at night (sleep), and daily walking steps (steps):

(1) From the 180-days moving average TD curves, the author observed that the correlations of body weight (BW) versus 3 inputs are as follows: BW vs. food = 77%; BW vs. sleep = -47%; BW vs. steps = 27%. Another annual data curve has the correlations of body weight (BW) versus 3 inputs as follows: BW vs. food = 89%; BW vs. sleep = -49%; BW vs. steps = 30%. Furthermore, from his weight gain and weight loss studies, similar findings were observed as follows: Weight gain vs. food portion = +89%; Weight loss vs. sleep hours = +44%. This means that how much he eats directly contributes to his weight gain during the day and how long he sleeps also directly contributes to his weight loss during the night. Furthermore, exercise has a moderate contribution level on both his weight gain ($R = +55\%$) and his weight loss ($R = -53\%$).

(2) Researching the part of the variation of both strain and stress from the stress-strain diagram of the SD-VGT results, it can be seen that food, sleep, and steps have similar waveform patterns due to using the same strain change rate, i.e. body weight change rate. The energy contribution % from the 3 inputs are: Food = 35%; Sleep = 37%; steps = 28%. The two time-period analysis results reflect his energy occupying 70% of total energy in Y15-Y18; and occupying 30% of total energy in Y19-Y22. Furthermore, the sleeping area is slightly larger than the food area in Y19-Y22 due to higher sleep values in this period which is reversed from the pattern of Y15-Y18.

(3) From the frequency-domain FD analysis results, the three newly defined variables of (strain * stress) or (strain * strain change rate * viscosity) have three calculated energy areas underneath the respective frequency curves. Food energy = 43%; Sleep energy = 37%; Steps energy = 20%. This FD energy ratio of 43% : 37% : 20% is comparable with the SD-VGT energy ratio of 36% : 37% : 28%. In other words, from either SD analysis or FD

analysis, both food and sleep have contributed almost equal amounts of energy, or similar energy ratios, to body weight, while steps have contributed the least amount of energy to body weight.

This article explains the relationship between body weight vs. influence of food consumption during the day, sleep hours at night, and walking steps throughout the day using 8 annual data from 7/25/2015 to 7/25/2022. The quantitative findings from this paper have matched with the medical community's general healthcare recommendations of "eating less and sleeping well" and "exercise is important, but it has less influence on health than food". The SD-VGT energy tool adopted from engineering and the FD-FFT energy tool adopted from physics have further provided some deeper findings, useful hints, and realistic interpretations of complex biomedical results from humans weight resulting from food consumption, sleep quality, and exercise amount. Body weight has a strong influence on glucose levels and body weight maintenance is not a simple or easy task which is equally difficult as glucose control, or probably more important and much harder than glucose control (at least, in the author's case). Control of both body weight and glucose levels requires a good understanding and deeper research on the complex biomedical phenomena and biophysical behaviors of lifestyle details. It has further proven that the energy results, for example, the energy ratios among food, sleep, and exercise on body weight, are comparable to each other regardless of which analysis tool was used. Either the space-domain approach or frequency-domain approach can reveal useful conclusions, except we must be super careful about depending on statistics tools alone.

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, in order to make further improvements and advancements in science and engineering. More importantly, Professor Jones has also provided him with a personal example of doing outstanding teaching and research job with an excellent work attitude, extreme focus, total 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.eclaircmd.com.

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- (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).
- (4) Journal of Tumor Science Research (contact: Reinaud J)
- (5) Advances in Theoretical & Computational Physics (contact: Rapture D.).

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