Viscoelastic or Viscoplastic Glucose Theory (VGT #64): Estimated Risk Probability Percentages of Prostate Cancer and its Moving Trend over 12+ Years from 1/1/2010 to 4/18/2022 using Metabolism Index, Obesity, Diet, and Exercise as the 4 Influential Factors for Prostate Cancer Risk % Based on GH-Method: Math-Physical Medicine (No. 653)

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Abstract

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"Prostate Cancer:
(1) NIH: National Cancer Institute

What is the PSA test?
Prostate-specific antigen, or PSA, is a protein produced by normal, as well as malignant, cells of the prostate gland. The PSA test measures the level of PSA in the blood. For this test, a blood sample is sent to a laboratory for analysis. The results are usually reported as nanograms of PSA per milliliter (ng/mL) of blood. The blood level of PSA is often elevated in people with prostate cancer, and the PSA test was originally approved by the FDA in 1986 to monitor the progression of prostate cancer in men who had already been diagnosed with the disease. In 1994, FDA approved the PSA test to be used in conjunction with a digital rectal exam (DRE) to aid in the detection of prostate cancer in men 50 years and older. Until about 2008, many doctors and professional organizations had encouraged yearly PSA screening for prostate cancer beginning at age 50.

What is a normal PSA test result?
There is no specific normal or abnormal level of PSA in the blood. In the past, PSA levels of 4.0 ng/mL and lower were considered normal. However, some individuals with PSA levels below 4.0 ng/mL have prostate cancer and many with higher PSA levels between 4 and 10 ng/mL do not have prostate cancer (1). In addition, various factors can cause someone's PSA level to fluctuate. For example, the PSA level tends to increase with age, prostate gland size, and inflammation or infection. A recent prostate biopsy will also increase the PSA level, as can ejaculation or vigorous exercise (such as cycling) in the 2 days before testing. Conversely, some drugs—including finasteride and dutasteride, which are used to treat BPH—lower the PSA level. In general, however, the higher a man's PSA level, the more likely it is that he has prostate cancer. (The author's note: due to insufficient PSA data collection, it is not included in this VGT analysis.)

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Most men with high PSAs don't have prostate cancer. Their high PSAs might be due to:
• An enlarged prostate gland.
• A prostate infection.
• Recent sexual activity.
• A recent, long bike ride.

Up to 25% of men with high PSAs may have prostate cancer, depending on age and PSA level. But most of these cancers do not cause problems. It is common for older men to have some cancer cells in their prostate glands. These cancers are usually slow to grow. They are not likely to spread beyond the prostate. They usually don't cause symptoms or death. Studies show that routine PSA tests of 1,000 men ages 55 to 69 prevent one prostate cancer death.

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Summary:
Prostate cancer and type 2 diabetes are among the most common diseases in men. Although studies indicate that people with diabetes suffer more frequently from cancer, men with diabetes do not increasingly suffer from prostate cancer. **(The author's note: Diabetes does not cause prostate cancer directly, but it will increase the mortality rate of prostate cancer)**. *On the contrary, meta-analyses of studies have shown that diabetes patients are less likely to develop this carcinoma. However, the mortality rate is higher. This is also confirmed by current research carried out by researchers at the Institute for Diabetes Research and Metabolic Diseases (IDM) of Helmholtz Zentrum München at the University of Tübingen, a partner of the DZD, in cooperation with the Department of Urology at Tübingen University Hospital.*

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Junga Lee, Edward Giovannucci, and Justin Y. Jeon

Background
There are conflicting results as to the association between pre-existing diabetes and the risk of mortality in patients with prostate cancer. The purpose of this study is to estimate the influence of pre-existing diabetes on prostate cancer-specific **mortality** *and all-cause mortality.*

Methods
We searched PubMed and Embase to identify studies that investigated the association between pre-existing diabetes and the risk of death among men with prostate cancer. Pooled risk estimates and 95 % confidence intervals were calculated using fixed-effects models or random-effects models. Heterogeneity tests were conducted between studies. Publication bias was analyzed by using the Egger's test, Begg's test, and the trim and fill method.

Results. Of the 733 articles identified, 17 cohort studies that had 274,677 male patients were included in this meta-analysis. Pre-existing diabetes was associated with a 29 % increase in prostate cancer-specific mortality [relative risk (RR) 1.29, 95 % CI 1.22–1.38, $I2 = 66.68$ %], and with a 37 % increase in all-cause mortality (RR 1.37, 95 % CI 1.29–1.45, $p < 0.01$, $I2 = 90.26$ %). Additionally, in a subgroup analysis that was a type-specific analysis focusing on type 2 diabetes and was conducted only with three cohort studies, pre-existing type 2 diabetes was associated with all-cause mortality (RR 2.01, 95 % CI 1.37–2.96, $I2 = 95.55$ %) and no significant association with prostate cancer-specific mortality was detected (RR 1.17, 95 % CI 0.96–1.42, $I2 = 75.59$ %). There was significant heterogeneity between studies and no publication bias was found.

Conclusions
This meta-analysis suggests diabetes may result in a worse prognosis for men with prostate cancer. Considering heterogeneity between studies, additional studies should be conducted to confirm these findings and to allow generalization regarding the influence that each type of diabetes has on prostate cancer mortality.

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Risk factors for prostate cancer (PCa) are old age, race, family history, and obesity.

Prevention of PCa is: a healthy diet full of fruits and vegetables, choosing healthy foods over supplements, exercising most days of the week, and maintaining a healthy weight.

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Doctors suggest new names for low-grade prostate cancer, by Carla K. Johnson, April 18, 2022

This 1974 microscope image made available by the Centers for Disease Control and Prevention shows changes in cells indicative of adenocarcinoma of the prostate. Some doctors say it's time to rename low-grade prostate cancer to eliminate the alarming C-word.

Although most prostate cancers are harmless, approximately 34,000 Americans die from prostate cancer annually. A paper published on April 18, 2022, in the Journal of Clinical Oncology is reviving a debate about dropping the word "cancer" when patients learn the results of these low-risk biopsy findings. Credit: Dr. Edwin P. Ewing, Jr./CDC via AP

A cancer diagnosis is scary. Some doctors say it's time to rename low-grade prostate cancer to eliminate the alarming "C-word."

Based on the above-quoted information, there are a few important factors that are strongly related to prostate cancer - not necessarily in a form of a cause-symptom relationship but rather being risk factors for prostate cancer.

*Here are the author's selected 4 major risk factors for his prostate cancer study using VGT energy: metabolism index expressed by **MI value** (a combined score of 4 medical conditions and 6 lifestyle details with 0.735 as the dividing line), obesity or being overweight expressed by **body weight** (170 lbs. for BMI 25.0), diet (healthy **diet** full of fruits and vegetables and choose healthy foods over supplements as mentioned by the Mayo Clinic), and **exercise** (exercise most days of the week per the Mayo Clinic).*

In addition to the 4 important factors, MI, weight, diet, and exercise, some other components are connected to liver cancer as well, such as age, race, and family history which are pre-existing factors. Therefore, he chose to omit these non-modifiable factors, such as genetic factors, in his calculation and refers to his cancer risks as the "estimated relative risk probability percentage".

Although diabetes is not directly related to prostate cancers risk %, his lifestyle management efforts during the past 12 years, including diet and exercise, are directly beneficial to both his weight reduction and metabolism condition improvements. As a result, it is necessary to provide a brief description of his health history.

The author was diagnosed with type two diabetes (T2D) in 1997 with a random glucose check at a 300 mg/dL level; however, his T2D condition most likely began earlier. 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 life by conducting his 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), average glucose at 280 mg/dL, fasting plasma glucose (FPG) in the early morning at 180 mg/dL, lab-tested HbA1C at 10%, triglycerides at 1160, and his ACR at 116.

During the past 13 years, he has made significant lifestyle changes. For example, he consumes less than 20 grams of carbohydrates and sugar per meal, stops eating processed food, reduces his food quantity by 50%, walks 6-7 miles or 10-11 kilometers daily, sleeps 7-8 hours each night, and avoids stress as much as possible. As a matter of fact, he has never drunk alcohol, smoked cigarettes, or used any illicit drugs in his life.

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Relationships between Biomedical Causes and Biomedical Symptoms
As a mathematician/engineer for over 40 years and then conducting his medical research work during 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. Over the past 13 years, 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)
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VGT Stress
= σ (based on the change rate of strain, symptom, multiplying with one or more viscosity factors or influential factors)
*= η * (dε/dt)*
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*= (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.

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, and his developed metabolism index (MI) Model in the Method section.

The following four described biophysical characteristics have demonstrated certain behaviors of his prostate cancer risk probability under 4 specific influential factors, using the viscoelastic or viscoplastic energy (VGT) approach:
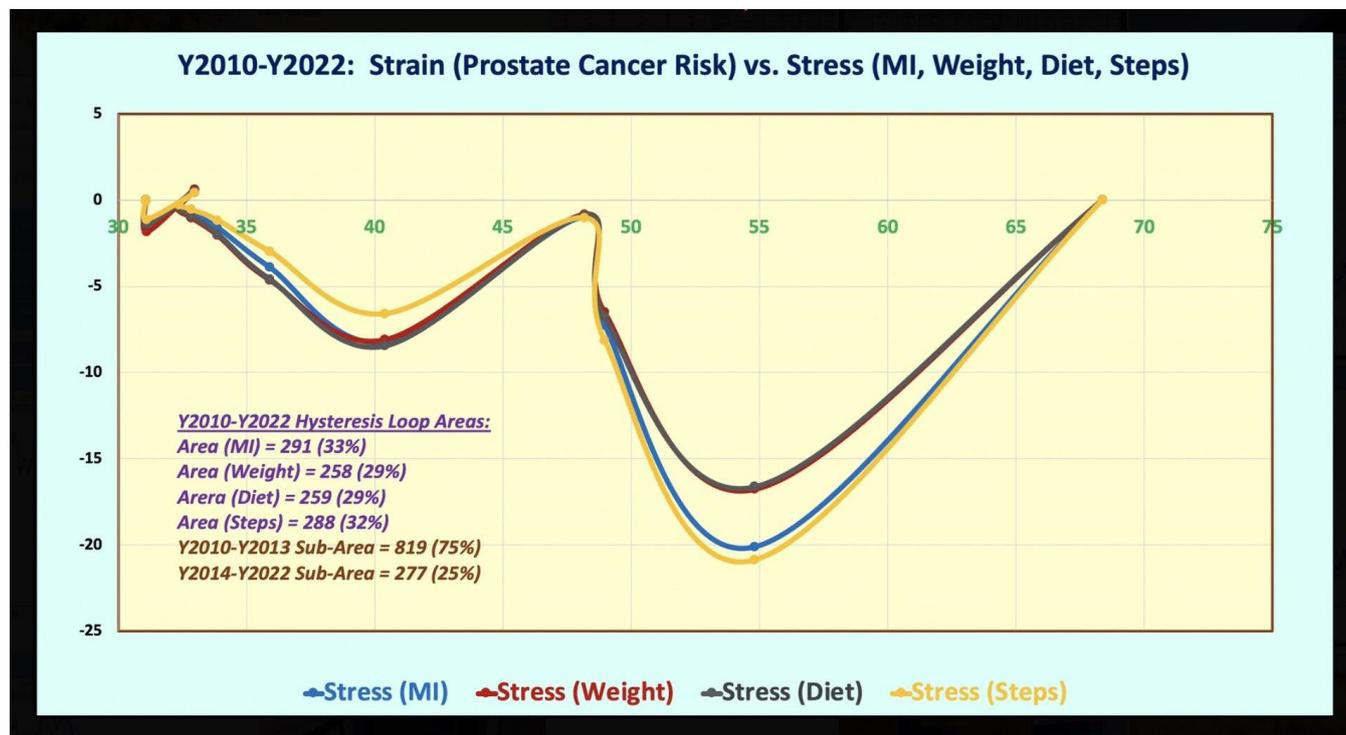
*(1) From the x-axis value or the strain value on the stress-strain diagram, **his prostate cancer risk % range covers from the high-end of 68% in 2010 to the low-end of 31% in 2022.** It should be mentioned again that these cancer risk % are just relative numbers, not absolute numbers. Nevertheless, the most important observation is that **his prostate cancer risks are decreasing.***
*(2) From the y-axis (stress) values and the hysteresis loop areas, we can see that both the stress values and the hysteresis loop areas for the period of Y2010-Y2013 are larger than the period of Y2014-Y2022. This indicates that **he is "healthier" during the recent 8 years; therefore, his prostate cancer risks have been reduced accordingly due to the improvements made on the four influential factors.***
*(3) Based on the comparison of loop area size, or degrees of influence, the summarized sub-area of 75% for earlier years of Y2010-Y2013 is three times bigger than the summarized sub-area of 25% for recent years of Y2014-Y2022. **His stringent lifestyle management program initiated in Y2014 has indeed changed his risk perspective of having prostate cancer.***

(4) When he delved deeper into the comparisons among the four influential factors, he can further identify some additional details regarding his "efforts and results" for each influential factor. Examples of these detailed observations are: MI and exercise have a similar degree of contribution to his prostate cancer risk %, ~32%-33%; while weight and diet have a similar degree of contribution to his prostate cancer risk %, 29%.

Y2010-Y2022: Strain (Prostate Cancer Risk) vs. Stress (MI, Weight, Diet, Steps)

Y2010-Y2022 Hysteresis Loop Areas:
Area (MI) = 291 (33%)
Area (Weight) = 258 (29%)
Arera (Diet) = 259 (29%)
Area (Steps) = 288 (32%)
Y2010-Y2013 Sub-Area = 819 (75%)
Y2014-Y2022 Sub-Area = 277 (25%)

Stress (MI)   Stress (Weight)   Stress (Diet)   Stress (Steps)

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viscoplasticity theories from the disciplines of engineering and physics, and his developed metabolism index (MI) Model in the Method section.

Methods

Metabolism Index (MI) Model

This model was developed in Y2014 by the author using the topology concept, nonlinear algebra, geometric algebra, and engineering finite element method. In summary, the human body metabolism is a complex mathematical problem with a matrix format of m causes by n symptoms, plus sometimes, one symptom or many symptoms would be turned into causes of another symptom.

This MI model contains 10 specific categories, including 4 output categories of medical conditions (body weight, glucose, blood pressure, and lipids), and 6 input categories of lifestyle details (food quantity and quality, drinking water intake, physical exercise, sleep, stress, and daily life routines). These 10 categories are comprised of approximately 500 detailed elements. He has also defined two new resulting parameters: the metabolism index or MI, as the combined score of the above 10 metabolism categories and 500 elements using his developed algorithm, along with the general health status unit (GHSU), as the 90-day moving average value of MI.

A physical analogy of this complex mathematical metabolism model is similar to ***"using multiple nails that are encircled by many rubber bands"***. For example, at first, we hammer 10 nails into a piece of flat wood with an initial shape of a circle, then take 3,628,800 (=10!) rubber bands to encircle the nails, including all 10 nails. These ~3.6 million rubber bands (i.e. big number of relationships) indicate the possible relationships existing among these 10 nails (i.e. 10 original metabolism data). Some rubber bands encircle 2 nails or 3 nails and so on until the last rubber band encircles all of these 10 nails together (no rubber band to encircle a single nail is allowed). Now, if we move any one of the nails outward (i.e., moving away from the center of the nail circle), then this moving action would create some internal tension inside the encircled rubber band. *Moving one nail "outward" means one of these ten metabolism categories is becoming "unhealthy" which would cause some stress to our body.* Of course, we can also move some or all of the 10 nails outward at the same time, but with different moving scales. If we can measure the summation of the internal tension created in the affected rubber bands, then this summarized tension force is equivalent to the metabolism value of human health. The higher tension means a higher metabolism value which creates an unhealthy situation. The author uses the above-described scenario of moving nails and their encircled rubber bands to explain his developed mathematical metabolism model of human health.

During 2010 and 2011, the author collected sparse biomarker data, but from the beginning of 2012, he has been gathering his body weight and finger-piercing glucose values each day. More complete data collection started in Y2015. In addition, he accumulates medical conditions data including BP, heart rate (HR), and blood lipids along with lifestyle details (LD). Since 2020, he has added the daily body temperature (BT) and blood oxy-

gen level (SPO2) due to his concerns about being exposed to COVID-19. Based on the collected big data of biomarkers, he further organized them into two main groups. The first is the medical conditions group (MC) with 4 categories: weight, glucose, BP, and blood lipids. The second is the lifestyle details group (LD) with 6 categories: food & diet, exercise, water intake, sleep, stress, and daily routines. At first, he calculated a unique combined daily score for each of the 10 categories within the MC and LD groups. The combined scores of the 2 groups, 10 categories, and 500+ detailed elements constitute an overall "metabolism index (MI) model". It includes the root causes of 6 major lifestyle inputs and symptoms from 4 lifestyle-induced rudimentary chronic diseases, i.e. obesity, diabetes, hypertension, and hyperlipidemia. Therefore, *the MI model, especially its 4 chronic disease conditions, can be used as the foundation and building block for his additional research work that can expand into various complications associated with different organs, such as cancer.*

Of course, the same methodology can be extended to the study of many other medical complications, such as various heart problems (CVD & CHD), stroke, neuropathy, hypothyroidism, diabetic constipation, diabetic skin fungal infection, various cancers, and dementia.

In general, some genetic conditions and lifetime unhealthy habits, which include tobacco smoking, alcohol drinking, and illicit drug use, account for approximately 15% to 25% of the root cause of chronic diseases and their complications, as well as cancers and dementia.

His calculated risk probability % for CKD, CVD, DR, stroke, and various cancers have some differences in their root-cause variables, their associated weighting factors for each key cause, and certain biomedical interpretations and assumptions. Specifically, the CVD/Stroke risk includes two major scenarios that combine emphasized weighting factors, blood vessel blockage due to blood glucose and blood lipids, and blood vessel rupture caused by blood glucose and blood pressure. Some recent research work has identified the relationship between pancreatic cancer with hyperglycemia and insulin resistance phenomena of T2D and chronic inflammation. Some aggressive prostate cancers are linked to 5 types of bacteria. There is also evidence of a relationship between BP and DR (Reference: BP control and DR, by R. Klein and BEK Klein from British Journal of Ophthalmology). The CKD risks include hyperglycemic damage to micro-blood vessels and nerves which causes protein leakage found in urine and waste deposit within the kidneys; therefore, it requires dialysis to remove waste products and excess fluids from the body. However, the cancer risk also consists of additional influences from environmental conditions, such as improper medications, viral infections, food pollution or poison, toxic chemical, radiation, air and water pollution, hormonal treatment, etc.

All of the above-mentioned diseases fall into the category of "symptoms" which are the outcomes of "root causes" of genetic conditions, unhealthy lifestyles, and poor living environments.

Elasticity, Plasticity, Viscoelasticity and ,Viscoplasticity
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.

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.

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.

The following brief introductions are excerpts from Wikipedia.

"Elasticity (Physics)
The physical property is when materials or objects return to the 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.*

The physical reasons for elastic behavior can be quite different for different materials. In metals, the atomic lattice changes size and shape when forces are applied (energy is added to the system). When forces are removed, the lattice goes back to the original lower energy state. For rubbers and other polymers, elasticity is caused by the stretching of polymer chains when forces are applied.

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.

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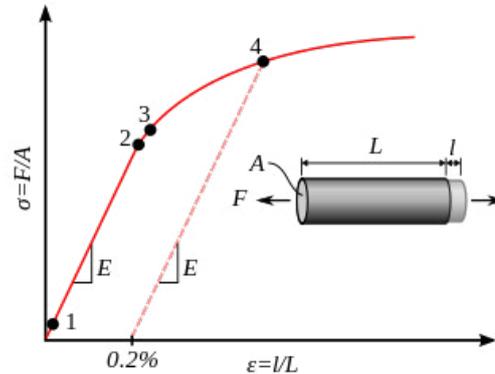
A stress-strain curve showing typical yield behavior for nonferrous alloys.

1. *True elastic limit*
2. *Proportionality limit*
3. *Elastic limit*
4. *Offset yield strength*
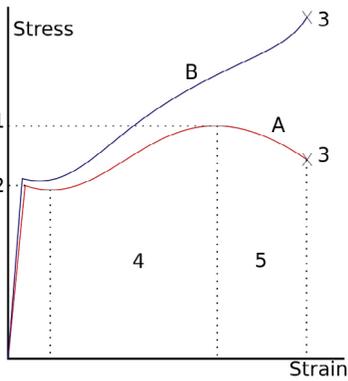
A stress-strain is typical of structural steel.

- 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)

Plastic deformation is observed in most materials, particularly metals, soils, rocks, concrete, and foams. However, the physical mechanisms that cause plastic deformation can vary widely. At a crystalline scale, plasticity in metals is usually a consequence of dislocations. Such defects are relatively rare in most crystalline materials, but are numerous in some and part of their crystal structure; in such cases, plastic crystallinity can result. In brittle materials such as rock, concrete, and bone, plasticity is caused predominantly by slip at microcracks. In cellular materials such as liquid foams or biological tissues, plasticity is mainly a consequence of bubble or cell rearrangements, notably T1 processes.

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.

Elastic deformation, however, is an approximation and its quality depends on the time frame considered and loading speed. If, as indicated in the graph opposite, the deformation includes elastic deformation, it is also often referred to as "elasto-plastic deformation" or "elastic-plastic deformation".

Perfect plasticity is a property of materials to undergo irreversible deformation without any increase in stresses or loads. Plastic materials that have been hardened by prior deformation, such as cold forming, may need increasingly higher stresses to deform further. Generally, plastic deformation is also dependent on the deformation speed, i.e. higher stresses usually have to be applied to increase the rate of deformation. Such materials are said to deform visco-plastically."

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. When a material exhibits a linear response it is categorized as a Newtonian material. In this case, the stress is linearly proportional to the strain rate. If the material exhibits a non-linear response to the strain rate, it is categorized as Non-Newtonian fluid. There is also an interesting case where the viscosity decreases as the shear/strain rate remains constant. A material that exhibits this type of behavior is known as thixotropic. 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 curve**
- **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
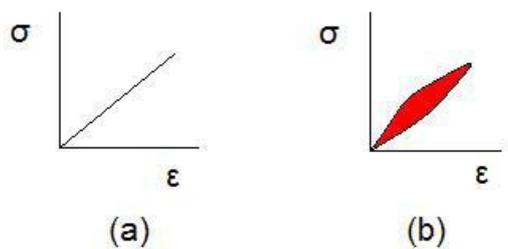
Stress-strain curves for a purely elastic material (a) and a visco-elastic material (b). The red area is a hysteresis loop and shows the amount of energy lost (as heat) in a loading and unloading cycle. It is equal to

$$\oint \sigma d\varepsilon$$

where σ is stress and ε is strain.

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.

Specifically, viscoelasticity is a molecular rearrangement. When a stress is applied to a viscoelastic material such as a polymer, parts of the long polymer chain change positions. This movement or rearrangement is called "**creep**". Polymers remain a solid material even when these parts of their chains are rearranging to accompany the stress, and as this occurs, it creates a back stress in the material. When the back stress is the same magnitude as the applied stress, the material no longer creeps. When the original stress is taken away, the accumulated back stresses will cause the polymer to return to its original form. **The material creeps, which gives the prefix visco-, and the material fully recovers, which gives the suffix -elasticity.**

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.
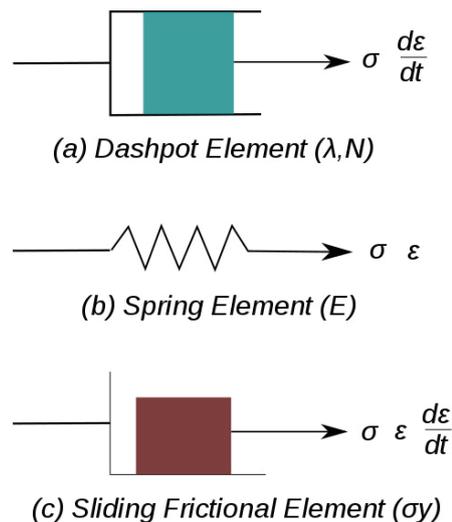

(a) Dashpot Element (λ,N)

(b) Spring Element (E)

(c) Sliding Frictional Element (σy)

Figure 1. Elements used in one-dimensional models of visco-plastic materials.

The elastic response of viscoplastic materials can be represented in one dimension by Hookean spring elements. Rate-dependence can be represented by nonlinear dashpot elements in a manner similar to viscoelasticity. Plasticity can be accounted for by adding sliding frictional elements as shown in Figure 1. In Figure E is the modulus of elasticity, λ is the viscosity parameter and N is a power-law type parameter that represents non-linear dashpot [σ(dε/dt)= σ = λ(dε/dt)(1/N)]. The sliding element can have a yield stress (σy) that is strain rate dependent, or even constant, as shown in Figure 1c.

Viscoplasticity is usually modeled in three dimensions using overstress models of the Perzyna or Duvaut-Lions types. In these models, the stress is allowed to increase beyond the rate-independent yield surface upon application of a load and then allowed to relax back to the yield surface over time. The yield surface is usually assumed not to be rate-dependent in such models. An alternative approach is to add a strain rate dependence to the yield stress and use the techniques of rate-independent plasticity to calculate the response of a material.

For metals and alloys, viscoplasticity is the macroscopic behavior caused by a mechanism linked to the movement of dislocations in grains, with superposed effects of inter-crystalline gliding. The mechanism usually becomes dominant at temperatures greater than approximately one-third of the absolute melting temperature. However, certain alloys exhibit viscoplasticity at room temperature (300K). For polymers, wood, and bitumen, the theory of viscoplasticity is required to describe behavior beyond the limit of elasticity or viscoelasticity.

In general, viscoplasticity theories are useful in areas such as
- the calculation of permanent deformations,
- the prediction of the plastic collapse of structures,
- the investigation of stability,
- crash simulations,
- systems exposed to high temperatures such as turbines in engines, e.g. a power plant,
- dynamic problems and systems exposed to high strain rates.

Phenomenology

For qualitative analysis, several characteristic tests are performed to describe the phenomenology of viscoplastic materials. Some examples of these tests are

1.   hardening tests at constant stress or strain rate,
2.   creep tests at constant force, and
3.   stress relaxation at constant elongation.
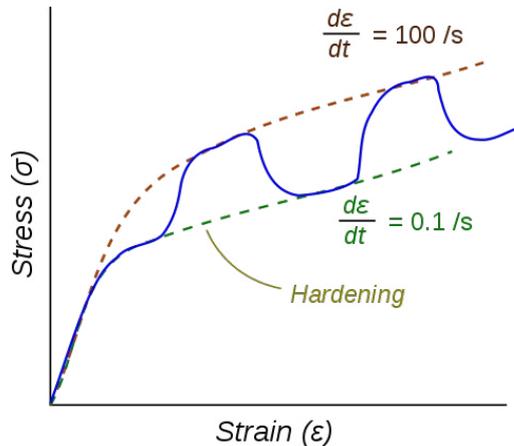
Strain hardening test

Figure 2. *Stress-strain response of a viscoplastic material at different strain rates.*

The dotted lines show the response if the strain rate is held constant. The blue line shows the response when the strain rate is changed suddenly.

One consequence of yielding is that as plastic deformation proceeds, an increase in stress is required to produce additional strain. This phenomenon is known as Strain/Work hardening. For a viscoplastic material, the hardening curves are not significantly different from those of rate-independent plastic material. Nevertheless, three essential differences can be observed.
1. At the same strain, the higher the rate of strain the higher the stress
2. A change in the rate of strain during the test results in an immediate change in the stress-strain curve.
3. The concept of a plastic yield limit is no longer strictly applicable.

The hypothesis of partitioning the strains by decoupling the elastic and plastic parts is still applicable where the strains are small, i.e.,

$\varepsilon = \varepsilon e + \varepsilon vp$

where εe is the elastic strain and εvp is the viscoplastic strain. To obtain the stress-strain behavior shown in blue in the figure, the material is initially loaded at a strain rate of 0.1/s. The strain rate is then instantaneously raised to 100/s and held constant at that value for some time. At the end of that period, the strain rate is dropped instantaneously back to 0.1/s and the cycle is continued for increasing values of strain. There is clearly a lag between the strain-rate change and the stress response. This lag is modeled quite accurately by overstress models (such as the Perzyna model) but not by models of rate-independent plasticity that have a rate-dependent yield stress.''

Time-Frequency Analysis via fast Fourier Transform
Time and Frequency Domain Analysis of Signals:
A Review by Getachew Admassie Ambaye
Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology (BiT), Bahir Dar, Ethiopia

The time domain is the analysis of mathematical functions, and physical signals with respect to time. In the time domain, the signal or function's value is known for all real numbers, in the case of continuous-time, or at various separate instants in the case of discrete-time. An oscilloscope is a tool commonly used to visualize real-world signals in the time domain. A time-domain graph shows how a signal changes with time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. The frequency-domain refers to the analysis of mathematical functions or signals with respect to frequency, rather than time. 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. And finally, the time-frequency signal analysis introduced, it's a new method in which the problem that had on the frequency signal analysis will be solved.

Time-frequency analysis
Techniques and methods in signal processing *(from Wikipedia)*
In signal processing, the time-frequency analysis comprises those techniques that study a signal in both the time and frequency domains simultaneously, using various time-frequency. Rather than viewing a 1-dimensional signal (a function, real or complex-valued, whose domain is the real line) and some transform (another function whose domain is the real line, obtained from the original via some transform), time-frequency analysis studies a two-dimensional signal – a function whose domain is the two-dimensional real plane, obtained from the signal via a time-frequency transform.

Fourier Transform (from Wikipedia):
Mathematical transform that expresses a function of time as a function of frequency

A Fourier transform (FT) is a mathematical transform that decomposes functions depending on space or time into functions depending on the spatial frequency or temporal frequency. An example application would be decomposing the waveform of a musical chord in terms of the intensity of its constituent pitches. The term Fourier transform refers to both the frequency domain representation and the mathematical operation that associates the frequency domain representation to a function of space or time.

Results

Figure 1 shows the data tables used in this study.

4/18/22 Prostate Cancer	Viscosity 1 MI	Viscosity 2 Weight	Viscosity 3 Diet	Viscosity 4 Steps	MI/0.735 Norm. MI	M9/0.735 Norm. Weight	10000/steps Norm. Diet	25/25/25/25 Norm. Steps	*50 Cancer Risk %	Cancer (MI)	Ratio
Y2010	1.40	220	1.48	6000	1.90	1.29	1.97	1.67	68	76	90%
Y2011	1.09	210	0.90	6500	1.48	1.24	1.22	1.54	55	60	91%
Y2012	0.91	189	0.85	7200	1.24	1.11	1.16	1.39	49	50	97%
Y2013	0.94	183	0.83	7492	1.28	1.07	1.13	1.33	48	51	94%
Y2014	0.78	177	0.80	11767	1.06	1.04	1.09	0.85	40	46	87%
Y2015	0.64	175	0.75	14997	0.87	1.03	1.02	0.67	36	45	80%
Y2016	0.59	173	0.72	17017	0.80	1.02	0.98	0.59	34	41	82%
Y2017	0.57	174	0.68	17863	0.78	1.03	0.93	0.56	33	40	83%
Y2018	0.57	171	0.67	18458	0.78	1.01	0.91	0.54	32	39	83%
Y2019	0.58	173	0.63	15742	0.79	1.02	0.86	0.64	33	41	80%
Y2020	0.52	170	0.58	16256	0.71	1.00	0.79	0.62	31	38	81%
Y2021	0.54	169	0.51	14566	0.73	0.99	0.69	0.69	31	40	77%
Y2022	0.53	169	0.52	14604	0.72	0.99	0.71	0.68	31	40	78%
Average	0.7	181	0.76	12958.62	1.01	1.04	1.00	1.00	40	47	85%

4/18/22 Prostate Cancer	Strain Cancer Risk %	Viscosity 1 Stress (MI)	Viscosity 2 Stress (Weight)	Viscosity 3 Stress (Diet)	Viscosity 4 Stress (Steps)	4/18/22 Prostate Cancer	Area (MI)	Area (Weight)	Area (Diet)	Area (Steps)	Sub-Area	Sub-Area %
Y2010	68	0	0	0	0	Y2010	0	0	0	0		
Y2011	55	-20	-17	-17	-21	Y2011	137	114	113	142		
Y2012	49	-7	-7	-7	-8	Y2012	80	68	69	85		
Y2013	48	-1	-1	-1	-8	Y2013	3	3	3	4	819	75%
Y2014	40	-6	-8	-8	-7	Y2014	36	35	36	30		
Y2015	36	-4	-6	-6	-3	Y2015	27	29	29	22		
Y2016	34	-2	-2	-2	-1	Y2016	6	7	7	4		
Y2017	33	-1	-1	-1	-1	Y2017	1	2	1	1		
Y2018	32	0	-1	0	0	Y2018	0	1	0	0		
Y2019	33	0	1	1	0	Y2019	0	0	0	0		
Y2020	31	-1	-2	-1	-1	Y2020	1	1	1	1		
Y2021	31	0	0	0	0	Y2021	0	0	0	0		
Y2022	31	0	0	0	0	Y2022	0	0	0	0	277	25%
Average	40	-3.4	-3.2	-3.2	-3.3	Average	291	258	259	288	1097	100%
Stress Ratio to A1C		100%	94%	94%	96%	Area Ratio to A1C	100%	89%	89%	99%		
						0.3, 0.3, 0.2, 0.2	33%	29%	29%	32%	123%	

This 1974 microscope image made available by the Centers for Disease Control and Prevention

Figure 1: Data tables (the liver graph is courtesy of the CDC)

Figure 2 depicts the stress-strain diagram of prostate cancer risk % with 4 hysteresis loops via VGT analysis in a space domain.
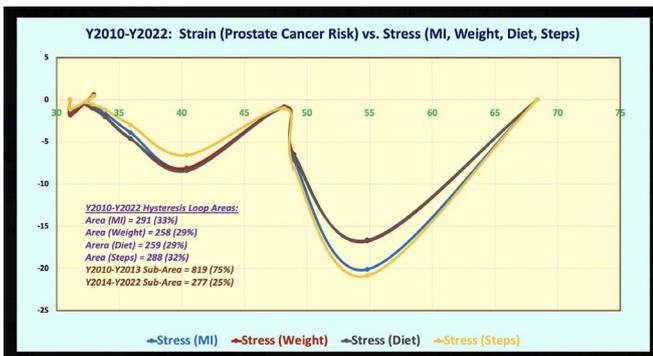
Y2010-Y2022: Strain (Prostate Cancer Risk) vs. Stress (MI, Weight, Diet, Steps)

Y2010-Y2022 Hysteresis Loop Areas:
Area (MI) = 291 (33%)
Area (Weight) = 258 (29%)
Area (Diet) = 259 (29%)
Area (Steps) = 288 (32%)
Y2010-Y2013 Sub-Area = 819 (75%)
Y2014-Y2022 Sub-Area = 277 (25%)

→Stress (MI)   →Stress (Weight)   →Stress (Diet)   →Stress (Steps)

Figure 2: Stress-strain diagram of prostate cancer risk % with 4 hysteresis loops via VGT analysis in a space domain

Conclusion

The following four described biophysical characteristics have demonstrated certain behaviors of his prostate cancer risk probability under 4 specific influential factors, using the viscoelastic or viscoplastic energy (VGT) approach:

(1) From the x-axis value or the strain value on the stress-strain diagram, *his prostate cancer risk % range covers from the high-end of 68% in 2010 to the low-end of 31% in 2022.* It should be mentioned again that these cancer risk % are just relative numbers, not absolute numbers. Nevertheless, the most important observation is that his prostate cancer risks are decreasing.

(2) From the y-axis (stress) values and the hysteresis loop areas, we can see that both the stress values and the hysteresis loop areas for the period of Y2010-Y2013 are larger than the period of Y2014-Y2022. This indicates that *he is "healthier" during the recent 8 years; therefore, his prostate cancer risks have been reduced accordingly due to the improvements made on the four influential factors.*

(3)   Based on the comparison of loop area size, or degrees of influence, the summarized sub-area of 75% for earlier years of Y2010-Y2013 is three times bigger than the summarized sub-area of 25% for recent years of Y2014-Y2022. *His stringent lifestyle management program initiated in Y2014 has indeed changed his risk perspective of having prostate cancer.*

(4) When he delved deeper into the comparisons among the four influential factors, he can further identify some additional details regarding his "efforts and results" for each influential factor. Examples of these detailed observations are: *MI and exercise have a similar degree of contribution to his prostate cancer risk %, ~32%-33%; while weight and diet have a similar degree of contribution to his prostate cancer risk %, 29%.*

This prostate cancer risk article has demonstrated how the author utilizes the physics and engineering, VGT energy methodology, to construct and display his research result findings of prostate cancer risk % resulting from four interrelated influential factors.

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.