The GH-Method

Nonlinear Plastic Glucose Theory (NPGT #2): Applying Elasticity Theory, Plasticity Theory, and Energy Theory to Investigate Hyperglycemic Postprandial Plasma Glucose (PPG) Behaviors Using 30 Days within a 3.5-Year CGM Sensor Glucose Period from 5/1/2015 to 5/7/2018 and 12 Days within a 3-Year Finger Glucose Period from 5/1/2015 to 5/7/2018 Based on GH-Method: Math-Physical Medicine (No. 568)

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Note: Readers who want to get a quick overview can read the abstract, results, and graphs.

Abstract

The author's background covers mathematics, physics, and various engineering disciplines not including biology and chemistry. As a result, he can only investigate the observed biomedical phenomena using his ready-learned math-physical tools. For background information, he provides a more detailed description of his self-study of medicine and medical research on endocrinology, chronic diseases, and related complications in the Methods section. The following paragraphs just summarize certain key data and associated timelines within his 27-year history of type 2 diabetes (T2D). In 1995, he was diagnosed with T2D and started taking three different types of diabetes medications. Fifteen years after his initial diagnosis, his HBA1C in 2010 reached to 10% to 14.7% with an average glucose between 278 mg/dL and 310 mg/dL. In addition, he suffered many diabetic complications, such as hypertension, hyperlipidemia, cardiac episodes, retinopathy, neuropathy, foot ulcer, bladder infection, hypothyroidism, kidney disease, diabetic constipation, and diabetic skin fungal infection, but no stroke. From 2011 to 2014, during the 4-years period of his self-study on internal medicine and food nutrition, his glucose range was 131 mg/dL to 156 mg/dL with an HbA1C between 6.8% to 7.7%. Since 2015, he started to research and identify several effective ways to predict and control his glucoses; therefore, from 2015 to 2017, his glucose range was 122 mg/dL to 144 mg/dL with an HbA1C between 6.6% to 7.2%. Furthermore, from 2018-2019, he maintained an extremely busy travel schedule to attend 65+ medical conferences while making 120+ presentations. As a result, during the pre-COVID traveling period of 2018-2019, his glucose range only reduced slightly between 115 mg/dL and 134 mg/dL with an HbA1C of 6.7% to 6.8%. Over the past two years of the COVID-19 self-quarantined period from 2020 to 2021, his glucose range drops to 105 mg/dL to 120 mg/dL with an HbA1C of 6.2% to 6.3%. His latest lab-tested A1C on 10/22/2021 was 5.8% with an average glucose of 102.7 mg/dL which are the lowest in his 27-year history of T2D. One special note is that the author ceased taking any diabetes medications since 12/08/2015. Therefore, his research work of both NPGT #1 (CGM sensor PPG of Y2018-Y2021) and NPGT #2 (finger PPG of Y2015-Y2018) are "medication-free". Once medication enters into our bodies, it takes over the control of glucose outputs, i.e. symptoms. In his two studies, his research data came from two sources, i.e. his body health (pancreatic beta cells and liver) and his lifestyle management (diet and exercise), without any medication intervention. Starting on 1/1/2012, he began measuring his glucose using a finger-piercing device for 4 glucose data per day, and then supplementing with a continuous glucose monitoring (CGM) device since 5/8/2018 to collect 96 glucose data per day. During the 6.5-year period of finger-piercing measurements, he measured fasting plasma glucose (FPG) once in the early morning and three times for postprandial plasma glucose (PPG) at 2-hours (120-minutes) after the first bite of meal. It should be pointed out that his PPG values at 120-minutes instant are usually lower than most of other PPG data points resulted from the combination of his low-carbs/sugar diet and persistent post-meal exercise. But, using finger-piercing method, he

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was unable to catch the "glucose peaks" which usually occur approximately 45-75 minutes (or ~60-minutes) after the first-bite of his meal (0-minute). As explained earlier, unfortunately, using only daily average value from the finger-pierced glucose data at 120-minutes after the first bite of meal during his worst diabetes period from 2000 to 2011, not only are they insufficient for achieving his purpose but also irrelevant to conduct a meaningful research work on the verification with the applicability of "glucose plasticity theory". In order to obtain his maximum glucoses or PPG peaks, he must rely on his CGM sensor device data with a useful data-mining tool. In the early morning of 12/24/2021, the author came up with an idea on how to solve this dilemma. From his earlier research findings, he has already learned that FPG in the early morning is the closet biomarker which indicates his on-going health state of pancreatic beta cells while sleeping without the influence of both food and exercise. Of course, there are still some other minor influential factors, such as ambient temperature, sleep conditions, stress, etc. A noteworthy footnote is that body weight and body temperature in the early morning are closely correlated with FPG. There are two assumptions to be made in this research paper No. 568. First, he selects the FPG as his finger-pierced PPG at 0-minute (i.e., first bite of meal). Actually, this selection could result into a number at lower scale due to the possible influences from between-meal's snacks or fruits. Second, regarding his PPG values at 180-minutes, he chooses the same GH.w-Modulus value of 14.7 (from his paper No. 567) multiplying his post-meal walking k-steps. This GH.w-Modulus was defined in his previous papers regarding linear elastic glucose theory (LEGT). GH.w-Modulus (usually around 5.0) is the conversion ratio for calculating PPG reduction amount resulting from post-meal walking k-steps. The glucose data used in this study are from a total of 4,783 finger-pierced glucoses collected over the past 1,101 days covering 3,682 meals and snacks/fruits from 5/1/2015 to 5/7/2018. However, while using this glucose database, he had to modify and enhance his developed software program to perform necessary data-mining tasks to extract those 30 worst days of the hyperglycemic cases (2.7% for PPG greater than 200 mg/dL) from a big database of 1,101 days (100%). To offer a simple explanation to readers who do not have physics or engineering background, the author includes a brief excerpt from Wikipedia regarding the basic concept description of elasticity theory and plasticity theory from the disciplines of engineering and physics in the section of Method. The analogy between physics and medicine are two-fold. First, the force or stress in physics and engineering (y-axis) corresponds to the influential force or load on our body for pushing PPG upward in medicine, i.e. carbohydrates and sugar intake amount. Second, the deformation or strain in physics and engineering (x-axis) corresponds to the actual PPG level in medicine. The medical field is quite different from the engineering field, where the engineering materials such as steel, copper, concrete, and aluminum are inorganic in most cases. These material properties do not change significantly over their expected lifespans. However, in medicine, the body with its organs and cells are organic and go through many distinct stages over their natural lifespans, such as birth, splitting, growth, mutation, development, repair, sickness, and death. Therefore, medical properties are kind of "moving targets" which vary with individual person and different time-window. After declaring the analogy of elasticity and plasticity theories, the energy theory in physics must be brought into context. The human body and organs are composed of different organic cells that require energy infusion from glucose carried in red blood cells and energy consumption through labor-work or exercise. When the residual energy, i.e. left-over energy, is stored in a plastic glucose scenario, it will cause different degrees of damage to certain internal organs. According to physics, energies associated with the residual glucoses are proportional to the square of the residual glucoses. Those residual energies from elevated glucoses are circulating inside our body via blood vessels and then impact all of our internal organs to create different degrees of damage. The author has applied Fast Fourier Transform (FFT) operations to convert the glucose wave from a time-domain into a frequency-domain. The y-axis amplitude values in the frequency-domain indicate the proportional energy levels associated with each different frequency of glucose occurrence. Currently, many people live a sedentary lifestyle and lack sufficient exercise to burn off the energy influx which causes them to become overweight or obese. In addition, many types of processed food add unnecessary ingredients and harmful chemicals that are toxic to the bodies, which lead to the development of different chronic diseases. In engineering analysis, when the load is applied to the structure, it bends or twists, i.e. deforms; however, when the load is removed, it will either be restored (elastic) or remain in a permanent deformed (plastic) shape. In corresponding medical analysis, after eating carbohydrates or sugar from food, our glucose level (sugar amount inside of blood) will increase; therefore, the carbs/sugar functions as the energy supply. After labor work or exercise, the glucose level will decrease. As a result, the exercise burns off the energy, which is similar to load removal in the engineering case. In the biomedical case, the energy consumption process takes time which is not as simple and quick as the structural load removal in the engineering case. Therefore, the glucose behaviors, for both elastic glucose and plastic glucose, are "dynamic" in nature, i.e. time-dependent. Professor Norman Jones taught the author "dynamic plastic behaviors of various structural components" when he was a graduate student at the Massachusetts Institute of

Technology from 1972-1976. Since early 2014, based on his educational background, the author has always suspected the possible existence of this "plastic glucose" phenomena in biomedical environment. However, he could not verify his suspicion due to the difficulty of collecting his hyperglycemia data in early years and lacking of a suitable data-mining tool later on for him to investigate his hyperglycemic situation (high glucose level). As a professional engineer, he has already learned that most of his glucose data behavior would follow the "elastic" pattern in a normal situation. In this paper No. 568 of finger PPG study (NPGT #2), he has finally discovered that 97.3% of his maximum PPG data are actually below 200 mg/dL and behave elastically. In his previous paper No.567 of CGM sensor PPG study (NPGT #1), he also discovered that 99.1% of his maximum PPG data are actually below 200 mg/dL and behave elastically. The exceptional "plastic glucose" case (in this study, 2.7% of his total finger-pierced PPG data are located within the range from 200 mg/dL to 300 mg/dL; while in his previous study, 0.9% of his total CGM sensor PPG data are located within the range from 200 mg/dL to 300 mg/dL) and its glucose behaviors possess a type of abnormal situation in a "plastic" pattern. This percentage division of majority % vs. minority % (for this case, 97.3% vs. 2.7%, or for previous study, 99.1% vs. 0.9%) matches his personal experiences and previous work findings from designing defense weapons, space shuttle, nuclear power plants, computer hardware devices, machine components, earthquake engineering, and semiconductor chips. From the concerns of complete coverage for the scope and possible severe damage on the object, a thorough understanding and deeper study of this low percentage of occurrence associated with "plastic" scenarios is absolutely necessary. For example, the majority of the population is diabetes-free (~80% to 90%) and the hyperglycemic percentages (extremely high glucose level) of existing diabetes patients is probably quite low as well. However, for severe diabetes patients, their lives are at high risk since diabetes leads to many complications and ultimately death which can be a very painful process. As a result, the author decides to conduct his research on "plastic glucose theory" and hopefully be able to gain a better understanding of this extreme case of plastic scenario. Regarding the energy consumption, the author maintains a good exercise program over the years by walking ~4,000 steps after each meal with an average of ~15,000 steps daily. This post-meal walking will effectively bring his PPG level lower. In his previous NPGT #1 study, both of his elastic and plastic glucose cases, his post-meal walking were identical at 4.2 k-steps. In this NPGT #2 study, his elastic glucose case has an average post-meal walking of 4.3k-steps while his plastic glucose case has a lower average post-meal walking of 3.5k-steps. This walking steps reduction is due to a substantial portion of his high carbs/sugar meals were consumed on cross-continental flights which had no room for having any type of exercise while on the airplane. Nevertheless, either 3.5k or 4.3k walking steps have probably reached near his upper-bound limit. In theory, if he increases his post-meal walking to 7k-steps in hopes of reducing his plastic PPG at 180-minutes to the same level at 0-minute, he will have to walk continuously for more than one hour after each meal which is realistically difficult. The elastic PPG behavior (by eating less carbs/sugar with an average of 12 grams per meal) shows that his PPG at 180-minutes will be reduced to the same PPG level at 0-minute of 122 mg/dL, after exhausting the influential forces from carbs/sugar and 4.3k-steps of exercise. In other words, his PPG level will completely bounce back to its initial state. Therefore, it is "elastic". Borrowing the concept from plastic theory in physics, he can now interpret the plastic PPG behavior clearly. After eating high carbs/sugar food with an average of 90 grams per meal (too high of energy input) and walking 3.5 k-steps after meal (insufficient to burn-off energy input), it pushes his PPG up to 218 mg/dL around 60-minutes and then reduces it back to 153 mg/dL at 180-minutes via exercise. Unfortunately, this ending glucose level of 153 mg/dL has still created a 37 mg/dL of residual glucose which is higher than his PPG at 0-minute of 116 mg/dL. (Please note that he uses his FPG in early morning of 116 mg/dL as his PPG at 0-minute). This 37 mg/dL of residual PPG will then be converted into an excessive residual energy which will cause different degrees of damage on various internal organs such as heart, brain, kidney, eyes, nerves, feet, toes, skin, bladder, and intestines. In summary, as described in these 2 research articles, he has successfully kept his hyperglycemia glucoses (averaged PPG values around 217-218 mg/dL) within the limit of 12 meals only (0.9%) during his CGM sensor PPG years of Y2018-Y2021; and 30 meals only (2.7%) during his finger-pierced PPG years of Y2015-Y2018. Figure 6 of PPG density distribution diagrams for both sensor PPG and finger PPG have further proved the existence of these two small percentages (0.9% and 2.7%) of hyperglycemia cases. Even calculating the square of this residual PPG amount of w4 mg/dL or 37 mg/dL for estimating his residual energy amount, the potential damages on his internal organs are still small, and therefore, his health has still been well-protected. This quick self-examination of health has offered him a clear explaination on why, since 5/1/2015, he has not suffered furthermore from any of his previous suffered complications, except diabetic skin fungal infection. This summary paragraph has precisely described his original intention for identifying this practical preach to achieve good results of his personal health through this research work of glucose plasticity.

Keywords: Elasticity theory; Plasticity theory; Energy theory; Postprandial plasma glucose; Glucose; Diabetes

Abbreviations: T2D: type 2 diabetes; FPG: fasting plasma glucose; PPG: postprandial plasma glucose; CGM: continuous glucose monitoring; MPM: math-physical medicine

1. INTRODUCTION

The author's background covers mathematics, physics, and various engineering disciplines not including biology and chemistry. As a result, he can only investigate the observed biomedical phenomena using his ready-learned math-physical tools. For background information, he provides a more detailed description of his self-study of medicine and medical research on endocrinology, chronic diseases, and related complications in the Methods section. The following paragraphs just summarize certain key data and associated timelines within his 27-year history of type 2 diabetes (T2D).

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One special note is that the author ceased taking any diabetes medications since 12/08/2015. Therefore, his research work of both NPGT #1 (CGM sensor PPG of Y2018-Y2021) and NPGT #2 (finger PPG of Y2015-Y2018) are "medication-free". Once medication enters into our bodies, it takes over the control of glucose outputs, i.e. symptoms. In his two studies, his research data came from two sources, i.e. his body health (pancreatic beta cells and liver) and his lifestyle management (diet and exercise), without any medication intervention.

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But, using finger-piercing method, he was unable to catch the "glucose peaks" which usually occur approximately 45-75 minutes (or ~60-minutes) after the first-bite of his meal (0-minute). As explained earlier, unfortunately, using only daily average value from the finger-pierced glucose data at 120-minutes after the first bite of meal during his worst diabetes period from 2000 to 2011, not only are they insufficient for achieving his purpose but also irrelevant to conduct a meaningful research work on the verification with the applicability of "glucose plasticity theory". In order to obtain his maximum glucoses or PPG peaks, he must rely on his CGM sensor device data with a useful data-mining tool.

In the early morning of 12/24/2021, the author came up with an idea on how to solve this dilemma. From his earlier research findings, he has already learned that FPG in the early morning is the closet biomarker which indicates his on-going health state of pancreatic beta cells while sleeping without the influence of both food and exercise. Of course, there are still some other minor influential factors, such as ambient temperature, sleep conditions, stress, etc. A noteworthy footnote is that body weight and body temperature in the early morning are closely correlated with FPG.

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The medical field is quite different from the engineering field, where the engineering materials such as steel, copper, concrete, and aluminum are inorganic in most cases. These material properties do not change significantly over their expected lifespans. However, in medicine, the body with its organs and cells are organic and go through many distinct stages over their natural lifespans, such as birth, splitting, growth, mutation, development, repair, sickness, and death. Therefore, medical properties are kind of "moving targets" which vary with individual person and different time-window.

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In engineering analysis, when the load is applied to the structure, it bends or twists, i.e. deforms; however, when the load is removed, it will either be restored (elastic) or remain in a permanent deformed (plastic) shape. In corresponding medical analysis, after eating carbohydrates or sugar from food, our glucose level (sugar amount inside of blood) will increase; therefore, the carbs/sugar functions as the energy supply. After labor work or exercise, the glucose level will decrease. As a result, the exercise burns off the energy, which is similar to load removal in the engineering case. In the biomedical case, the energy consumption process takes time which is not as simple and quick as the structural load removal in the engineering case. Therefore, the glucose behaviors, for both elastic glucose and plastic glucose, are "dynamic" in nature, i.e. time-dependent.

2. METHODS

2.1 MPM background

To learn more about his developed GH-Method: math-physical medicine (MPM) methodology, readers can read the following three papers selected from the published 400+ medical papers.

The first paper, No. 386, describes his MPM methodology in a general conceptual format. The second paper, No. 387, outlines the history of his personalized diabetes research, various application tools, and the differences between biochemical medicine (BCM) approach versus the MPM approach. The third paper, No. 397, depicts a general flow diagram containing ~10 key MPM research methods and different tools.

All of the listed papers in the References section are from his written and published medical research papers.

2.2 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 an average daily glucose of 250 mg/dL (HbA1C of 10%). During that year, his triglycerides reached to 1161 and albumin-creatinine ratio (ACR) at 116. He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him regarding his needs of kidney dialysis treatment and his future high risk of dying from his severe diabetic complications. Other than cerebrovascular disease (stroke), he has suffered most of known diabetic complications, including both macro-vascular and micro-vascular complications.

In 2010, he decided to launch his self-study on endocrinology, diabetes, and food nutrition in order to save his own life. During 2015 and 2016, he developed four prediction models related to diabetes conditions: weight, postprandial plasma glucose (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 since 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 dinning out frequently, post-meal exercise disruption, jet lag, and along with the overall metabolism impact due to his irregular life patterns through a busy travel schedule; therefore, his glucose control and overall metabolism state were somewhat affected during this two-year heavier traveling period.

During 2020-2021 with a COVID-19 quarantined lifestyle, not only has he published ~500 medical papers in 100+ journals, but he has also reached his best health conditions for the past 28 years. By Y2021, his weight was further reduced to 165 lbs. (BMI 24.4) along with a 5.8% A1C value on 10/22/2021, 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 developed various high-tech tools contribute to his excellent health status since 1/19/2020, the beginning date of his COVID-19 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 present day. In his research work, he uses his CGM sensor glucose at time-interval of 15 minutes (96 data per day). By the way, the difference of average sensor glucoses between 5-minute intervals and 15-minute intervals is only 0.4% (average glucose of 114.81 mg/dL for 5-minutes and average glucose of 114.35 mg/dL for 15-minutes with a correlation of 93% between these two sensor glucose curves) during the period from 2/19/20 to 8/13/21.

Therefore, over the past 12 years, he could study and analyze the collected ~3 million data regarding his health status, medical conditions, and lifestyle details. He applies his knowledge, models, and tools from mathematics, physics, engineering, and computer science to conduct his medical research work. His medical research work is based on the aims of achieving both "high precision" with "quantitative proof" in the medical findings.

The following timetable provides a rough sketch of the emphasis of 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.

Again, to date, he has collected more than two million data regarding his medical conditions and lifestyle details. In addition, he has written 567 medical papers and published 500+ paper in 100+ various medical journals. Moreover, he has also given ~120 presentations at ~65 international medical conferences. He has continuously dedicated his time and efforts on his medical research work and shared his findings and learnings with other patients worldwide.

2.3 Elasticity and plasticity

The following paragraphs are excerpts from Wikipedia:

"Elasticity (physics)

Physical property when materials or objects return to 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.

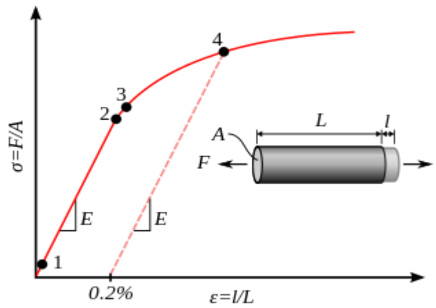
Hooke's law states that the force required to deform elastic objects should be directly proportional to the distance of deformation, regardless of how large that distance becomes. This is known as perfect elasticity, in which a given object will return to its original shape no matter how strongly it is deformed. This is an ideal concept only; most materials which 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.

Plasticity (physics)

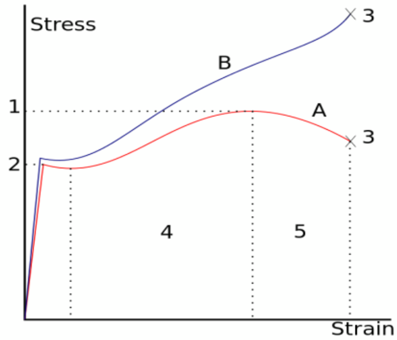
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

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.



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 curve 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."

3. RESULTS

Figure 1 shows the author's collected data of maximum PPG, PPG at 0-min, PPG at 180-min, carbs/sugar intake grams, post-meal walking k-steps, glucose differences between 0-min and max, glucose differences between 180-min and max.

There are two data tables in this figure. The upper table lists input data for his finger PPG from 5/1/2015 to 5/7/2018 (NPGT#2). The lower table lists input data for his CGM sensor PPG from 5/8/2018 to 12/20/2021 (NPGT#1).

Figure 2 illustrates a simplified triangular linear PPG diagram using the maximum PPG or Peak PPG (not averaged peaks) as inputs. This figure combines two papers of both NPGT#1 (Paper No.567) and NPGT#2 (Paper No.568) with both elastic and plastic scenarios.

Plasticity Theory (12/24/21)				=FPG*1.0	Eff. "+PPG" =	GH.p		Max.-K-steps*14.7	Eff. "-PPG" =	GH.w
Max. PPG (200-300)	Max. F.PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
5/7/15	224	100	130	130	94	0.9	4.1	163	61	14.7
5/14/15	218	100	130	130	88	0.9	6.5	122	96	14.7
6/24/15	208	28	114	114	94	3.4	3.1	162	46	14.7
6/26/15	224	50	116	116	108	2.2	3.8	167	57	14.7
7/4/15	201	46	119	119	82	1.8	3.7	147	54	14.7
7/14/15	203	42	115	115	88	2.1	4.5	137	66	14.7
8/10/15	230	40	118	118	112	2.8	2.1	199	31	14.7
8/21/15	201	68	119	119	82	1.2	3.0	157	44	14.7
10/25/15	219	40	129	129	90	2.3	3.4	169	50	14.7
12/11/15	217	90	110	110	107	1.2	4.0	158	59	14.7
1/26/16	202	80	119	119	83	1.0	3.6	149	53	14.7
1/28/16	208	60	94	94	114	1.9	7.2	102	106	14.7
2/19/16	251	80	124	124	127	1.6	6.5	155	96	14.7
5/6/16	202	100	112	112	90	0.9	5.4	123	79	14.7
5/20/16	205	50	128	128	77	1.5	1.3	186	19	14.7
6/4/16	232	70	118	118	114	1.6	1.5	210	22	14.7
6/6/16	242	100	118	118	124	1.2	3.1	196	46	14.7
10/23/16	205	100	114	114	91	0.9	4.1	145	60	14.7
12/3/16	202	126	104	104	98	0.8	4.0	143	59	14.7
1/2/17	218	90	109	109	109	1.2	0.1	217	1	14.7
1/5/17	204	84	88	88	116	1.4	4.0	145	59	14.7
1/11/17	231	110	131	131	100	0.9	0.5	224	7	14.7
2/22/17	206	116	122	122	84	0.7	3.1	161	45	14.7
6/20/17	224	110	105	105	119	1.1	0.9	211	13	14.7
8/5/17	205	120	102	102	103	0.9	4.5	138	67	14.7
9/24/17	206	100	112	112	94	0.9	1.9	178	28	14.7
10/10/17	241	120	131	131	110	0.9	3.6	188	53	14.7
2/27/18	203	80	115	115	88	1.1	0.4	197	6	14.7
3/14/18	201	100	122	122	79	0.8	4.1	141	60	14.7
5/7/18	298	300	106	106	192	0.6	6.1	208	90	14.7
30 days (2.725%)	218	90.0	116	116	102	1.4	3.5	153	60	14.7
Plasticity Theory:					Eff. "+PPG" =				Eff. "-PPG" =	
5/8/18-12/10/21	Max. F.PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
1,101 days (100%)	148	14.5	119	119	29	2.0	4.4	119	29	6.5
1,101 daya (97.3%)	142	12.0	116	116	26	2.2	4.3	115	27	6.3
	Max. PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
Elastic Range (1,101 days)	142	12	116	116	26	2.2	4.337	115	27	6.3
Plastic Days (30 days)	218	90	116	116	102	1.4	3.472	153	60	14.7
Difference (Plastic - Elastic)	76	78	0	0	76	-0.8	-0.865	38	33	8.4
Plastic (What-if 6.5k-steps)							7.000	115		

Plasticity Theory:					Eff. "+PPG" =				Eff. "-PPG" =	
Max. PPG (200-300)	Max. F.PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
9/6/20	228.00	100	121	146	82	0.8	4.253	172	56	13.2
11/9/19	213.00	100	114	141	72	0.7	4.625	161	52	11.2
10/29/19	300.00	160	111	100	200	1.3	5.631	130	170	30.2
6/12/19	200.00	40	120	124	76	1.9	4.207	167	33	7.8
4/25/19	213.00	110	90	100	113	1.0	2.912	148	65	22.3
4/3/19	203.00	100	120	144	59	0.6	2.067	189	14	6.8
2/8/19	200.00	40	109	135	65	1.6	4.033	135	65	16.1
2/5/19	205.00	16	152	122	83	5.2	5.052	137	68	13.5
12/28/18	210.00	140	106	130	80	0.6	6.063	155	55	9.1
11/22/18	200.00	50	151	137	63	1.3	4.234	158	42	9.9
9/28/18	202.00	120	128	137	65	0.5	3.55	132	70	19.7
5/29/18	235.00	14	104	143	92	6.6	4.215	166	69	16.4
12 days (0.91%)	217	82.5	119	130	88	1.8	4.237	154	63	14.7
Plasticity Theory:					Eff. "+PPG" =				Eff. "-PPG" =	
5/8/18-12/10/21	Max. F.PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
1323 days (100%)	149	14	107	123	26	1.9	4.258	123	26	6.1
1311 daya (99.1%)	147	12.9	105	122	25	2.0	4.219	122	26	6.0
	Max. PPG	Carbs/Sugar	S.FPG	PPG @ 0-min	Max-0min	(Eff.+PPG) / Carbs	K-Steps	PPG @ 180-min	Max-180min	(Eff.-PPG) / K-steps
Elastic Range (1311 days)	147	13	105	122	25	2.0	4.219	122	26	6.0
Plastic Days (12 days)	217	83	119	130	88	1.8	4.237	154	63	14.7
Difference (Plastic - Elastic)	70	70	13	8	62	-0.1	0	33	38	8.6
Plastic (What-if 6.5k-steps)							6.500	122		14.7

Figure 1: Data table for both NPGT#1 (CGM sensor PPG from 5/8/18-12/20/21) and NPGT#2 (finger PPG from 5/1/15-5/7/18).

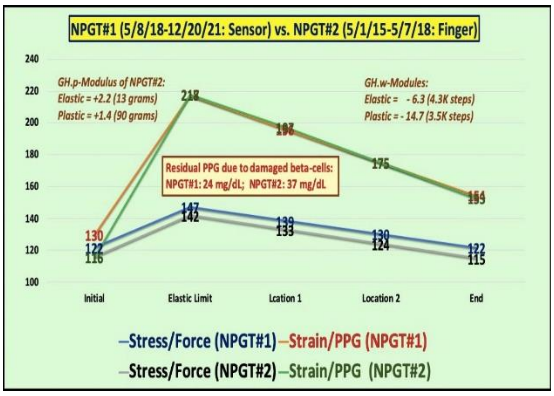


Figure 2: Simplified triangular PPG curves of both elastic and plastic cases (using maximum PPG as inputs) for both sensor PPG and finger PPG of two different periods.

For NPGT#1 (CGM sensor PPG), the 0-min PPG and 180-min PPG for the blue line elastic PPG case are identical at 122 mg/dL with a peak of 147 mg/dL (this is max. PPG value). On the other hand, the red line plastic PPG case has a peak at 217 mg/dL and a residual PPG gap of 24 mg/dL between 180-min of 154 mg/dL and 0-min of 130 mg/dL. This indicates that glucose is unable to bounce back to its original state, which is in a plastic state.

For NPGT#2 (finger PPG), the 0-min PPG and 180-min PPG for the elastic case are identical at 116 mg/dL with a peak of 142 mg/dL (this is max. PPG value). On the other hand, the red PPG curve has a peak at 218 mg/dL and a residual PPG gap of 37 mg/dL between 180-min of 153 mg/dL and 0-min of 116 mg/dL. This indicates that glucose is unable to bounce back to its original state, which is in a plastic state.

Figure 3 demonstrates the analogy of elastic theory and plastic theory applied on the biomedical glucose behavior study. An interpretation using energy theory is also inserted in this figure. Both upper diagram for CGM sensor PPG (NPGT#1) and lower diagram for finger PPG (NPGT#2) are quite similar to each other. Their two blue lines indicate elastic PPG scenario which PPG values increasing from 0-minute to the maximum PPG and then PG at 180-minutes bouncing back to its original level. Their two red curves indicate plastic PPG scenario which PPG values increasing from 0-minute to the maximum PPG and then PPG at 180-minutes lowering somewhat with remaining glucose gaps, i.e. residual PPG, 24 mg/dL for sensor case and 37 mg/dL for finger case.

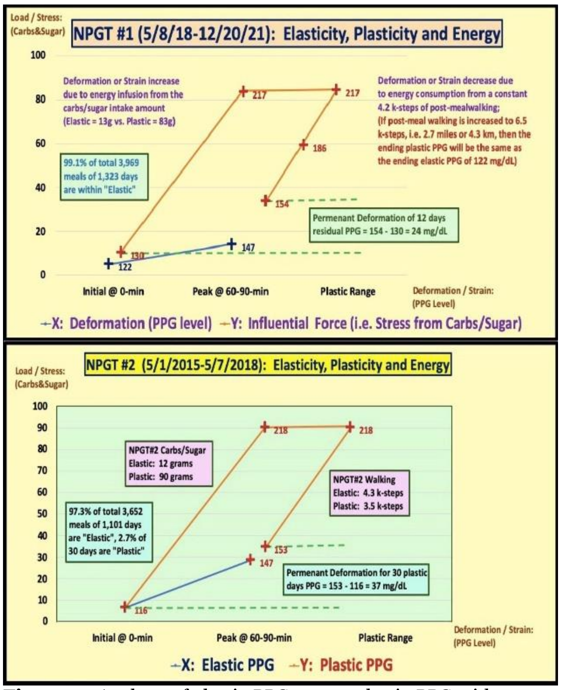


Figure 3: Analogy of elastic PPG versus plastic PPG with energy theory interpretation for sensor PPG (upper diagram), and finger PPG (lower diagram).

Figure 4 shows a group of pictures of 26 meals with their maximum PPG beyond 200 mg/dL for NPGT #2 study during 5/1/2015 - 5/7/2018. The lower single picture shows his highest PPG value of 298 mg/dL on 5/7/2018 resulted from eating a shaved ice with Japanese rice cake and leeches (both are loaded with sugar and super sweet). The other 25 meal photos show the majority of his meals having plastic glucose which were dine-out meals in variety of restaurants. It can be seen that they are highly carbs/sugar loaded meals of noddles, lasagna, breads, and rice. Quite a few meals were taken on board of an airplane flight.

Figure 4: Sample photos of 26 hyperglycemia meals for the period from 5/1/2015 to 5/8/2018.

Figure 5 reflects two CGM sensor PPG waveforms of Y2018-Y2021 in a time-domain. They are synthesized PPG waveforms covering 0-min to 180-mine at 15-minutes interval. The red curve is the plastic case while the blue curve is the elastic case. It should be emphasized that the PPG values are the average value of 12 days plastic data, not the maximum peak value of each day. In the blue curve, its 0-min PPG and 180-min PPG are identical at 122 mg/dL, with a peak occurring around 60-min of 134 mg/dL (this is average PPG value). This curve has an "elastic" behavior. On the other hand, the synthesized average PPG of the red curve has elevated PPG above 200 mg/dL, within the range from 90-min to 180-min. The difference between 180-min of 205 mg/dL and 0-min of 145 mg/dL is 60 mg/dL. This 60 mg/dL glucose gap indicates that PPG is unable to bounce back to its original state at 0-min, which is in a plastic state.

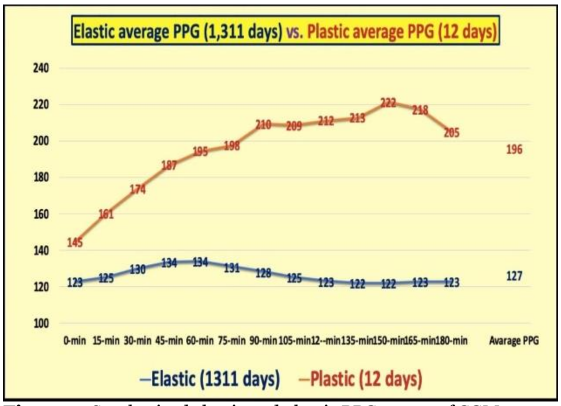


Figure 5: Synthesized elastic and plastic PPG curves of CGM sensor PPG during Y2018-Y2021 in time-domain, using averaged PPG as inputs.

Due to the fact of only one finger-piercing glucose data available for each meal during during the period from Y2012 to Y2018, the author can not draw a comparable synthesized waveform in a time-domain using his collected finger-piercing PPG dataset.

Figure 6 shows the two diagrams of PPG density distribution for both CGM sensor PPG during Y2018-Y2021 (upper diagram) and finger-pierced PPG during Y2015-Y2018 (lower diagram). It is clear that these two distribution diagrams are quite similar in waveform to each other and with very small percentages for glucoses higher than 200 mg/dL.

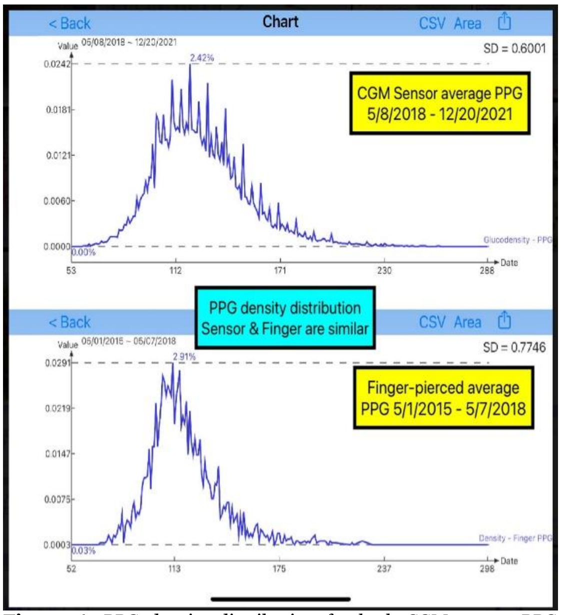


Figure 6: PPG density distribution for both CGM sensor PPG during Y2018-Y2021 (upper diagram) and finger-piercing PPG during Y2015-Y2018 (lower diagram).

4. CONCLUSION

Professor Norman Jones taught the author "dynamic plastic behaviors of various structural components" when he was a graduate student at the Massachusetts Institute of Technology from 1972-1976. Since early 2014, based on his educational background, the author has always suspected the possible existence of this "plastic glucose" phenomena in biomedical environment. However, he could not verify his suspicion due to the difficulty of collecting his hyperglycemia data in early years and lacking of a suitable data-mining tool later on for him to investigate his hyperglycemic situation (high glucose level).

As a professional engineer, he has already learned that most of his glucose data behavior would follow the "elastic" pattern in a normal situation. In this paper No. 568 of finger PPG study (NPGT #2), he has finally discovered that 97.3% of his maximum PPG data are actually below 200 mg/dL and behave elastically. In his previous paper No.567 of CGM sensor PPG study (NPGT #1), he also discovered that 99.1% of his maximum PPG data are actually below 200 mg/dL and behave elastically. The exceptional "plastic glucose" case (in this study, 2.7% of his total finger-pierced PPG data are located within the range from 200 mg/dL to 300 mg/dL; while in his previous study, 0.9% of his total CGM sensor PPG data are located within the range from 200 mg/dL to 300 mg/dL) and its glucose behaviors possess a type of abnormal situation in a "plastic" pattern. This percentage division of majority % vs. minority % (for this case, 97.3% vs. 2.7%, or for previous study, 99.1% vs. 0.9%) matches his personal experiences and previous work findings from designing defense weapons, space shuttle, nuclear power plants, computer hardware devices, machine components, earthquake engineering, and semiconductor chips.

From the concerns of complete coverage for the scope and possible severe damage on the object, a thorough understanding and deeper study of this low percentage of occurrence associated with "plastic" scenarios is absolutely necessary. For example, the majority of the population is diabetes-free (~80% to 90%) and the hyperglycemic percentages (extremely high glucose level) of existing diabetes patients is probably quite low as well. However, for severe diabetes patients, their lives are at high risk since diabetes leads to many complications and ultimately death which can be a very painful process.

As a result, the author decides to conduct his research on "plastic glucose theory" and hopefully be able to gain a better understanding of this extreme case of plastic scenario.

Regarding the energy consumption, the author maintains a good exercise program over the years by walking ~4,000 steps after each meal with an average of ~15,000 steps daily. This post-meal walking will effectively bring his PPG level lower. In his previous NPGT #1 study, both of his elastic and plastic glucose cases, his post-meal walking were identical at 4.2 k-steps. In this NPGT #2 study, his elastic glucose case has an average post-meal walking of 4.3k-steps while his plastic glucose case has a lower average post-meal walking of 3.5k-steps. This walking steps reduction is due to a substantial portion of his high carbs/sugar meals were consumed on cross-continental flights which had no room for having any type of exercise while on the airplane. Nevertheless, either 3.5k or 4.3k walking steps have probably reached near his upper-bound limit. In theory, if he increases his post-meal walking to 7k-steps in hopes of reducing his plastic PPG at 180-minutes to the same level at 0-minute, he will have to walk continuously for more than one hour after each meal which is realistically difficult.

The elastic PPG behavior (by eating less carbs/sugar with an average of 12 grams per meal) shows that his PPG at 180-minutes will be reduced to the same PPG level at 0-minute of 122 mg/dL, after exhausting the influential forces from carbs/sugar and 4.3k-steps of exercise. In other words, his PPG level will completely bounce back to its initial state. Therefore, it is "elastic".

Borrowing the concept from plastic theory in physics, he can now interpret the plastic PPG behavior clearly. After eating high carbs/sugar food with an average of 90 grams per meal (too high of energy input) and walking 3.5 k-steps after meal (insufficient to burn-off energy input), it pushes his PPG up to 218 mg/dL around 60-minutes and then reduces it back to 153 mg/dL at 180-minutes via exercise. Unfortunately, this ending glucose level of 153 mg/dL has still created a 37 mg/dL of residual glucose which is higher than his PPG at 0-minute of 116 mg/dL. (Please note that he uses his FPG in early morning of 116 mg/dL as his PPG at 0-minute). This 37 mg/dL of residual PPG will then be converted into an excessive residual energy which will cause different degrees of damage on various internal organs such as heart, brain, kidney, eyes, nerves, feet, toes, skin, bladder, and intestines.

In summary, as described in these 2 research articles, he has successfully kept his hyperglycemia glucoses (averaged PPG values around 217-218 mg/dL) within the limit of 12 meals only (0.9%) during his CGM sensor PPG years of Y2018-Y2021; and 30 meals only (2.7%) during his finger-pierced PPG years of Y2015-Y2018. Figure 6 of PPG density distribution diagrams for both sensor PPG and finger PPG have further proved the existence of these two small percentages (0.9% and 2.7%) of hyperglycemia cases. Even calculating the square of this residual PPG amount of w4 mg/dL or 37 mg/dL for estimating his residual energy amount, the potential damages on his internal organs are still small, and therefore, his health has still been well-protected. This quick self-examination of health has offered him a clear explaination on why, since 5/1/2015, he has not suffered furthermore from any of his previous suffered complications, except diabetic skin fungal infection. This summary paragraph has precisely described his original intention for identifying this practical preach to achieve good results of his personal health through this research work of glucose plasticity.

5. REFERENCES

For editing purposes, 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.

6. ACKNOWLEDGEMENT

Without Professor Norman Jones at MIT as his academic advisor, the author would not be able to conduct this particular research project and also published 500+ medical research papers. The author has never forgotten his advice to him that he should always enhance his strength on foundations, such as mathematics and physics, in order to make further improvement and advancement. Professor Jones has also provided him a personal example of doing outstanding teaching and research job with an excellent work attitude, extreme dedication, and ultimate commitment on advancing both science and engineering.