The GH-Method

Nonlinear Plastic Glucose Theory (NPGT #3): Applying Elasticity Theory, Plasticity Theory, and Energy Theory to Investigate Hyperglycemic Postprandial Plasma Glucose Behaviors, for Values Greater than 180 mg/dL, Using CGM Sensor Collected Glucose Data from 5/8/2018 to 12/31/2021 where 20 Meals are Plastic and 3,817 Meals are Elastic Based on GH-Method: Math-Physical Medicine (No. 572)

Gerald C. Hsu*

eclaireMD Foundation, USA

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 on his self-study of medicine and research on endocrinology, chronic diseases and their complications in the Methods section. The following paragraphs summarize key data for glucose and HbA1C along with associated timelines during his 27-year history of type 2 diabetes (T2D). In 1995, he was diagnosed with type w diabetes (T2D) and started taking three different types of diabetes medications. Fifteen years after his initial diagnosis, his HBA1C in 2010 reached to above 10% to 14.7% with an average glucose between 278 mg/dL and 310 mg/dL (based on meager data, not a completed dataset). In addition, he suffered many diabetic complications, such as hypertension, hyperlipidemia, 5 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-year 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%. In 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 travel 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 quarantine period of 2020-2021, his glucose range decreased 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. As a result, his research papers of NPGT #1 (CGM sensor PPG of Y2018-Y2021 for PPG >200 mg/dL), NPGT #2 (finger-pierced PPG of Y2015-Y2018 for PPG >200 mg/dL), and now this NPGT #3 (CGM sensor PPG of Y2018-Y2021 for PPG >180 mg/dL) are "medication-free". Once medication enters the body, it takes over the control of glucose outputs, i.e. symptoms. In these three studies, the collected glucose data for his research work is from two main sources or root-causes, which are his body health (pancreatic beta cells and liver) and his lifestyle management (diet and exercise), without any medication intervention. The author has spent a considerable amount of research time during 2020 and 2021 to write 39 papers about his developed linear elastic glucose theory (LEGT). This LEGT can be expressed through the following linear equation: Predicted PPG = FPG * GH.f + (carbs&sugar grams) * GH.e + (post-meal walking k-steps * GH.w), where: GH.f-Modulus can estimate the starting PPG of a meal at 0-minute using FPG value during sleep; GH.e-Modulus can estimate the peak PPG level at 60-minutes after a

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*Corresponding author: Gerald C. Hsu, eclaireMD Foundation, USA

meal using carbs&sugar grams; GH.w-Modulus can estimate the decreased PPG level at 180-minutes after a meal using post-meal walking k-steps. The above-described linear elastic equation can be applied to the 3,817 meals with "elastic glucose" behaviors (99.5% of total). A synthesized PPG waveform, by combining all of the 3,817 elastic PPG curves together, has the following described biophysical behavior pattern. It starts from 123 mg/dL at 0-minute, where his PPG value increased due to the consumption of 11.2 grams of carbs&sugar for energy input (low energy input or low stress) and reaches a PPG peak level of 133 mg/dL at 60-minutes, before starting to decline due to walking exercise, which burns off the energy to finally return to its ending-PPG level of 122 mg/dL at 180-minutes. This end-glucose value returning to its initial-glucose position, after burning off energy influx, is called "elastic". On the contrary, another scenario of the glucose behavior can be explained using his 20 meals with "plastic glucose" behaviors (0.5% of total). A synthesized PPG waveform, by combining all of the 20 PPG curves together, has the following different biophysical behavior pattern. It starts from 140 mg/dL at 0-minute, where his PPG value increases due to the consumption of 80.2 grams of carbs&sugar for energy input (high energy input or high stress) and reaches to the first PPG peak level of 187 mg/dL at 60-minutes and then continuously climbs but with a lower slope (43% of earlier elastic phase) due to the excessive carbs&sugar consumption, until it reaches to another peak PPG level of 207 mg/dL at 120-minutes. At this instant, the effect from his walking exercise finally kicks in to burn off the energy intake until it decreases to the end-glucose level of 194 mg/dL at 180-minutes. This end-glucose value of 194 mg/dL is still 54 mg/dL higher than its initial-glucose position of 140 mg/dL. This type of "permanent deformation" or "residual glucose" value of 54 mg/dL is called "plastic" or "elasto-plastic". As reported by the World Health Organization (WHO) and International Diabetes Federation (IDF), there are 537 million people (6.8%) who have diabetes and 541 million people (6.8%) who will develop diabetes among the total global population of 7.9 billion. According to the Centers for Disease Control (CDC) of US, there are 22% to 46% of diabetes patients who have glucose levels above 140 mg/dL. In accordance with the National Institute of Health (NIH) and National Center for Biotechnology Information (NCBI), people with hyperglycemia (>180 mg/dL) account for approximately 38% to 40% of hospitalization cases and 70% to 80% of cardiac illness or surgical cases. In a rough estimation, we can safely say that there are at least 20% of existing diabetes patients in the world, or more than 100 million diabetes patients (~1.3% of world population of 7.9 billion) with hyperglycemia higher than 180 mg/dL. This particular research work of nonlinear plastic glucose theory (NPGT) aims to explore additional insights about the hyperglycemic (high glucose level) phenomena in order to help those 1.3% or 100+ million diabetes patients. Based on other research papers (References 1 and 2), people without diabetes have PPG waveforms within a range between 80 mg/dL (start and end) and 120 mg/dL (peak). For pre-diabetes patients, their PPG waveforms range between 100 mg/dL (start and end) and 180 mg/dL (peak). For severe diabetes patients who indeed posses "plastic glucose" phenomena, their PPG waveforms range between 180 mg/dL (start), 370 mg/dL (peak at 1-hour), and 325 mg/dL (end at 3-hours) or 270 mg/dL (end at 5-hours). Even at 5-hours after eating, it still has a "residual glucose" of 90 mg/dL. It has no realistic meaning to study the PPG behavior after 5-hours since the time duration between two meals rarely goes beyond 5 hours, except those between dinner and breakfast of next day, i.e. the pre-bed time window. The author has indeed collected glucose data during that window, but he placed them into a special group of pre-bed glucose. Utilizing the author's PPG data and curves to make a comparison against above-referenced glucose data and curves, they have remarkable resemblance. His elastic glucose data and curve are similar to the pre-diabetes case, while his plastic glucose data and curve are similar to severe diabetes case. In this plastic glucose study of NPGT #3, he developed the following simplified glucose equation: Predicted PPG = (carbs&sugar grams) * GH.e + (carbs&sugar grams) * GH.p +(post-meal walking k-steps * GH.w), where: GH.e-Modulus can estimate the first elastic peak PPG at 60-minutes after a meal using carbs&sugar grams; GH.p-Modulus can estimate the second elasto-plastic peak PPG at 120-minutes after a meal using the same value of carbs&sugar grams; GH.w-Modulus can estimate the decreased PPG at 180-minutes after a meal using post-meal walking k-steps. It should be noted that his plastic slope, GH.p-Modulus value of 0.254, is less than half or at the 43% level, of his elastic slope, GH.e-Modulus value of 0.586. In order to utilize his stored glucose database for this hyperglycemia study, he has modified and enhanced his developed software program to perform the necessary data-mining tasks to extract the 20 hyperglycemic meals (only 0.5% for those PPG values greater than 180 mg/dL) from a big database of 3,837 meals (100%). Such a low percentage of 0.5% for plastic cases is resulted from his well-controlled T2D during the selected period from 5/8/2018 to 12/31/2021. 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 concept of elasticity theory and plasticity theory from the disciplines of engineering and physics in the Method section. 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, e.g.

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carbohydrates and sugar intake amount, or post-meal walking. This stress component has no difference between elastic and plastic. Second, the deformation or strain in physics and engineering (x-axis) corresponds to the actual PPG level in medicine. This strain component has difference between elastic glucose and plastic glucose. However, the medical field is still 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, the biomedical properties are "moving targets" which vary with the individual person, severity of diabetes, and selected different time-windows. Because of these fundamental characteristics, calculations of cross-section of subject and bending moment of resistance or the shape-factors in solid mechanics are not applicable in the biomedical plasticity study. The most important part, in his opinion, is that by applying the concept of plasticity theory on understanding the biomedical phenomena is extremely useful for exploring deep insights for predicting abnormal glucose behaviors in order to help the 100+ million diabetes patients or 1.3% of the world population of 7.9 billion who are currently suffering from hyperglycemia. 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 by red blood cells; and energy consumption from labor-work or exercise. When the residual energy resulted from plastic glucose scenario is stored inside of our bodies, it will cause different degrees of damage to many internal organs. According to physics, energies associated with the residual glucose waves are proportional to the square of the residual glucose amplitude. The residual energies from elevated glucoses are circulating inside the body via blood vessels which then impact all of the internal organs to cause 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. Overweight and obesity lead into chronic diseases, including diabetes. 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 many other diseases, such as cancers. For example, there are ~85% of worldwide diabetes patients who are overweight, and there are ~75% of patients of cardiac illnesses or surgeries have diabetes conditions. In engineering analysis, when the load is applied on 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 shape (plastic) with plastic hinges. In its corresponding medical analysis, after eating carbohydrates or sugar from food, our glucose level will increase; therefore, the sugar and carbohydrates function as the energy supply. After having 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 some 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, due to 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 related hyperglycemic data in early years and lacking a suitable data-mining tool to investigate his hyperglycemic situation. Only until late 2021, he has finally discovered ways to explore related data and then conduct his research on plastic glucose behaviors. 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. 572 (NPGT #3), he has discovered that 99.5% of his maximum PPG data are actually below 180 mg/dL and behave elastically. The data associated with this exceptional "plastic glucose" case (in this study, 0.5% of his total CGM sensor PPG data) are located within the range from 180 mg/dL to 300 mg/dL and its glucose behaviors indeed possess a type of "elasto-plastic" behavior pattern. By the way, the American Diabetes Association (ADA) has also defined 180 mg/dL as the dividing line for the time-above-range (TAR) of glucoses. This percentage division of majority % vs. minority % (for this case, 99.5% vs. 0.5%) matches with his personal experiences and previous professional work findings from designing defense weapons, space shuttle, nuclear power plants, computer hardware devices, machine components, earthquake engineering, and semiconductor chips. He has learned that "special cases" are usually rare to encounter and difficult to deal with, however, they are also very important in terms of increasing safety margin and avoiding disastrous situations from happening. Therefore, from the

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concerns of complete scope coverage of a subject and possible severe outcomes, a good understanding and investigation of this low percentage of occurrence associated with "plastic" scenarios is absolutely necessary. Those patients with severe diabetes conditions are at high risk for developing into many complications and ultimately death which can be a very painful process. In summary, borrowing the concept from plastic theory in physics and engineering, the author can now interpret the elasto-plastic PPG behavior clearly and be able to predict the plastic glucose values and their behavior patterns. Through a quick self-examination of his own health conditions, it has offered him a clear explanation on why, since 5/8/2018, he has not suffered from any of his previous complications, except diabetic skin fungal infection. This piece of research work has satisfied somewhat about his original suspicion regarding plastic glucose behavior and identified a practical way to control his hyperglycemia.

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

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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 on his self-study of medicine and research on endocrinology, chronic diseases and their complications in the Methods section. The following paragraphs summarize key data for glucose and HbA1C along with associated timelines during his 27-year history of type 2 diabetes (T2D).

In 1995, he was diagnosed with type w diabetes (T2D) and started taking three different types of diabetes medications. Fifteen years after his initial diagnosis, his HBA1C in 2010 reached to above 10% to 14.7% with an average glucose between 278 mg/dL and 310 mg/dL (based on meager data, not a completed dataset). In addition, he suffered many diabetic complications, such as hypertension, hyperlipidemia, 5 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-year 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%. In 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 travel 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 quarantine period of 2020-2021, his glucose range decreased 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. As a result, his research papers of NPGT #1 (CGM sensor PPG of Y2018-Y2021 for PPG >200 mg/dL), NPGT #2 (finger-pierced PPG of Y2015-Y2018 for PPG >200 mg/dL), and now this NPGT #3 (CGM sensor PPG of Y2018-Y2021 for PPG >180 mg/dL) are "medication-free". Once medication enters the body, it takes over the control of glucose outputs, i.e. symptoms. In these three studies, the collected glucose data for his research work is from two main sources or root-causes, which are his body health (pancreatic beta cells and liver) and his lifestyle management (diet and exercise), without any medication intervention.

The author has spent a considerable amount of research time during 2020 and 2021 to write 39 papers about his developed linear elastic glucose theory (LEGT). This LEGT can be expressed through the following linear equation:

Predicted PPG
= FPG * GH.f + (carbs&sugar grams) * GH.e
+ (post-meal walking k-steps * GH.w)

Where:

GH.f-Modulus can estimate the starting PPG of a meal at 0-minute using FPG value during sleep;

GH.e-Modulus can estimate the peak PPG level at 60-minutes after a meal using carbs&sugar grams;

GH.w-Modulus can estimate the decreased PPG level at 180-minutes after a meal using post-meal walking k-steps.

The above-described linear elastic equation can be applied to the 3,817 meals with "elastic glucose" behaviors (99.5% of total). A synthesized PPG waveform, by combining all of the 3,817 elastic PPG curves together, has the following described biophysical behavior pattern.

It starts from 123 mg/dL at 0-minute, where his PPG value increased due to the consumption of 11.2 grams of carbs&sugar for energy input (low energy input or low stress) and reaches a PPG peak level of 133 mg/dL at 60-minutes, before starting to

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decline due to walking exercise, which burns off the energy to finally return to its ending-PPG level of 122 mg/dL at 180-minutes. This end-glucose value returning to its initial-glucose position, after burning off energy influx, is called "elastic".

On the contrary, another scenario of the glucose behavior can be explained using his 20 meals with "plastic glucose" behaviors (0.5% of total). A synthesized PPG waveform, by combining all of the 20 PPG curves together, has the following different biophysical behavior pattern. It starts from 140 mg/dL at 0-minute, where his PPG value increases due to the consumption of 80.2 grams of carbs&sugar for energy input (high energy input or high stress) and reaches to the first PPG peak level of 187 mg/dL at 60-minutes and then continuously climbs but with a lower slope (43% of earlier elastic phase) due to the excessive carbs&sugar consumption, until it reaches to another peak PPG level of 207 mg/dL at 120-minutes. At this instant, the effect from his walking exercise finally kicks in to burn off the energy intake until it decreases to the end-glucose level of 194 mg/dL at 180-minutes. This end-glucose value of 194 mg/dL is still 54 mg/dL higher than its initial-glucose position of 140 mg/dL. This type of "permanent deformation" or "residual glucose" value of 54 mg/dL is called "plastic" or "elasto-plastic".

As reported by the World Health Organization (WHO) and International Diabetes Federation (IDF), there are 537 million people (6.8%) who have diabetes and 541 million people (6.8%) who will develop diabetes among the total global population of 7.9 billion. According to the Centers for Disease Control (CDC) of US, there are 22% to 46% of diabetes patients who have glucose levels above 140 mg/dL. In accordance with the National Institute of Health (NIH) and National Center for Biotechnology Information (NCBI), people with hyperglycemia (>180 mg/dL) account for approximately 38% to 40% of hospitalization cases and 70% to 80% of cardiac illness or surgical cases. In a rough estimation, we can safely say that there are at least 20% of existing diabetes patients in the world, or more than 100 million diabetes patients (~1.3% of world population of 7.9 billion) with hyperglycemia higher than 180 mg/dL. This particular research work of nonlinear plastic glucose theory (NPGT) aims to explore additional insights about the hyperglycemic (high glucose level) phenomena in order to help those 1.3% or 100+ million diabetes patients.

Based on other research papers (References 1 and 2), people without diabetes have PPG waveforms within a range between 80 mg/dL (start and end) and 120 mg/dL (peak). For pre-diabetes patients, their PPG waveforms range between 100 mg/dL (start and end) and 180 mg/dL (peak). For severe diabetes patients who indeed posses "plastic glucose" phenomena, their PPG waveforms range between 180 mg/dL (start), 370 mg/dL (peak at 1-hour), and 325 mg/dL (end at 3-hours) or 270 mg/dL (end at 5-hours). Even at 5-hours after eating, it still has a "residual glucose" of 90 mg/dL. It has no realistic meaning to study the PPG behavior after 5-hours since the time duration between two meals rarely goes beyond 5 hours, except those between dinner and breakfast of next day, i.e. the pre-bed time window. The author has indeed collected glucose data during that window, but he placed them into a special group of pre-bed glucose.

Utilizing the author's PPG data and curves to make a comparison against above-referenced glucose data and curves, they have remarkable resemblance. His elastic glucose data and curve are similar to the pre-diabetes case, while his plastic glucose data and curve are similar to severe diabetes case.

In this plastic glucose study of NPGT #3, he developed the following simplified glucose equation:

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It should be noted that his plastic slope, GH.p-Modulus value of 0.254, is less than half or at the 43% level, of his elastic slope, GH.e-Modulus value of 0.586.

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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 by red blood cells; and energy consumption from labor-work or exercise. When the residual energy resulted from plastic glucose scenario is stored inside of our bodies, it will cause different degrees of damage to many internal organs. According to physics, energies associated with the residual glucose waves are proportional to the square of the residual glucose amplitude. The residual energies from elevated glucoses are circulating inside the body via blood vessels which then impact all of the internal organs to cause 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. Overweight and obesity lead into chronic diseases, including diabetes. 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 many other diseases, such as cancers. For example, there are ~85% of worldwide diabetes patients who are overweight, and there are ~75% of patients of cardiac illnesses or surgeries have diabetes conditions.

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In engineering analysis, when the load is applied on 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 shape (plastic) with plastic hinges. In its corresponding medical analysis, after eating carbohydrates or sugar from food, our glucose level will increase; therefore, the sugar and carbohydrates function as the energy supply. After having 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 some 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

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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 572 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.

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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.

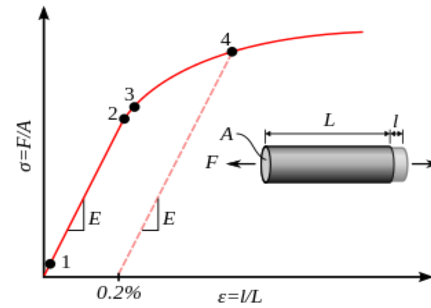
Hooke's law states that the force required to deform elastic objects should be directly proportional to the distance of deformation, regardless of how large that distance becomes. This is known as perfect elasticity, in which a given object will return to its original shape no matter how strongly it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

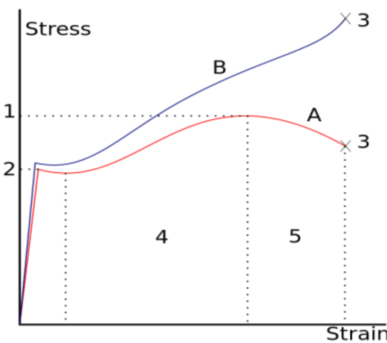
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

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.

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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 table of elastic PPG and plastic PPG, including PPG at 0-minute, peak PPG at 60-minutes, PPG at 120-minutes, PPG at 180-minutes, carbs/sugar intake grams, post-meal walking k-steps, and various GH-Modulus.

1/1/22	3,892 meals	3,892 meals	3,892 meals
5/8/18-12/31/21	Elastic - Real	Elastic - Theory	Interpolation
0-min	123	123	123
15-min	125	125	125
30-min	130	128	128
45-min	133	130	130
60-min	133	133	133
75-min	130	131	131
90-min	127	130	130
105-min	124	129	129
120-min	122	127	127
135-min	121	126	126
150-min	121	125	125
165-min	122	123	123
180-min	122	122	122
Avarage PPG	125	127	127
Correllation	100%	80.4%	80.2%
	GH.e	GH.w	
GH.x Modulus	0.889	-2.566	
Carbs/Sugar grams	11.2		
Ealking k-steps	4.279		

1/1/22	20 meals	20 meals	20 meals
5/8/18-12/31/21	Plastic - Real	Plastic - Theory	Interpolation
0-min	140	140	140
15-min	152	152	152
30-min	162	163	163
45-min	177	175	175
60-min	187	187	187
75-min	194	192	192
90-min	202	197	197
105-min	205	202	202
120-min	207	207	207
135-min	204	204	204
150-min	206	200	200
165-min	202	197	197
180-min	194	194	194
Avarage PPG	187	185	185
	100%	99.5%	99.5%
	GH.e	GH.p	GH.w
GH.x Modulus	0.586	0.254	-4.138
Carbs/Sugar grams	80.2		
Ealking k-steps	3.287		

Figure 1: Data table for both elastic PPG and plastic PPG for a period from 5/8/2018 to 12/31/2021.

Figure 2 illustrates a simplified 2-segments linear elastic PPG model and a simplified 3-segments nonlinear PPG model. The linear glucose model has reached a 80.4% correlation with the real PPG waveform, while the nonlinear plastic glucose model has attained a 99.5% correlation with the real hyperglycemic PPG curve. All related GH-Modulus are listed in the diagrams. It should be pointed out that the slope of the elasto-plastic segment is only 43% of the slope of the elastic segment. Furthermore, with the introduction of one extra GH.p-Modulus for the elasto-plastic segment, it improves the prediction accuracy up to 99.5%.

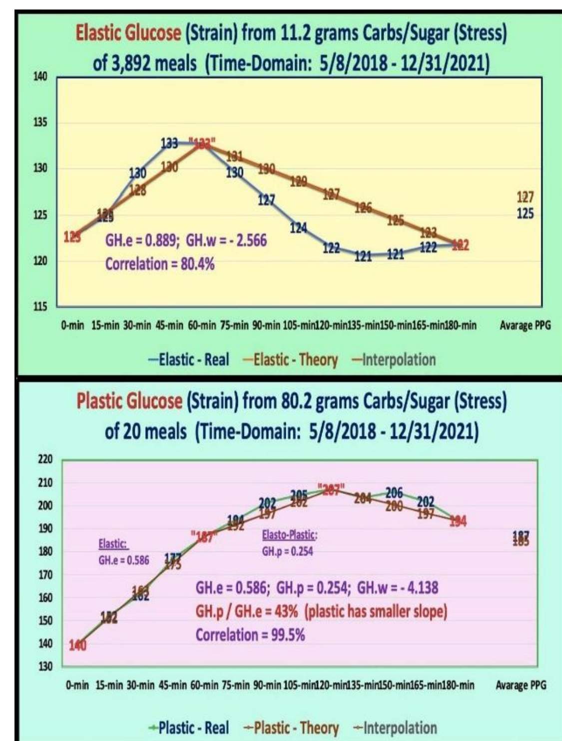

Figure 2: Time-domain PPG curves of both elastic and plastic glucoses with both linear elastic and nonlinear plastic models.

Figure 3 demonstrates the analogy of elastic theory and plastic theory applied to the biomedical glucose behavior study. An interpretation using energy theory is also inserted in this figure. The blue line indicates an elastic PPG scenario in which PPG values increase from 0-minute to the maximum PPG and then PPG at 180-minutes bouncing back to its original level. The blue color straight line is the elastic case which simply starts from 123 mg/dL at 0-minute, and then rises to the peak level of 133 mg/dL at 60-minutes, and then bounces back to 123 mg/dL at 180-minutes. This is a perfect elastic glucose case.

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The orange curve signifies plastic PPG scenario where the PPG values increase from the initial PPG of 140 mg/dL at 0-minute to the elastic yielding of PPG of 187 mg/dL at 60-minutes, and then completing the elastic-plastic phase to reach the PPG level of 207 mg/dL at 120-minutes, and finally drops down to the PPG level of 194 mg/dL at 180-minutes. There is a remaining glucose gap, or residual PPG, of 54 mg/dL.

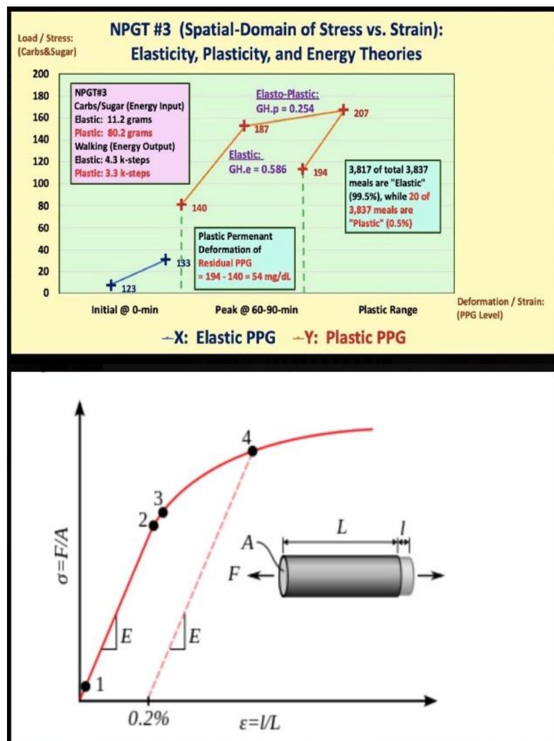

Figure 3: Spatial-domain of stress (carbs&sugar) vs. strain (PPG) of both elastic PPG & plastic PPG with textbook's diagram.

Figure 4 reveals some support diagrams from References 1 and 2 for normal people's PPG (under everyday life conditions and after different meals), prediabetes PPG, and severe diabetes PPG cases. People without diabetes have PPG waveforms ranging between 80 mg/dL (start and end) and 120 mg/dL (peak). For pre-diabetes patients, their PPG waveforms range between 100 mg/dL (start and end) and 180 mg/dL (peak). For severe diabetes patients, their PPG waveforms range between 180 mg/dL (start), 370 mg/dL (peak at 1-hour), and 325 mg/dL (end at 3-hours) or 270 mg/dL (end at 5-hours). The author has decided to use a 3-hour timeframe for his PPG studies since it will not overlap with another meal PPG timeframe. PPG data after 5-hours have no realistic purpose since the time duration between two meals rarely go beyond 5 hours, except diner PPG and pre-bed glucose.

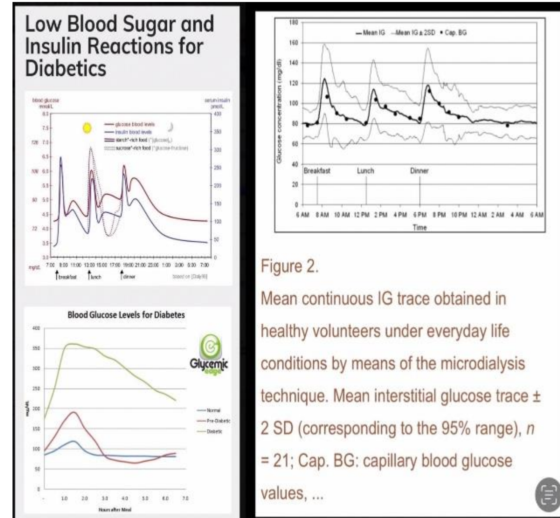

Figure 4: Comparison of PPG curves among normal people, pre-diabetes patients, severe diabetes patients (from references 1 and 2).

3.1 Application example of hyperglycemia

Hypothetically, if the author had a meal within the same time-frame, therefore, his body conditions and heath state are the same as this study, such that those calculated GH.p-Modulus and GH.w modulus can be applied. Furthermore, for this meal, assuming the carbs/sugar intake amount of 60 grams and post-meal walking of 5.0 k-steps, he is then able to predict his hyperglycemic PPG values and waveform using the following equation of nonlinear plastic glucose theory (NPGT):

Predicted PPG (for 60g & 5k-steps):

Initial PPG = 140 mg/dL, same as this study

PPG at 60-minutes = 175 mg/dL (60g * GH.e of 0.586)

PPG at 120-minutes = 190 mg/dL (60g * GH.p of 0.254)

PPG at 180-minutes = 169 mg/dL (5.0k-steps * GH.w of -4.138); with a residual glucose of 29 mg/dL.

The rest glucose values in this case, between these 4 key values, can be constructed using interpolation method.

Figure 5 shows the results of above hypothetical case using NPGT for building up a predicted elasto-plastic glucose dataset (with a lower averaged glucose of 172 mg/dL) and its associated PPG waveform of

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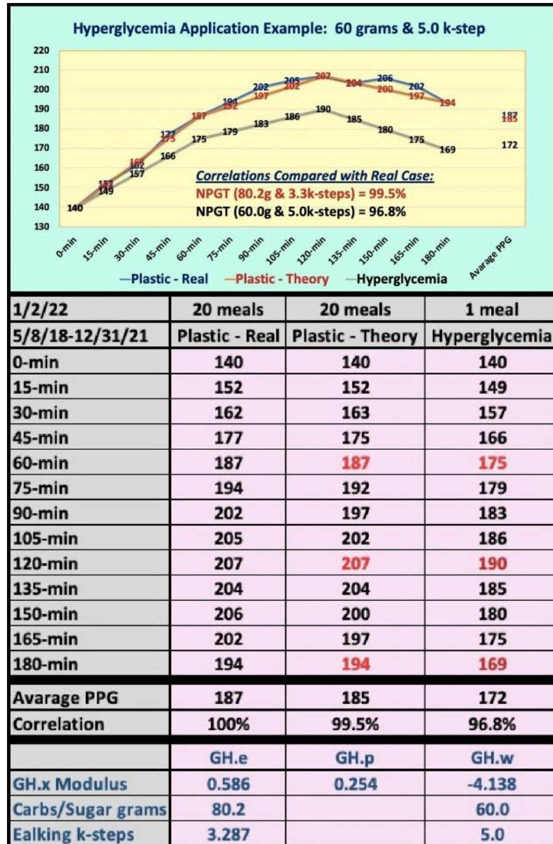
60g+5.0k-steps. These results of a hypothetical single meal of 60 grams and 5.0 k-steps are compared against both 20-meals real data curve of 80g+3.3k-steps (R=96.8%) and 20-meals plastic theory generated curve of 80g+3.3k-steps (R=97.5%).



1/2/22	20 meals	20 meals	1 meal
5/8/18-12/31/21	Plastic - Real	Plastic - Theory	Hyperglycemia
0-min	140	140	140
15-min	152	152	149
30-min	162	163	157
45-min	177	175	166
60-min	187	187	175
75-min	194	192	179
90-min	202	197	183
105-min	205	202	186
120-min	207	207	190
135-min	204	204	185
150-min	206	200	180
165-min	202	197	175
180-min	194	194	169
Avarage PPG	187	185	172
Correlation	100%	99.5%	96.8%
	GH.e	GH.p	GH.w
GH.x Modulus	0.586	0.254	-4.138
Carbs/Sugar grams	80.2		60.0
Ealking k-steps	3.287		5.0

Figure 5: Application example of nonlinear plastic glucose theory for a hypothetical meal with 60 grams carbs/sugar & 5.0 k-steps walking.

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, due to 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 related hyperglycemic data in early years and lacking a suitable data-mining tool to investigate his hyperglycemic situation. Only until late 2021, he has finally discovered ways to explore related data and then conduct his research on plastic glucose behaviors.

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. 572 (NPGT #3), he has discovered that 99.5% of his maximum PPG data are actually below 180 mg/dL and behave elastically. The data associated with this exceptional "plastic glucose" case (in this study, 0.5% of his total CGM sensor PPG data) are located within the range from 180 mg/dL to 300 mg/dL and its glucose behaviors indeed possess a type of "elasto-plastic" behavior pattern. By the way, the American Diabetes Association (ADA) has also defined 180 mg/dL as the dividing line for the time-above-range (TAR) of glucoses.

This percentage division of majority % vs. minority % (for this case, 99.5% vs. 0.5%) matches with his personal experiences and previous professional work findings from designing defense weapons, space shuttle, nuclear power plants, computer hardware devices, machine components, earthquake engineering, and semiconductor chips. He has learned that "special cases" are usually rare to encounter and difficult to deal with, however, they are also very important in terms of increasing safety margin and avoiding disastrous situations from happening. Therefore, from the concerns of complete scope coverage of a subject and possible severe outcomes, a good understanding and investigation of this low percentage of occurrence associated with "plastic" scenarios is absolutely necessary. Those patients with severe diabetes conditions are at high risk for developing into many complications and ultimately death which can be a very painful process. In summary, borrowing the concept from plastic theory in physics and engineering, the author can now interpret the elasto-plastic PPG behavior clearly and be able to predict the plastic glucose values and their behavior patterns.

Through a quick self-examination of his own health conditions, it has offered him a clear explanation on why, since 5/8/2018, he has not suffered from any of his previous complications, except diabetic skin fungal infection. This piece of research work has satisfied somewhat about his original suspicion regarding plastic glucose behavior and identified a practical way to control his hyperglycemia.

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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.

Readers may use this article as long as the work is properly cited, and their use is educational and not for profit, and the author's original work is not altered.

(1) Guido Freckmann, Sven Hagenlocher, Cornelia Haug, Journal of diabetes science and technology, "Continuous Glucose Profiles in Healthy Subjects under everyday life conditions and after different meals"

(2) Glycemic Edge: https://www.glycemicedge.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.

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