The GH-Method

Viscoelastic Medicine Theory (VMT #273): Pathophysiological Interpretations of Diabetic Foot Ulcers (DFU) versus 2 Diabetes Markers (Daily Averaged Glucose & HbA1C) and 2 Lifestyle Details (Carbs/Sugar Intake Grams and Walking Steps) Using Collected Data from 1/1/2010 to 6/19/2023 and a Quantitative Analysis Applying SD-VMT Quantitative Energy Model of GH-Method: Math-Physical Medicine (No. 872)

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Abstract

Diabetic foot ulcers (DFU) and Diabetic foot infections (DFI) are common complications of diabetes that can lead to limb amputation. The pathological and physiological explanations of diabetic foot ulcers involve neuropathy, ischemia, infection, and impaired wound healing. Patients with infected DFUs are more likely to require limb amputation. Several studies have reported reduced lifespan in individuals with DFUs compared to those without DFUs. In this article, the author investigate the relationships between his DFU% and 4 selected inputs, i.e. eAG, A1C, carbs/and steos. First, he cited some of those pathophysiological explanations of diabetic foot ulcers and type 2 diabetes. He then applies the space-domain viscoplastic medicine theory (SD-VMT) energy model to quantitatively determine the degree of influences from these 4 inputs on his DFUs. He uses his collected data between 1/1/2010 and 6/20/2023 as the data source. In summary, there are 4 findings from this particular DFU study: A. In time domain, his annual DFU% are 76-100 during 2010-2014 which indicates his diabetic foot ulcers period. After 2015, it has not shown any severe DFU conditions (< 60). B. In time domain, his 4 correlations of FLI versus 4 inputs are: eAG = 74%; A1C = 96%; carbs = 96%; steps =88%. These 4 high correlations have demonstrated the very close connection existed between his foot ulcers and his type 2 diabetes. C. His SD-VMT energies are: eAG = 19%; A1C = 24%; carbs = 35%; steps = 32%. The 1.25 ratio of A1C versus eAG indicates that HbA1C is a better indicator of his T2D conditions. The 1.58 ratio of Carbs versus Steps indicates that diet is a more important lifestyle factor than exercise. D. Time-zone analysis results are: Y10-Y16 = 89%; Y17-Y23 = 11%. This energy distribution pattern indicates that the time period of Y10-Y16 (89%) is his diabetic foot ulcer period, but Y17-Y23 period has contributed a very small portion of energy (11%) to his overall foot ulcer situation.

Keywords: Viscoelastic; Viscoplastic; Diabetic foot ulcer; Lifestyle; Walking; Hyperglycemia; Glucose; Exercise

Abbreviations: DFU: diabetic foot ulcers; DFI: diabetic foot infections; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; SD: space-domain

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1. INTRODUCTION

1.1 Pathophysiological interpretation

Pathophysiological explanation of diabetic foot ulcers versus type 2 diabetes:

Diabetic foot ulcers (DFU) and Diabetic foot infections (DFI) are common complications of diabetes that can lead to limb amputation. The pathological and physiological explanations of diabetic foot ulcers involve a complex interaction between various factors, including neuropathy, ischemia, infection, and impaired wound healing.

Neuropathy is one of the primary risk factors for diabetic foot ulcers. Elevated blood sugar levels can cause damage to nerves in the feet, resulting in a loss of sensation. This can lead to injuries to the feet that go unnoticed and untreated, ultimately resulting in foot ulcers.

Ischemia, or reduced blood flow to the feet, is another contributing factor to the development of DFUs. A 2018 study published in the Journal of Diabetes Research found that DFUs were more common in patients with peripheral artery disease (PAD), a condition that reduces blood flow to the legs and feet. The elevated blood sugar levels characteristic of diabetes can lead to damage to blood vessels, leading to reduced blood flow to the feet. Reduced blood flow can contribute to impaired wound healing, making it more difficult for foot ulcers to heal.

In addition to neuropathy and ischemia, infection is another factor that can contribute to the development of diabetic foot ulcers. Elevated blood sugar levels can impair the function of the immune system, making individuals with diabetes more susceptible to infections. Infections that begin in the feet can lead to the development of foot ulcers that are difficult to treat. A 2017 study published in the Journal of Diabetes and its Complications found that patients with DFUs had a higher incidence of infection compared to patients without DFUs. Additionally, the same study found that patients with infected DFUs were more likely to require amputation.

Lastly, impaired wound healing is a key component of diabetic foot ulcers. Elevated blood sugar levels can contribute to impaired wound healing by interfering with the function of cells that are necessary for wound healing, such as fibroblasts and epithelial cells. Additionally, elevated blood sugar levels increase the risk of infection, further delaying the healing process. A 2018 study published in the Journal of Diabetes Research found that patients with DFUs had significantly higher levels of glucose and inflammatory markers compared to patients without DFUs.

Overall, diabetic foot ulcers are a complex, multifactorial condition that requires careful management of blood sugar levels, wound care, and infection control to prevent complications and limb loss. A study published in Diabetes Care found that comprehensive foot care programs reduced the incidence of DFUs by 49%, emphasizing the importance of proactive management of diabetic foot complications.

Pathophysiological explanations of the relationship between diabetic foot ulcers versus type 2 diabetes, carbs/sugar intake amount and post-meal exercise:

Diabetic foot ulcers (DFUs) are a common complication of type 2 diabetes that may result from various factors, including high blood sugar levels, nerve damage, reduced circulation, and impaired immune function. The relationship between DFUs and type 2 diabetes, carb/sugar intake amount, and post-meal exercise can be explained by several pathophysiological mechanisms.

(1) High blood sugar levels: One of the primary mechanisms that link DFUs and type 2 diabetes is high blood sugar levels. Elevated blood sugar levels can damage blood vessels, impair insulin signaling, and promote the formation of advanced glycation end products (AGEs) that can damage tissues and organs. Hyperglycemia can also impair immune function and reduce wound healing, increasing the risk of DFUs and delaying their healing.

(2) Nerve damage: Another mechanism that can contribute to DFUs is neuropathy or nerve damage. Prolonged hyperglycemia can damage nerves, leading to numbness,

tingling, and loss of sensation in the feet. As a result, individuals with neuropathy may not feel pain or discomfort from injuries or pressure points on their feet, increasing the risk of DFUs.

(3) Reduced circulation: Reduced circulation or peripheral arterial disease (PAD) is a common complication of type 2 diabetes. PAD can impair blood flow to the feet, reducing oxygen and nutrient supply and impairing wound healing. Additionally, reduced circulation can make infections and non-healing wounds more severe and increase the risk of amputations.

(4) Carbs/sugar intake: High-carbohydrate and high-sugar diets can contribute to hyperglycemia, increasing the risk of DFUs. Excessive carbohydrate and sugar intake can cause rapid blood sugar spikes, leading to inflammation, oxidative stress, and damage to blood vessels and nerves. Additionally, high carbohydrate and sugar diets can promote the growth of harmful bacteria that can cause infections.

(5) Post-meal exercise: Physical activity after meals can help reduce postprandial hyperglycemia and improve insulin sensitivity, reducing the risk of DFUs. Exercise can stimulate glucose uptake into muscles, enhance blood flow, and stimulate wound healing. Additionally, post-meal exercise can help reduce inflammation and improve immune function in individuals with diabetes.

Overall, the relationship between DFUs and type 2 diabetes, carb/sugar intake amount, and post-meal exercise can be explained by various pathophysiological mechanisms. Management of hyperglycemia, neuropathy, reduced circulation, and other risk factors can help reduce the risk of DFUs and improve outcomes in individuals with type 2 diabetes.

Expected lifespan of patients with DFI or DFU:

The expected lifespan of individuals with diabetic foot ulcers (DFUs) depends on various factors, including the severity of the DFUs, the individual's overall health status, and the effectiveness of treatments. DFUs can be a serious complication of diabetes and can lead to amputations, infections, and other complications that can affect lifespan.

Several studies have reported reduced lifespan in individuals with DFUs compared to those without DFUs. A study published in the Journal of Diabetes Investigation found that the mortality rate in patients with DFUs was 36% higher compared to those without DFUs. Additionally, a study published in Diabetes Care reported that the five-year survival rate for individuals with DFUs was significantly lower compared to those without DFUs.

However, it is essential to note that the lifespan of individuals with DFUs can be improved with proper management and treatment. Effective management of diabetes through lifestyle modifications, medication, and regular medical checkups can help prevent and manage DFUs. Additionally, proactive management of DFUs, including wound care, infection control, and blood sugar control, can improve healing and reduce the risk of complications.

Overall, the lifespan of individuals with DFUs is variable and depends on various factors. Early detection and management of DFUs can improve outcomes and reduce the risk of complications and premature mortality.

Diabetic Foot Infection (DFI) is a complication of diabetic foot ulcers (DFU) and is associated with a higher risk of amputation and mortality. Several studies have reported on the expected lifespan of individuals with diabetic foot ulcers (DFUs) which are often a precursor to diabetic foot infection (DFI). Several studies have reported on the expected lifespan of individuals with DFI.

A 2019 study published in Clinical Microbiology and Infection reported that the 1-year mortality rate in patients with DFI was 7.3%, and the 5-year mortality rate was 25.5%. The study also found that individuals with advanced age, cardiovascular disease, peripheral vascular disease, and renal failure had a higher risk of mortality.

Another study published in the Journal of Diabetes and its Complications reported that the 1-year mortality rate in patients with DFI was 6.3%, and the 3-year mortality rate was 23.9%. The study also found that the incidence of amputation was significantly higher in individuals with DFI compared to those without DFI.

A systematic review and meta-analysis of studies published in Diabetes/Metabolism Research and Reviews in 2019 also reported a higher risk of mortality in individuals with DFI. The study found that the risk of mortality was 2.3 times higher in individuals with DFI compared to those without DFI.

Overall, these studies indicate that individuals with DFI have a higher risk of mortality compared to those without DFI. The risk of mortality is higher in individuals with advanced age, cardiovascular disease, peripheral vascular disease, and renal failure. However, early detection and management of DFI can improve outcomes and reduce the risk of complications and premature mortality.

A study published in the Journal of Diabetes and its Complications reported that the 5-year survival rate for individuals with DFUs was lower than those without DFUs (68.6% vs. 88.9%). The study found that the incidence of mortality was higher in individuals with DFUs who were older, had longer duration of diabetes, and had other complications such as peripheral arterial disease and renal failure.

Another study published in Diabetes Care reported that the 5-year mortality rate in individuals with DFUs was approximately 50 percent higher than in those without DFUs. The study also found that the risk of mortality was higher in individuals with advanced age, co-morbidities such as cardiovascular disease and renal failure, and those who had undergone amputations.

A systematic review and meta-analysis of studies published in Diabetes/Metabolism Research and Reviews in 2019 reported that the risk of mortality in individuals with DFUs was significantly higher than in those without DFUs, and varied between 1.5 to 3.5 times higher depending on the study.

Overall, the studies indicate that individuals with DFUs have a higher risk of mortality compared to those without DFUs. The risk of mortality is higher in individuals who are older, have longer duration of diabetes, other complications such as peripheral arterial disease and renal failure, or who have undergone amputations. Effective management of DFUs, including wound care and blood sugar control, can help improve outcomes and reduce the risk of complications and premature mortality.

In addition, the China mission group of Defense Intelligence Agency (DIA) Diabetic lower extremity arterial disease (LEAD) study showed that the prevalence of LEAD among type 2 diabetic (T2D) patients over 50 years old was 21.2%. According to the results of epidemiological surveys in China, the high prevalence of LEAD in diabetic patients is related to the clustering and increased risk of other multiple risk factors such as older age, hypertension, dyslipidemia, and smoking. However, the diagnosis rate and treatment rate of LEAD in diabetic patients are low, and only 55.0%, 28.2% and 42.5% of the patients who achieved the blood sugar, blood pressure and blood lipid control targets recommended by the guidelines.

This particular article:

This article discusses relationships between DFU risk probabilities versus 4 inputs related to type 2 diabetes (T2D), i.e. daily averaged glucose (eAG) and HbA1C; and 2 lifestyle details, i.e. carbohydrates and sugar intake grams and post-meal walking steps. The author has used his collected data from 1/1/2010 through 6/20/2023.

His selected single output variable is his guesstimated DFU risk probability percentages (DFU %) from Y2010 to Y2023. The author had suffered from notices severe DFUs during the period from 2010 to 2014 with his DFU% above 70%. After 2026, his DFU% have been less than 60%.

In this article, at first, the author describes the qualitative relationship between DFU and T2D patients' mdcjcal conditions and lifestyle details using pathophysiological interpretations. Then, he applies time-domain analysis and the viscoplastic energy models in space-domain (SD) to provide a quantitative picture of their respective energy contribution levels (or degree of influence levels) from each of these 4 input components on his diabetic foot ulcers.

Furthermore, he calculated his time-zone energies in his SD-VMT analysis results regarding his DFUs.

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 his published 760+ 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 the 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.

2.2 The author's diabetes history

The author was a severe T2D patient since 1995. He weighed 220 lb. (100 kg) at that time. By 2010, he still weighed 198 lb. with average daily glucose of 250 mg/dL (HbA1C at 10%). During that year, his triglycerides reached 1161 (high risk for CVD and stroke) and his albumin-creatinine ratio (ACR) at 116 (high risk for chronic kidney disease). He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him regarding the need for kidney dialysis treatment and the future high risk of dying from his severe diabetic complications.

In 2010, he decided to self-study endocrinology with an emphasis on diabetes and food nutrition. He spent the entire year of 2014 developing a metabolism index (MI) mathematical model. During 2015 and 2016, he developed four mathematical prediction models related to diabetes conditions: weight, PPG, fasting plasma glucose (FPG), and HbA1C (A1C). Through using his developed mathematical metabolism index (MI) model and the other four glucose prediction tools, by the end of 2016, his weight was reduced from 220 lb. (100 kg) to 176 lb. (89 kg), waistline from 44 inches (112 cm) to 33 inches (84 cm), average finger-piercing glucose from 250 mg/dL to 120 mg/dL, and A1C from 10% to ~6.5%. One of his major accomplishments is that he has no longer taken any diabetes-related medications since 12/8/2015.

In 2017, he achieved excellent results on all fronts, especially his glucose control. However, during the pre-COVID period, including both 2018 and 2019, he traveled to ~50 international cities to attend 65+ medical conferences and made ~120 oral presentations. This hectic schedule inflicted damage to his diabetes control caused by stress, dining out frequently, post-meal exercise disruption, and jet lag, along with the overall negative metabolic impact from the irregular life patterns; therefore, his glucose control was somewhat affected during the two-year traveling period of 2018-2019.

He started his COVID-19 self-quarantined life on 1/19/2020. By 10/16/2022, his weight was further reduced to ~164 lb. (BMI 24.22) and his A1C was at 6.0% without any medication intervention or insulin injection. In fact, with the special COVID-19 quarantine lifestyle since early 2020, not only has he written and published ~500 new research articles in various medical and engineering journals, but he has also achieved his best health conditions for the past 27 years. These achievements have resulted from his non-traveling, low-stress, and regular daily life routines. Of course, his in-depth knowledge of chronic diseases, sufficient practical lifestyle management experiences, and his developed high-tech tools have also contributed to his excellent health improvements.

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. Furthermore, he extracted the 5-minute intervals from every 15-minute interval for a total of 96 glucose data each day stored in his computer software.

Through the author's medical research work of over 40,000 hours and reading over 4,000 published medical papers online in the past 13 years, he discovered and became convinced that good life habits of not smoking, moderate or no alcohol intake, avoiding illicit drugs; along with eating the right food with well-balanced nutrition, persistent exercise, having a sufficient and good quality of sleep, reducing all kinds of unnecessary stress, maintaining a regular daily life routine contribute to the risk reduction of having many diseases, including

CVD, stroke, kidney problems, micro blood vessels issues, peripheral nervous system problems, and even cancers and dementia. In addition, a long-term healthy lifestyle can even "repair" some damaged internal organs, with different required time-length depending on the particular organ's cell lifespan. For example, he has "self-repaired" about 35% of his damaged pancreatic beta cells during the past 10 years.

2.3 Energy theory

The human body and organs have around 37 trillion live cells which 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 (resulting from the plastic glucose scenario) is stored inside our bodies, it will cause different degrees of damage or influence to many of our internal organs.

According to physics, energies associated with the glucose waves are proportional to the square of the 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 or influence, e.g. diabetic complications. Elevated glucose (hyperglycemia) causes damage to the structural integrity of blood vessels. When it combines with both hypertension (rupture of arteries) and hyperlipidemia (blockage of arteries), CVD or Stroke happens. Similarly, many other deadly diseases could result from these excessive energies which would finally shorten our lifespan. For example, the combination of hyperglycemia and hypertension would cause micro-blood vessel leakage in kidney systems which is one of the major causes of CKD.

The author then applied Fast Fourier Transform (FFT) operations to convert the input 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 component of input occurrence. Both output symptom value (i.e. strain amplitude in the time domain) and output symptom fluctuation rate (i.e. the strain rate and strain frequency) are influencing the energy level (i.e. the Y-amplitude in the frequency domain).

Many people live a sedentary lifestyle and lack sufficient exercise to burn off the energy influx which causes them to become overweight or obese. Being overweight and having obesity leads to a variety of chronic diseases, particularly 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 deadly diseases, such as cancers. For example, ~85% of worldwide diabetes patients are overweight, and ~75% of patients with cardiac illnesses or surgeries have diabetes conditions.

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 to its original shape (i.e, elastic case) or remain in a deformed shape (i.e. plastic case). In a biomedical system, the glucose level will increase after eating carbohydrates or sugar from food; therefore, carbohydrates and sugar 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, both energy influx and dissipation processes take some time, which is not as simple and quick as the structural load removal in the engineering case. Therefore, the age difference and 3 input behaviors are "dynamic" in nature, i.e. time-dependent. This time-dependent nature leads to a "viscoelastic or viscoplastic" situation. For the author's case, it is "viscoplastic" since most of his biomarkers are continuously improved during the past 13-year time window.

2.4 Time-dependent output strain and stress of (viscous input*output rate)

Hooke's law of linear elasticity is expressed as:

Strain (ε: epsilon)
= Stress (σ: sigma) / Young's modulus (E)

For biomedical glucose application, his developed linear elastic glucose theory (LEGT) is expressed as:

PPG (strain)
= carbs/sugar (stress) * GH.p-Modulus (a positive number) + post-meal walking k-steps * GH.w-Modulus (a negative number)

Where GH.p-Modulus is the reciprocal of Young's modulus E.

However, in viscoelasticity or viscoplasticity theory, the stress is expressed as:

Stress
= viscosity factor (η: eta) * strain rate (dε/dt)

Where strain is expressed as Greek epsilon or ε.

In this article, to construct an "ellipse-like" diagram in a stress-strain space domain (e.g. "hysteresis loop") covering both the positive side and negative side of space, he has modified the definition of strain as follows:

Strain
= (body weight at a certain specific time instant)

He also calculates his strain rate using the following formula:

Strain rate
= (body weight at next time instant) - (body weight at present time instant)

The risk probability % of developing into CVD, CKD, and Cancer is calculated based on his developed metabolism index model (MI) in 2014. His MI value is calculated using inputs of 4 chronic conditions, i.e. weight, glucose, blood pressure, and lipids; and 6 lifestyle details, i.e. diet, drinking water, exercise, sleep, stress, and daily routines. These 10 metabolism categories further contain ~500 elements with millions of input data collected and processed since 2010. For individual deadly disease risk probability %, his mathematical model contains certain specific weighting factors for simulating certain risk percentages associated with different deadly diseases, such as metabolic disorder-induced CVD, stroke, kidney failure, cancers, dementia; artery damage in heart and brain, micro-vessel damage in kidney, and immunity-related infectious diseases, such as COVID death.

Some of explored deadly diseases and longevity characteristics using the viscoplastic medicine theory (VMT) include stress relaxation, creep, hysteresis loop, and material stiffness, damping effect based on time-dependent stress and strain which are different from his previous research findings using linear elastic glucose theory (LEGT) and nonlinear plastic glucose theory (NPGT).

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

3. RESULTS

Figure 1 shows the data table, TD, and SD-VMT analysis results.

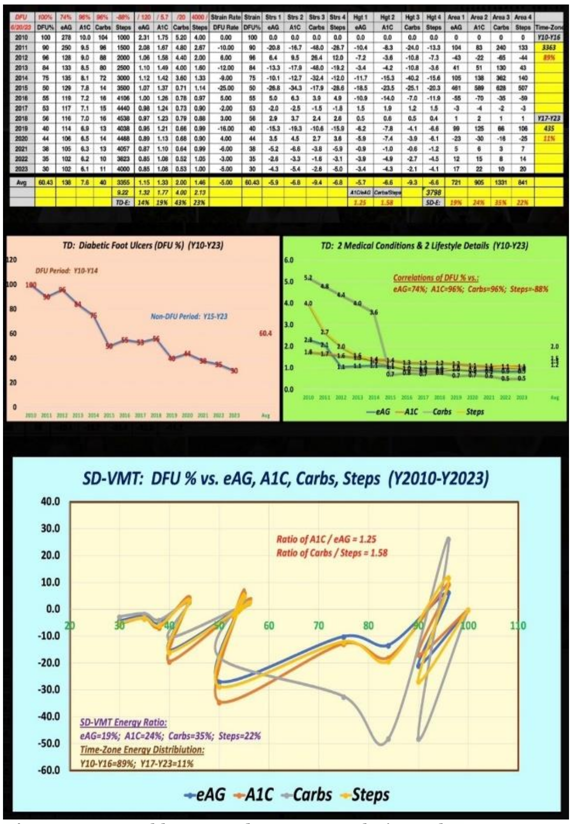

Figure 1: Data table, TD, and SD-VMT analysis results.

4. CONCLUSION

In summary, there are 4 findings from this particular DFU study:

A. In time domain, his annual DFU% are 76-100 during 2010-2014 which indicates his diabetic foot ulcers period. After 2015, it has not shown any severe DFU conditions (< 60).

B. In time domain, his 4 correlations of FLI versus 4 inputs are: eAG = 74%; A1C = 96%;

carbs = 96%; steps =88%. These 4 high correlations have demonstrated the very close connection existed between his foot ulcers and his type 2 diabetes.

C. His SD-VMT energies are: eAG = 19%; A1C = 24%; carbs = 35%; steps = 32%. The 1.25 ratio of A1C versus eAG indicates that HbA1C is a better indicator of his T2D conditions. The 1.58 ratio of Carbs versus Steps indicates that diet is a more important lifestyle factor than exercise.

D. Time-zone analysis results are: Y10-Y16 = 89%; Y17-Y23 = 11%. This energy distribution pattern indicates that the time period of Y10-Y16 (89%) is his diabetic foot ulcer period, but Y17-Y23 period has contributed a very small potion of energy (11%) on his overall foot ulcer situation.

5. REFERENCES

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

For reading more of the author's published VGT or FD analysis results on medical applications, please locate them through three published special editions from the following three specific journals:

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

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

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

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The GH-Method

Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

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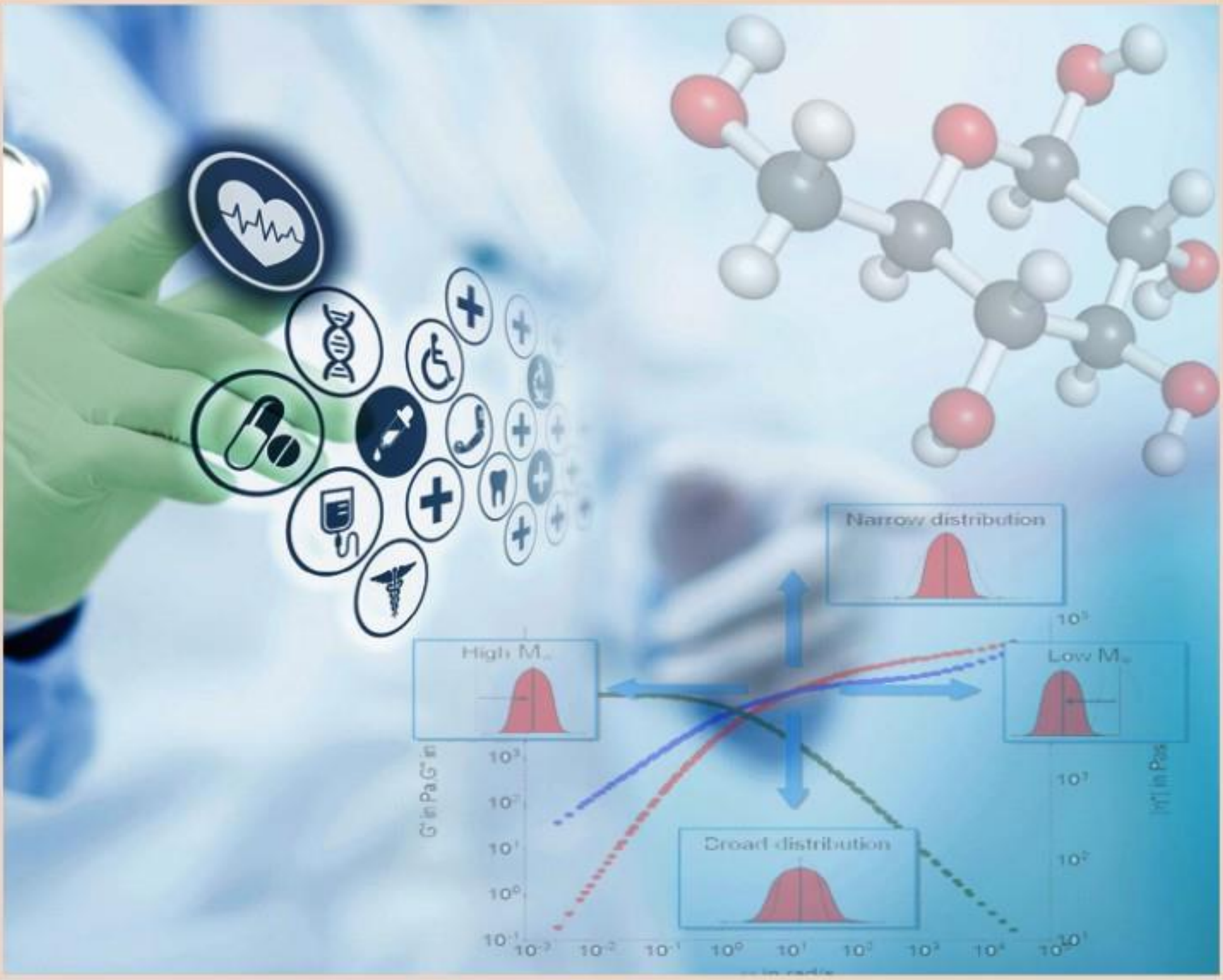

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