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Viscoelastic Medicine Theory (VMT #405): Relationships Between Three Glucose Biomarkers, TIR, TBR, TAR, and Three HbA1C Values, Finger, Sensor, Laboratory, Using Viscoplastic Energy Model of GH-Method: Math-Physical Medicine (No. 1007)

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Abstract

The ADA's 2019 Standards of Diabetes Care propose a composite metric encompassing time in range (TIR, 70-180 mg/dL), time below range (TBR, below 70 mg/dL), and time above range (TAR, above 180 mg/dL). For adults with diabetes, over 70% TIR is deemed good control, with TBR ideally under 4% and TAR under 25%.

The author tracked his daily HbA1C using four daily finger-prick tests since January 1, 2012, and a continuous glucose monitoring (CGM) device every 15 minutes since May 1, 2018. He also gathered his quarterly lab HbA1C test results. Typically, in terms of annual averaged values, his sensor-based HbA1C readings are higher than his laboratory HbA1C, which in turn is higher than his finger-prick HbA1C. He then used his three sets of annual average HbA1C values from 2018 to 2023 to conduct his three viscoplastic energy analyses resulting from his TIR, TBR, and TAR.

In this study, the researcher chose 1.0 as the normalization factor for these three inputs: TIR, TBR, and TAR. This decision highlights that TIR, particularly after his well-managed glucose levels post-2017, would exhibit the highest energy levels.

In summary, the three statistically averaged values of ADA glucose ranges are:

TIR% = 90.5%; TBR% = 1.4%; TAR% = 2.1%.

Note: The sum of these three percentages does not add up to 100%, which can be attributed to the incomplete data collection in 2018. Nevertheless, the data from 2018, though serving as an initial value, does not markedly influence the overall energy calculation in subsequent years.

Three averaged A1C values are ranked as follows:

- Sensor A1C: 6.97% > Lab A1C: 6.50% > Finger A1C: 6.48%.

- The SD-VMT energy analysis shows three corresponding energies for each type of HbA1C ranked as follows:

- Sensor A1C at 64 > Lab A1C at 24 > Finger A1C at 21.

Although the SD-VMT stress-strain energy curves show distinct curvatures and shapes, the final averaged SD-VMT energy ratios are remarkably similar. These energies indicate the different degrees of his organ damage due to diabetes.

TIR energy = 97.4%; TBR energy = 1.3%; TAR energy = 1.4%.

Key message:
All measured and calculated values fall within the ADA's recommended ranges for optimal health. His Time in Range (TIR) is outstanding, exceeding the 70%-80% guideline with a remarkable 97.4%. His Time Below Range (TBR) and Time Above Range (TAR) are both exceptionally low, at just over 1%, highlighting his successful glucose management. The analysis of his SD-VMT energy results confirms this. Despite living with type 2 diabetes, it is evident that his condition is excellently managed.

Keywords: Viscoelastic; Viscoplastic; Diabetes; Glucose; Biomarkers; Insulin; Hyperglycemia

Abbreviations: CGM: continuous glucose monitoring; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; SD: space-domain; VMT: viscoelastic medicine theory; FFT: Fast Fourier Transform; MI: Metabolism Index; TIR: Time in Range; TBR: Time Below Range; TAR: Time Above Range

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1. INTRODUCTION

The ADA's 2019 Standards of Diabetes Care propose a composite metric encompassing time in range (TIR, 70-180 mg/dL), time below range (TBR, below 70 mg/dL), and time above range (TAR, above 180 mg/dL). For adults with diabetes, over 70% TIR is deemed good control, with TBR ideally under 4% and TAR under 25%.

The author tracked his daily HbA1C using four daily finger-prick tests since January 1, 2012, and a continuous glucose monitoring (CGM) device every 15 minutes since May 1, 2018. He also gathered his quarterly lab HbA1C test results. Typically, in terms of annual averaged values, his sensor-based HbA1C readings are higher than his laboratory HbA1C, which in turn is higher than his finger-prick HbA1C. He then used his three sets of annual average HbA1C values from 2018 to 2023 to conduct his three viscoplastic energy analyses resulting from his TIR, TBR, and TAR.

In this study, the researcher chose 1.0 as the normalization factor for these three inputs: TIR, TBR, and TAR. This decision highlights that TIR, particularly after his well-managed glucose levels post-2017, would exhibit the highest energy levels.

1.1 Biomedical information:

The following sections contain excerpts and concise information drawn from multiple medical articles, which have been meticulously reviewed by the author of this paper. The author has adopted this approach as an alternative to including a conventional reference list at the end of this document, with the intention of optimizing his valuable research time. It is essential to clarify that these sections do not constitute part of the author's original contribution but have been included to aid the author in his future reviews and offer valuable insights to other readers with an interest in these subjects.

Physiological explanations regarding relationships between HbA1C and TIR, TBR, TAR:

HbA1c (hemoglobin A1c) and the metrics TIR (Time in Range), TBR (Time Below Range), and TAR (Time Above Range) are all measures related to blood glucose control in diabetes. Each metric provides a different perspective on long-term and short-term glucose management, and understanding their pathophysiological implications is important in diabetes care.

HbA1c reflects average blood glucose levels over a period of approximately 2-3 months by measuring the percentage of hemoglobin that is glycated. It provides an indication of overall long-term glucose control and risk for diabetes-related complications. A higher HbA1c level indicates higher average blood glucose levels over the prior months, which is associated with an increased risk of diabetic complications such as retinopathy, neuropathy, and cardiovascular diseases.

In contrast, TIR, TBR, and TAR assessed through continuous glucose monitoring (CGM) offer a more comprehensive view of short-term glucose control. TIR reflects the percentage of time spent within a target glucose range, providing insights into how well blood glucose levels are managed throughout the day. TBR and TAR further provide information about the frequency and duration of hypoglycemic (low) and hyperglycemic (high) episodes, respectively. However, if a longer period of data regarding TIR, TBR, and TAR is available, they can also provide useful information to the patient's glucose co-trim in addition to HbA1C values.

From a pathophysiological standpoint, TIR, TBR, and TAR metrics help to assess how well glucose levels are managed in real time, revealing fluctuations, trends, and patterns in blood glucose control. This information is valuable in understanding the impact of diet, physical activity, insulin or medication dosing, stress, and other factors on day-to-day glucose variability. It allows for the identification of specific areas for improvement and targeted interventions to optimize glycemic control and reduce the risk of acute and chronic complications.

In summary, while HbA1c provides a retrospective average of blood glucose control over an extended period, TIR, TBR, and TAR offer real-time data to evaluate short-term fluctuations and patterns in glucose control, which is essential in developing personalized diabetes management strategies to optimize overall health outcomes.

1.2 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 (Reference 1) describes his MPM methodology in a general conceptual format. The second paper, No. 387 (Reference 2) 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 (Reference 3) depicts a general flow diagram containing ~10 key MPM research methods and different tools.

The author's diabetes history:

The author has been a severe T2D patient since 1995. He weighed 220 lb. (100 kg) at that time. By 2010, he still weighed 198 lb. with an 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 lbs. (100 kg) to 176 lbs. (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 no longer takes 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 travelled 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 travelling 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 lbs. (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-travelling, 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 checked 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.

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 glucose circulate 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) influence the energy level (i.e., the Y-amplitude in the frequency domain).

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. 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 labour 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 processes of energy influx and energy dissipation 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 behaviours 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 have continuously improved during the past 13-year time window.

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, or 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 the 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).

2. RESULTS

Figure 1 shows data tables. Figure 2 shows the inputs and SD-VMT energy output diagram.

Finger A1C					/1	/1	/1	S, Rate	Strain	Strs 1	Strs 2	Strs 3	Hgt 1	Hgt 2	Hgt 3	Area 1	Area 2	Area 3	
12/22/23	F.A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	F.A1C	F.A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	Time-Zone
2018	7.00	63.09	0.10	2.84	63.09	0.10	2.84	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Y18-Y20
2019	6.89	94.86	0.22	4.92	94.86	0.22	4.92	-0.11	6.89	-10.43	-0.02	-0.54	-5.22	-0.01	-0.27	0.57	0.00	0.03	12.20
2020	6.46	97.78	0.75	1.47	97.78	0.75	1.47	-0.43	6.46	-42.05	-0.32	-0.63	-26.24	-0.17	-0.59	11.28	0.07	0.25	59%
2021	6.27	96.99	1.74	1.27	96.99	1.74	1.27	-0.19	6.27	-18.43	-0.33	-0.24	-30.24	-0.33	-0.44	5.74	0.06	0.08	Y21-Y23
2022	6.17	95.52	3.72	0.75	95.52	3.72	0.75	-0.10	6.17	-9.55	-0.37	-0.07	-13.99	-0.35	-0.16	1.40	0.04	0.02	8.48
2023	6.06	94.44	1.67	1.15	94.44	1.67	1.15	-0.11	6.06	-10.39	-0.18	-0.13	-9.97	-0.28	-0.10	1.10	0.03	0.01	41%
Avg	6.48	90.45	1.37	2.07	90.45	1.37	2.07	-0.16	6.48	-15.14	-0.21	-0.27	-14.28	-0.19	-0.26	20.10	0.20	0.39	
Correlation	100%	-66%	-78%	83%										SD-E:	21	97.1%	1.0%	1.9%	

Sensor A1C					/1	/1	/1	S, Rate	Strain	Strs 1	Strs 2	Strs 3	Hgt 1	Hgt 2	Hgt 3	Area 1	Area 2	Area 3	
12/22/23	S.A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	S.A1C	S.A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	Time-Zone
2018	7.67	63.09	0.10	2.84	63.09	0.10	2.84	0.00	7.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Y18-Y20
2019	7.85	94.86	0.22	4.92	94.86	0.22	4.92	0.18	7.85	17.07	0.04	0.89	8.54	0.02	0.44	1.54	0.00	0.08	24.33
2020	7.08	97.78	0.75	1.47	97.78	0.75	1.47	-0.77	7.08	-75.29	-0.58	-1.13	-29.11	-0.27	-0.12	22.41	0.21	0.09	38%
2021	6.67	96.99	1.74	1.27	96.99	1.74	1.27	-0.41	6.67	-39.77	-0.71	-0.52	-57.53	-0.65	-0.83	23.59	0.26	0.34	Y21-Y23
2022	6.28	95.52	3.72	0.75	95.52	3.72	0.75	-0.39	6.28	-37.25	-1.45	-0.29	-38.51	-1.08	-0.41	15.02	0.42	0.16	39.79
2023	6.28	94.44	1.67	1.15	94.44	1.67	1.15	0.00	6.28	0.00	0.00	0.00	-18.63	-0.73	-0.15	0.00	0.00	0.00	62%
Avg	6.97	90.45	1.37	2.07	90.45	1.37	2.07	-0.23	6.97	-22.54	-0.45	-0.18	-22.54	-0.45	-0.18	62.56	0.90	0.67	
Correlation	100%	-49%	-85%	89%										SD-E:	64	97.6%	1.4%	1.1%	

Lab A1C					/1	/1	/1	S, Rate	Strain	Strs 1	Strs 2	Strs 3	Hgt 1	Hgt 2	Hgt 3	Area 1	Area 2	Area 3	
12/22/23	Lab A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	Lab A1C	Lab A1C	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	TIR %	TBR %	TAR %	Time-Zone
2018	6.70	63.09	0.10	2.84	63.09	0.10	2.84	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Y18-Y20
2019	6.73	94.86	0.22	4.92	94.86	0.22	4.92	0.03	6.73	2.85	0.01	0.15	1.42	0.00	0.07	0.04	0.00	0.00	13.29
2020	6.20	97.78	0.75	1.47	97.78	0.75	1.47	-0.53	6.20	-51.82	-0.40	-0.78	-24.49	-0.20	-0.32	12.98	0.10	0.17	55%
2021	6.25	96.99	1.74	1.27	96.99	1.74	1.27	0.05	6.25	4.85	0.09	0.06	-23.49	-0.16	-0.36	-1.17	-0.01	-0.02	Y21-Y23
2022	6.35	95.52	3.72	0.75	95.52	3.72	0.75	0.10	6.35	9.55	0.37	0.07	7.20	0.23	0.07	0.72	0.02	0.01	10.68
2023	6.78	94.44	1.67	1.15	94.44	1.67	1.15	0.43	6.78	40.61	0.72	0.49	25.08	0.55	0.28	10.78	0.23	0.12	45%
Avg	6.50	90.45	1.37	2.07	90.45	1.37	2.07	0.01	6.50	1.01	0.13	0.00	-2.38	0.07	-0.04	23.35	0.35	0.28	
Correlation	100%	-45%	-39%	55%										SD-E:	24	97.4%	1.5%	1.2%	

Figure 1. Data table, inputs, and SD-VMT energy output diagram.

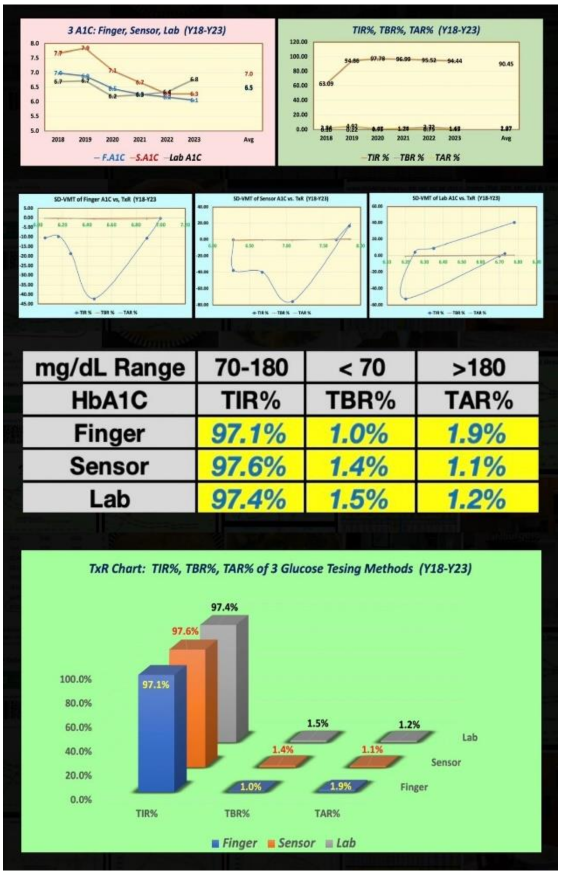

Figure 2: Inputs and SD-VMT energy output diagram.

3. CONCLUSION

In summary, the three statistical averaged values of ADA glucose ranges are:

TIR% = 90.5%; TBR% = 1.4%; TAR% = 2.1%.

Note: The sum of these three percentages does not add up to 100%, which can be attributed to the incomplete data collection in 2018. Nevertheless, the data from 2018, though serving as an initial value, does not markedly influence the overall energy calculation in subsequent years.

Three averaged A1C values are ranked as follows:

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Key message:

All measured and calculated values fall within the ADA's recommended ranges for optimal health. His Time in Range (TIR) is outstanding, exceeding the 70%-80% guideline with a remarkable 97.4%. His Time Below Range (TBR) and Time Above Range (TAR) are both exceptionally low, at just over 1%, highlighting his successful glucose management. The analysis of his SD-VMT energy results confirms this. Despite living with type 2 diabetes, it is evident that his condition is excellently managed.

4. REFERENCES

For editing purposes, the majority of the references in this paper, which are self-references, have been removed from 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.

For reading more of the author's published VGT or FD analysis results on medical applications, please locate them through platforms for scientific research publications, such as ResearchGate, Google Scholar, etc.

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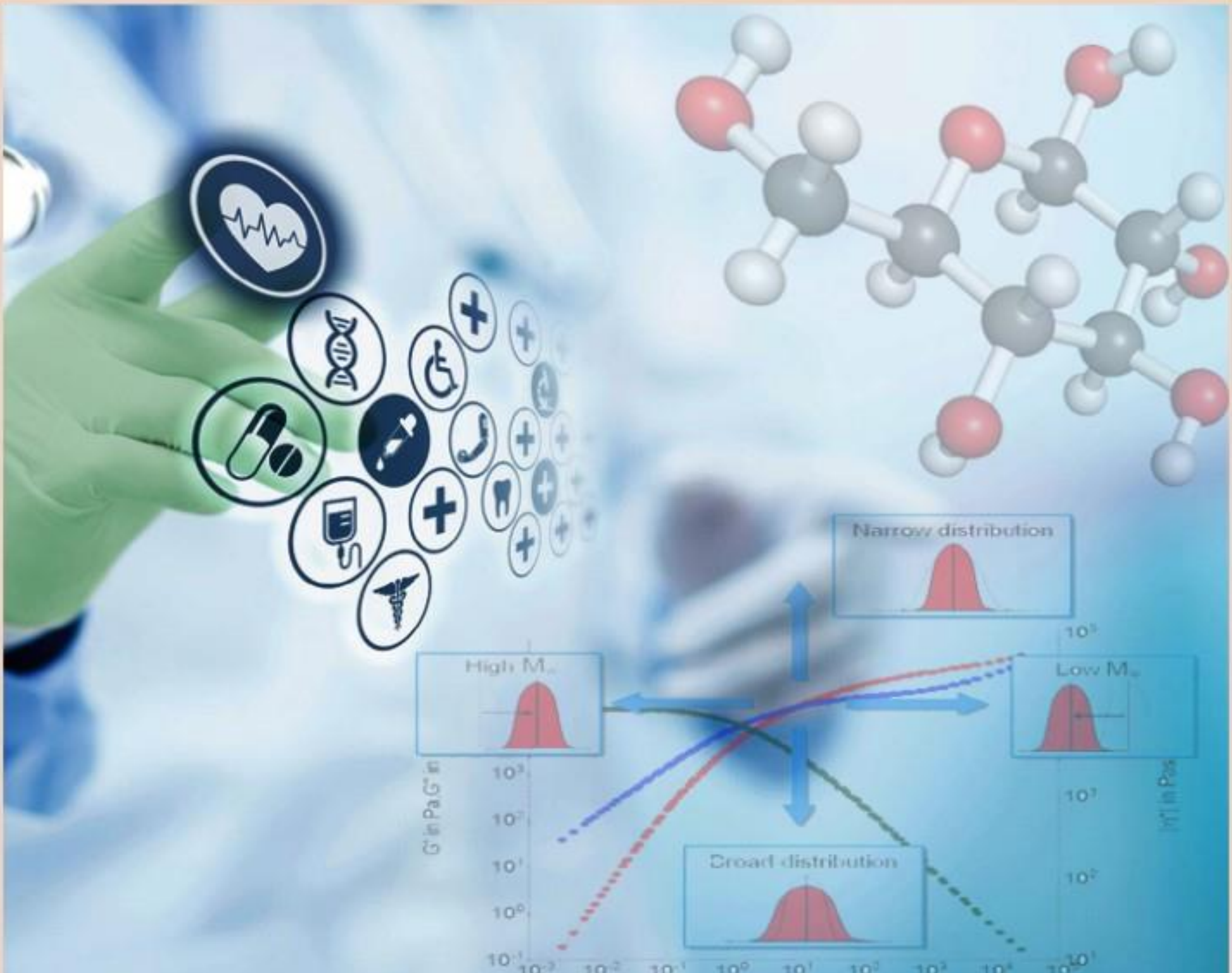

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