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The GH-Method

Viscoelastic and Viscoplastic Glucose Theory (VGT #130): The Fourth Sensitivity Study of Normalization Factors Using Three Different Energy Methods, Time Domain, Space Domain, and Frequency Domain, to Calculate Energies or Degrees of Influence on the Total 4,728 Postprandial Plasma Glucose (PPG) versus 3,682 Low-PPG Meals, 948 Mid-PPG Meals, and 98 High-PPG Meals Over a Period of 4+ Years from 5/8/2018 to 8/15/2022 Based on Math-Physical Medicine Methodology (No. 721)

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Keywords: Viscoelastic; Viscoplastic; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

Abbreviations: FFT: fast Fourier transform; T2D: type 2 diabetes; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; FD: frequency domain; SD: space domain; TD: time domain; MPM: math-physical medicine

1. INTRODUCTION

The author has conducted medical research work using viscoelastic or viscoplastic glucose theory (VGT) starting on 1/8/2022 with Paper No. 578. During his research period, he has written 129 papers where he learned in depth the subtlety and things to watch out for by applying this specific VGT research tool.

In the beginning, he selected multiple input viscosities without using any normalization factors (NF); therefore, he obtained some enlarged or dwindled stress components due to differences in their originally inherited measurement units. Afterward, he learned that some meaningful NF values should be used before calculating the hysteresis loop areas of the stress-strain diagram, i.e. input causes versus output symptoms diagram for the biomedical studies. Sometimes, NF values are used in reverse, such as applying 120 mg/dL divided by glucose values or utilizing 4,000 steps divided by the post-meal walking steps. This is due to the glucose unit following the pattern of "lower the better" whereas exercise is "more the better."

In this research article, he studies the contribution of energy (or degree of influence) of the total PPG associated with 4,728 meals from the low-PPG (<120 mg/dL) from 3,682 meals, mid-PPG (121-150 mg/dL) from 948 meals, and high-PPG (>150 mg/dL) from 84 meals. The mathematical ratio of the 3 meal groups is "92% : 5% : 2%" for high : mid : low" PPG levels.

At the beginning, he thought about only using 120 mg/dL (break-even line of diabetes) to divide the PPG values which would provide the energy contribution results from each type of meal, such as "high-PPG energy of 44% to 46% > mid-PPG energy of 31% to 38% > low-PPG energy of 23% to 33%". These calculated energies revealed the PPG characteristics resulting from each meal "type" or each average "PPG level."

However, these types of calculated energy contributions are missing the "overall impact

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on the total PPG from each PPG group by including influences from day number count". Therefore, he inserted another set of energy calculations using a modified NF value of NF = (input/120) * (day number count %) to conduct the same energy analyses via both SD-VGT and FD-FFT. Under this additional "influence of day number count %", the newly calculated energy contribution results are: "low-PPG energy of 71% to 92% > mid-PPG energy of 8% to 25% > high-PPG energy of 0.1% to 4%". This set of calculated energies uncovered the specific influences from "day number count %".

2. METHODS

2.1 Brief introduction of math-physical medicine (MPM) research

The author has collected 3+ million data regarding his health condition and lifestyle details over the past 13 years. He spent the entire year of 2014 developing a metabolism index (MI) model using a topology concept, nonlinear algebra, algebraic geometry, and finite element method. This model contains various measured biomarkers and recorded lifestyle details along with their induced new biomedical variables for an additional ~1.5 million data. Detailed data of his body weight, glucose, blood pressure, heart rate, blood lipids, body temperature, and blood oxygen level, along with essential lifestyle details, including diet, exercise, sleep, stress, water intake, and daily life routines are included in the MI database. In addition, these lifestyle details include some lifetime bad habits and certain environmental exposures. Fortunately, the author has none of these unhealthy habits and an extremely low degree of exposure to environmental factors. The developed MI model has a total of 10 categories covering approximately 500 detailed elements that constitute his defined "metabolism index model" which are the building blocks or root causes for diabetes and other chronic disease-induced complications, including but not limited to cardiovascular disease (CVD), chronic heart disease (CHD), stroke, chronic kidney disease (CKD), diabetic retinopathy (DR), neuropathy, foot ulcer, hypothyroidism, dementia, and various cancers. The end result of the MI development work is a combined MI value within any selected period with 73.5% as its dividing line between a healthy and unhealthy state. The MI serves as the foundation for many of his follow-up medical research work.

During the period from 2015 to 2017, he focused his research on type 2 diabetes (T2D), especially glucose, including fasting plasma glucose (FPG), PPG, estimated average glucose (eAG), and hemoglobin A1C (HbA1C). During the following period from 2018 to 2022, he concentrated on researching medical complications resulting from diabetes, chronic diseases, and metabolic disorders which include heart problems, stroke, kidney problems, retinopathy, neuropathy, foot ulcer, diabetic skin fungal infection, hypothyroidism, diabetic constipation, dementia, and various cancers. He also developed a few mathematical risk models to calculate the probability percentages of developing various diabetic complications based on this MI model. From his previous medical research work with 700+ published papers, he has identified and learned that the associated energy of hyperglycemic conditions is the primary source of causing many diabetic complications which lead to death. Therefore, a thorough knowledge of these energies is important for achieving a better understanding of the dangerous complications.

2.2 TD, SD, and FD analysis tools

This section has brief descriptions of TD correlation analysis with other observational results, SD VGT analysis with hysteresis loop area's energy results, and FD analysis with frequency curve area's energy results.

First of all, by using a TD analysis tool, we can examine the curves' moving trend and pattern visually along with their correlation numerically. We can also study the extremely high or low data values in the dataset. The visual observation or calculation-derived interpretations are a part of statistical analysis results which can indeed provide some useful hints or even derive some accurate conclusions. However, we must be aware of the limitations of the selected data size and time window and also be cautious of the appropriate statistics tool we choose.

The author would like to describe the essence of his developed "hybrid model" that combines both the SD viscoelastic/plastic VGT analysis method and FD fast Fourier transform (FFT) analysis method together with a comparison against the traditional time-domain statistical correlation analysis.

It is described in 10 steps in the English language instead of using mathematical equations to explain it. In this article, he has applied both the SD-VGT operations (steps 1-7) and the FD-FFT operations (steps 8-10). As a result, it is aimed at readers who do not have an extensive background in the academic subjects of engineering, physics & mathematics.

The first step is to collect the output data or symptom (strain or ε) on a time scale. The second step is to calculate the output change rate with time (dε/dt), i.e. the change rate of strain or symptom over each period. The third step is to gather the input data or cause (viscosity or η) on a time scale. The fourth step is to calculate the time-dependent input or cause (time-dependent stress or σ) by multiplying dε/dt and η together. The "time-dependent input or cause equation" of "stress σ = strain change rate of dε/dt * viscosity η" is the essential part of this "time dependency". The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a two-dimensional space-domain or SD (x-axis versus y-axis) with strain (output or symptom) on the x-axis and stresses (time-dependent inputs, causes, or stresses) on the y-axis.

The sixth step is to calculate the total enclosed area within these stress-strain curves or input-output curves (i.e. the hysteresis loops), which is also an indicator of associated energies (either created energy or dissipated energy) of this input and output dataset. These energy values can also be considered as the degrees of influence on output by inputs. The seventh step is the assembly of the area values of the selected periods to compare the "historical progression and contribution of medical condition" over certain time periods. For the frequency domain, the eighth step is to define a "hybrid input variable" by using "strain*stress" which yields another accurate estimation of energy ratio similar to the SD-VGT energy ratio associated with the hysteresis loop. The ninth step is to present these hybrid models' results of (strain*stress) in a time domain and then perform the fast Fourier transformation (FFT) operation to convert them into a frequency domain. The enclosed area of the frequency curve (where the x-axis is the frequency and the y-axis is the amplitude of energy) can be used to estimate the total FD-FFT energy. The tenth step is to compare these FD energy results against the SD-VGT energy results, or even TD energy results.

After providing the above 10-step description, the author would still like to use the following set of VGT stress-strain mathematical equations in a two-dimensional SD to address the selected medical variables:

Strain
= ε (time-dependency characteristics of individual strain value at the present time duration)

Stress
= σ (based on the change rate of strain multiplying with a chosen viscosity factor η)
= η * (dε/dt)
= η * (d-strain/d-time)
= (viscosity factor η using individual viscosity factor at present time duration) * (strain at present quarter - strain at previous time duration)

Some of these inputs (causes or viscosity factors) are further normalized by dividing them or being divided by a normalization factor using certain established health standards or medical pieces of knowledge. Some examples of normalization factors are 6.0 for HbA1C, 120 mg/dL for glucose, 25 for body mass index (BMI), 4,000 steps after each meal, 10,000 or 12,000 steps for daily walking exercise depending on time-period selection, 13 grams to 20 grams of carbs/sugar intake amount per meal depends on time-period selection. If using the originally collected data, i.e. the non-normalized data, it would distort the numerical comparison of the hysteresis loop areas. Using this "normalization process", we can remove the dependency of the individual unit or certain unique characteristics associated with each viscosity factor. This process allows us to convert the originally collected variables into a set of "dimensionless variables" for easier numerical comparison and result interpretation.

In this particular study, he has used two sets of "normalization factors": 120 mg/dL and (specific meal number / total meal number) * 120 mg/dL.

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 2 data tables.

8/15/22	Strain	Visc. 1	Visc. 2	Visc. 3	N.1 (/120)	N.2 (/120)	N.3 (/120)	Strain Rate	Strain	Stress 1	Stress 2	Stress 3	Area 1	Area 2	Area 3			8/15/22	I/O 1	I/O 2	I/O 3
PPG Study	Total PPG	Lo. PPG	Med. PPG	HI. PPG	Lo. PPG	Med. PPG	HI. PPG	Total Rate	Total PPG	Lo. PPG	Med. PPG	HI. PPG	Lo. PPG	Med. PPG	HI. PPG	Time #	Time %		Lo. PPG	Med. PPG	HI. PPG
0-min	121	119	128	136	0.99	1.07	1.14	0.00	121	0.00	0.00	0.00	0.0	0.0	0.0			0-min	0	0	0
15-min	124	121	132	143	1.01	1.10	1.19	2.32	124	2.34	2.55	2.77	2.7	3.0	3.2			15-min	290	315	343
30-min	128	125	138	153	1.04	1.15	1.27	4.38	128	4.56	5.04	5.58	15.1	16.6	18.3			30-min	584	645	715
45-min	131	127	144	164	1.06	1.20	1.37	3.30	131	3.51	3.95	4.51	13.3	14.8	16.6	0-60		45-min	460	518	592
60-min	132	127	146	172	1.06	1.22	1.43	0.20	132	0.21	0.24	0.29	0.4	0.4	0.5	105	51%	60-min	28	32	38
75-min	129	124	145	175	1.03	1.21	1.46	-2.69	129	-2.77	-3.26	-3.92	3.4	4.1	4.9			75-min	-357	-420	-505
90-min	126	120	144	181	1.00	1.20	1.51	-2.59	126	-2.60	-3.11	-3.90	7.0	8.3	10.1			90-min	-328	-393	-492
105-min	123	117	143	181	0.97	1.19	1.51	-3.13	123	-3.05	-3.72	-4.73	8.8	10.7	13.5	75-120		105-min	-376	-458	-582
120-min	121	114	141	183	0.95	1.17	1.53	-2.32	121	-2.21	-2.72	-3.54	6.1	7.5	9.6	94	46%	120-min	-267	-329	-428
135-min	120	114	139	179	0.95	1.16	1.49	-0.86	120	-0.81	-1.00	-1.28	1.3	1.6	2.1			135-min	-98	-120	-154
150-min	120	114	138	176	0.95	1.15	1.47	0.35	120	0.33	0.40	0.51	-0.1	-0.1	-0.1			150-min	40	49	62
165-min	121	116	138	174	0.96	1.15	1.45	0.82	121	0.79	0.95	1.19	0.5	0.6	0.7	135-180		165-min	96	115	144
180-min	121	116	137	166	0.97	1.14	1.38	0.16	121	0.16	0.18	0.22	0.1	0.1	0.1	7	3%	180-min	19	22	27
Average	124	120	140	168	1.00	1.16	1.40	-0.005	124	0.04	-0.04	-0.18	59	67	79	205	100%	Sum	91	-23	-242
	TD-E #	14301	19467	28203								SD-E%	33%	38%	45%	FD-E #	5E+06	FD-E #	1197497	1585911	2E+06
	TD-E %	23%	31%	46%												FD-E %	100%	FD-E %	24%	32%	44%

8/12/22	Strain	Visc. 1	Visc. 2	Visc. 3	N.1 with %	N.2 with %	N.3 with %	Strain Rate	Strain	Stress 1	Stress 2	Stress 3	Area 1	Area 2	Area 3			8/12/22	I/O 1	I/O 2	I/O 3
PPG Study	Total PPG	Lo. PPG	Med. PPG	HI. PPG	Lo. PPG	Med. PPG	HI. PPG	Total Rate	Total PPG	Lo. PPG	Med. PPG	HI. PPG	Lo. PPG	Med. PPG	HI. PPG	Time #	Time %		Lo. PPG	Med. PPG	HI. PPG
0-min	121	119	128	136	0.774	0.214	0.024	0.00	121	0.00	0.00	0.00	0.0	0.0	0.0			0-min	0	0	0
15-min	124	121	132	143	0.786	0.220	0.025	2.32	124	1.82	0.51	0.06	2.1	0.6	0.1			15-min	225	63	7
30-min	128	125	138	153	0.811	0.231	0.026	4.38	128	3.55	1.01	0.12	11.8	3.3	0.4			30-min	455	129	15
45-min	131	127	144	164	0.827	0.240	0.028	3.30	131	2.73	0.79	0.09	10.4	3.0	0.3	0-60 min		45-min	359	104	12
60-min	132	127	146	172	0.823	0.244	0.030	0.20	132	0.16	0.05	0.01	0.3	0.1	0.0	32	53%	60-min	22	6	1
75-min	129	124	145	175	0.802	0.243	0.030	-2.69	129	-2.16	-0.65	-0.08	2.7	0.8	0.1			75-min	-278	-84	-10
90-min	126	120	144	181	0.781	0.241	0.031	-2.59	126	-2.02	-0.62	-0.08	5.4	1.7	0.2			90-min	-255	-79	-10
105-min	123	117	143	181	0.759	0.238	0.031	-3.13	123	-2.37	-0.75	-0.10	6.9	2.1	0.3	75-120		105-min	-292	-92	-12
120-min	121	114	141	183	0.741	0.235	0.032	-2.32	121	-1.72	-0.55	-0.07	4.7	1.5	0.2	27	44%	120-min	-208	-66	-9
135-min	120	114	139	179	0.737	0.233	0.031	-0.86	120	-0.63	-0.20	-0.03	1.0	0.3	0.0			135-min	-76	-24	-3
150-min	120	114	138	176	0.742	0.231	0.030	0.35	120	0.26	0.08	0.01	-0.1	0.0	0.0			150-min	31	10	1
165-min	121	116	138	174	0.750	0.231	0.030	0.82	121	0.62	0.19	0.02	0.4	0.1	0.0	135-180		165-min	75	23	3
180-min	121	116	137	166	0.755	0.229	0.029	0.16	121	0.12	0.04	0.00	0.1	0.0	0.0	2	3%	180-min	15	4	1
Average	124	120	140	168	0.78	0.23	0.03	-0.005	124	0.03	-0.01	0.00	46	14	2	61	100%	Average	71	-5	0
	TD-E #	11137	3903	585								SD-E%	75%	22%	3%	FD-E #	790497	FD-E #	725865	63697	935
	TD-E %	71%	25%	4%												FD-E %	100%	FD-E %	92%	8%	0.1%

Figure 1: 2 Data tables.

Figure 2 displays the background data and the TD analysis results.

PPG Range	0-400	0-120	121-150	151-400	PPG mg/dL	0-120	121-150	151-400
PPG Study	Total PPG	Lo. PPG	Med. PPG	HI. PPG	PPG Study	Lo. PPG	Med. PPG	HI. PPG
No. of Meals	4728	3682	948	98	Norm %	78%	20%	2%
Ag. F. PPG	110.9	105.0	129.1	173.3	Correlation	96%	58%	-8%
Avg. Carbs	13.3	10.7	19.0	59.8				
Avg. Steps	4238	4328	3966	3356				

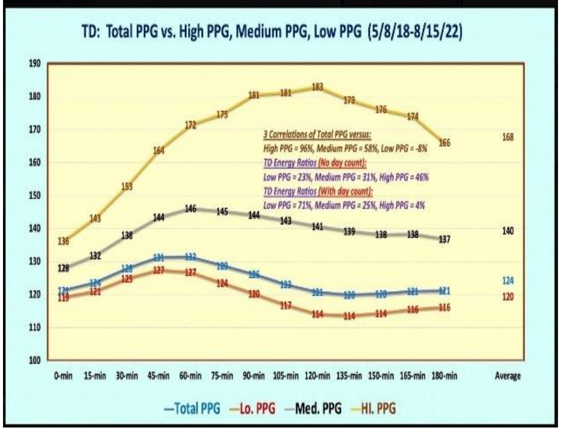


Figure 2: Background data and the TD analysis results.

Figure 3 depicts 2 SD-VGT analysis results.

Figure 4 reflects 2 FD-FFT analysis results.

Figure 5 illustrates the energy comparison of using three research tools with both no day number counts and with day number counts.

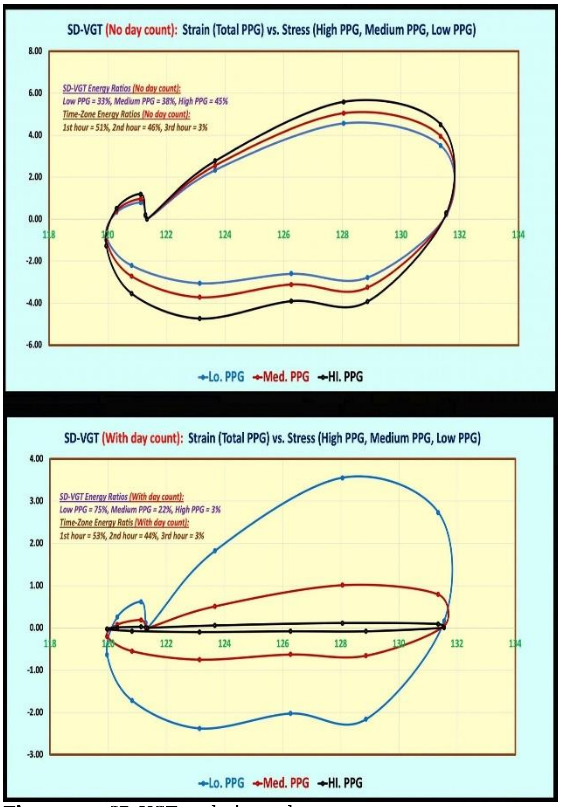
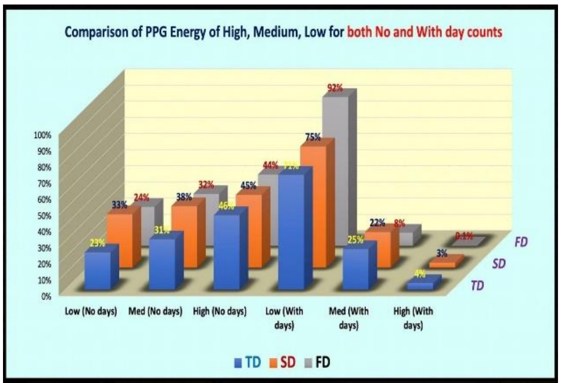


Figure 3: 2 SD-VGT analysis results.

Figure 4: 2 FD-FFT analysis results.



No & With days	TD	SD	FD
Low (No days)	23%	33%	24%
Med (No days)	31%	38%	32%
High (No days)	46%	45%	44%
Low (With days)	71%	75%	92%
Med (With days)	25%	22%	8%
High (With days)	4%	3%	0.1%

Figure 5: Energy ratio comparison for both excluding and including day number count in the normalization factors.

4. CONCLUSION

In summary, there are 6 key findings from this fourth special sensitivity study of NF in the biomedical energy analysis:

(1) From the TD diagram, the average PPG values are 124 mg/dL for the total PPG, 120 mg/dL for the low-PPG group, 140 mg/dL for the mid-PPG group, and 168 mg/dL for the high-PPG group. The majority (78%) of his total PPG case is from the low-PPG group. The mid-PPG group occupies 20% and the high-PPG group holds only 2%.

(2) From the TD diagram, the three correlation coefficients are: Total vs. Low = 96% (since low occupies 78% of total); Total vs. Mid = 58%; and Total vs. High = -8% (No correlation at all between total and high).

(3) TD squared-amplitude energy analysis results of "no day number count" and "with day number count" are: For the "no day number count in normalization factors" case: The TD squared amplitude energy ratios are: Low-PPG = 23%; Mid-PPG = 31%; and High-PPG = 46%. The hyperglycemic characteristics of the high-PPG group influence the total PPG the most. However, for the "with day number count in normalization factors" case: The TD squared amplitude energy ratios are: Low-PPG = 71%; Mid-PPG = 25%; and High-PPG = 4%. The Low-PPG group impacts the total PPG the most due to its high day number count of 78% of the total PPG.

(4) From the SD-VGT analysis results, there are two energy ratios from "no day number count" and "with day number count" which are: For the "no day number count in normalization factors" case: The SD-VGT energy ratios are: Low-PPG = 33%; Mid-PG = 38%; and High-PPG = 45%. Again, the hyperglycemic characteristics of the high-PPG group influence the total PPG the most. But, for the "with day number count in normalization factors" case: The SD-VGT energy ratios are: Low-PPG = 75%; Mid-PPG = 22%; and High-PPG = 3%. The low-PPG group impacts the total PPG the most due to its 78% high day number count % of the total PPG.

(5) From the SD-VGT analysis results, the author has further analyzed the energy's time-zone process from "energy generation through energy dissipation to the state of left-over energy". Again, there are two energy ratios from "no day number count" and "with day number count" which are: For the "no day number count in normalization factors" case: The SD-VGT energy ratios are: 1st hour = 51%; 2nd hour = 46%; and 3rd hour = 3%. However, for the "with day number count in normalization factors" case: The SD-VGT energy ratios are: 1st hour = 53%; 2nd hour = 44%; and 3rd hour = 3%. It is interesting to discover that, regardless of the inclusion or exclusion of meal numbers inside the normalization factors, these two time-zone energy ratios are similar to each other. In other words, generated energy via food consumption during the first hour contributes 51% to 53%, dissipated energy via exercise during the second hour contributes 44%-46%, and left-over energy within the third hour is 3%, regardless inclusion or exclusion of day number count % in the normalization factors. Another way to look at this observation is that the energy infusion from his food is almost completely depleted via post-meal exercise. As a result, this leaves a small amount of energy (3%) inside his body. This description fits with the definition of elastic behavior. Furthermore, by observing the stress-strain diagram, especially the hysteresis loop, it has an almost "closed loop"; therefore, his total PPG has a viscoelastic behavior.

(6) From the FD-FFT analysis results, there are two energy ratios from "no day number count" and "with day number count" which are: For the "no day number count in normalization factors" case: The FD-FFT energy ratios are: Low-PPG = 24%; Mid-PPG = 32%; and High-PPG = 44%. However, for the "with day number count in normalization factors" case: The FD-FFT energy ratios are: Low-PPG = 92%; Mid-PPG = 8%; and High-PPG = 0.1%.

In summary, excluding the day number count in the normalization factors, each PPG group's biophysical characteristics of hyperglycemia would dominate the energy contribution to the total PPG. However, once the author includes the day number count in the normalization factors, the PPG group with the highest day number count would dominate the energy contribution to the total PPG.

Regardless of which research model he adopts, their conclusive findings and behaviors from TD, SD, and FD are extremely close and similar to each other, except for the so-called "amplification" effect associated with the FD-FFT model.

This fourth sensitivity study of the normalization process has offered a deeper understanding of biophysical behaviors of various biomedical variables, i.e. biomarkers. This article has further proven the usefulness of math-physical medicine research methodology in medical research.

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.

Special Issue | Issue No. 5

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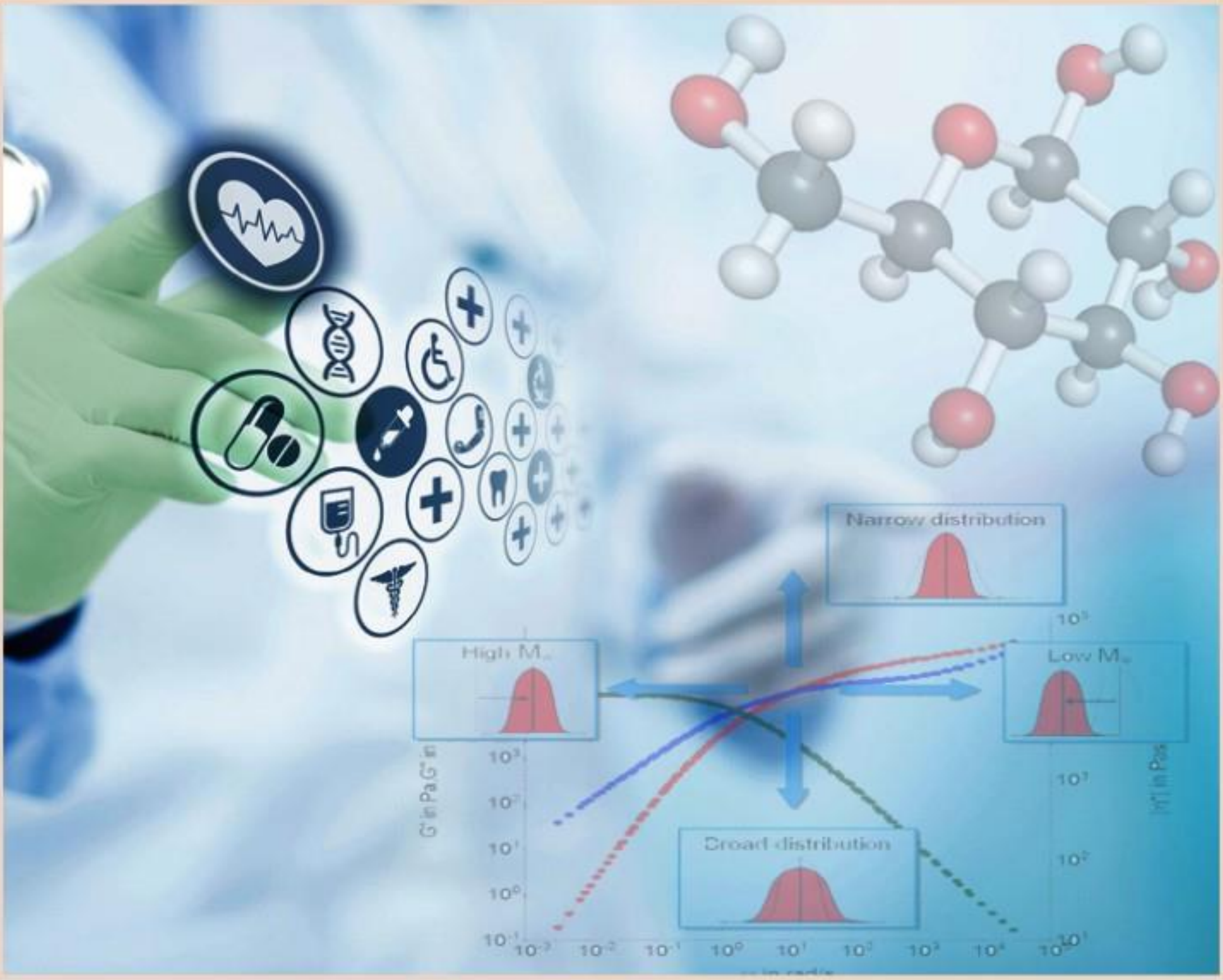

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