The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #162): Using Body Temperature and/or Body Weight to Predict Fasting Plasma Glucose with Data Collected by a Diabetes Patient Over 9 Quarters from 10/30/2020 to 10/30/2022 Based on the GH-Method: Math-Physical Medicine (No. 756)

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Abstract

Accumulating body weight and body temperature data is much easier than collecting glucose values. Therefore, diabetes patients can utilize their collected data on body weight in the early morning or obtain the average body weight and body temperature to predict their fasting glucose (FPG) in the early morning. In the author's case, his predicted FPG values have achieved over 99% accuracy. In other words, a diabetes patient's fasting glucoses are highly correlated with body weight and body temperature.

Keywords: Viscoelastic; Viscoplastic; Body temperature; Body weight; Diabetes; Fasting plasma glucose; Postprandial plasma glucose

Abbreviations: FPG: fasting plasma glucose; PPG: postprandial plasma glucose; BT: body temperature; BW: body weight; TD: time-domain; SD: space-domain; FD: frequency-domain

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1. INTRODUCTION

In many academic fields, for example, medicine, engineering, economics, business management, psychology, social science, etc., people are frequently seeking answers, illustrations, or explanations for the relationships between the input variables (e.g. forces on a structure or causes of a disease) and output variables (e.g. deformation on a structure or symptom of a disease). However, the relationships between input and output could be expressed with many different matrix formats of 1 x 1, 1 x n, m x 1, or m x n (m or n means different multiple variables). In addition to these mathematical complications, the output resulting from one or more inputs can also become an input of another output i.e., a symptom of certain causes can become a cause of another different disease or symptom. This particular phenomenon is a complex scenario of a "multi-dependent chain effect". In fact, engineering and biomedical complications are fundamentally mathematical problems that correlate with many inherent fundamental physical laws, theorems, or principles.

Over the past 13 years, in his medical research work, the author has encountered several hundred biomedical problems which have involved different biomarkers with various relationships of causes (input variables) versus symptoms (output variables). For example, food and exercise influence both body weight (BW) and postprandial plasma glucose (PPG), while the pancreatic health state, BW, body temperature (BT), and sleep conditions affect the fasting plasma glucose (FPG) in the early morning. A persistent high glucose condition, including FPG and PPG, can result in type 2 diabetes. When diabetes combines with hypertension (high blood pressure) and hyperlipidemia (high blood lipids), it would likely cause various cardiovascular diseases (heart attacks), strokes, or kidney complications. Furthermore, obesity and diabetes are also linked with various cancers and dementia. These multiple sets of lifestyle and biomedical inputs versus disease and symptom outputs have been studied and researched by the author (where he faced more than 700 sets of problems) during the past 13 years using 30+ different research tools he has learned from mathematics, physics, computer science, and engineering disciplines at 7 different universities.

Previously, he applied a signal processing technique to separate 19 components from the combined PPG wave. He has noticed his FPG level has served about 90% of the baseline of his PPG. He further identified the carbs/sugar intake amount (about 60%) and post-meal exercise (about 40%) as the two most important contributing factors for PPG formation. In addition, he also discovered more than 5 components causing FPG, including pancreatic beta cells health condition as the baseline, along with BW, sleep, and stress as additional influential forces. In his follow-on studies applying his knowledge regarding his FPG, he also identified the self-repairing capability of his pancreatic beta cells which has involved with the quality and quantity of his insulin secretion by ~35% improvement over the past 10 years. This finding caused him to believe that the lifespan of pancreatic beta cells is about 25 to 30 years if a linear theory is applied. Based on these findings, he then applied the theory of elasticity from engineering to develop a linear elastic glucose theory (LEGT). This is to predict the PPG value with high prediction accuracy, using carbs/sugar grams and post-meal walking k-steps as two major input components of PPG formation. Based on his BW in the early morning, he could also predict his FPG quite accurately.

During the COVID pandemic period, starting on 10/1/2020, he measured his BT in the early morning to monitor the health condition of his respiratory system. To date, with only 700+ days of data, he has already seen a high correlation coefficient of 86% existing between his FPG and BT. It should be noted that the correlation between his FPG and body weight is 85% (daily data) for ~10 years (from 12/1/12 to 10/29/22); however, it is -44% (daily data) over 2 years (from 10/1/20 to 10/29/22) and -11% (quarterly data). The above findings have demonstrated that statistical tools can sometimes result in some questionable outcomes depending upon the selection of time window, data quantity, data quality of containing key characteristics or not, etc.

Recently, he has applied the theories of viscoelasticity and viscoplasticity (VGT) from both engineering and physics to various problems and has written 161 research papers which include 152 biomedical papers and 9 economics and business management papers. This VGT technique emphasizes the time-dependency characteristics of certain variables. In the medical field, most biomarkers are time-dependent since body organ cells are organic in nature and change constantly. Incidentally, VGT can generate a stress-strain curve or cause-symptom curve, which also indicates the relative energy created during the uploading (increasing influential force) and dissipated during the unloading (decreasing influential force) process over the timespan of a biomarker wave.

In this article, the author has selected a dataset containing 3 biomarkers, sensor-collected FPG as the output (strain), and BW and BT as two inputs (stresses) over the past 9 quarters from 10/1/2020 to 10/30/2022. In this study, he used 170 lbs. (BMI 25.0) as the normalization factor for his BW and 98.6°F (37°C) as the normalization factor for his BT (normal body temperature). The measurement units for BW (pounds) and BT (degrees Fahrenheit) were defined long ago without considering the biomedical means in terms of their inherent biophysical inter-relationships. To place them on even ground with a sufficient biomedical sense, he has normalized the viscosity factor η of BW and BT respectively, using the following 2 formulas:

Normalized BW
= BW / healthy BW (170 lbs. for him)

Normalized BT
= BT / healthy BT (98.6°F)

The magnitude of stress components on the y-axis of the stress-strain diagram, such as the influential forces resulting from two causes (viscosity factors η of BW and BT), is greatly controlled by the values of BW and BT and the change rate of strain (FPG change rate). In this study, after going through the normalization process, both his BW and BT are varying around 1.0 with average values of 0.99 (or 99%). As a result, he has had very healthy conditions of both BW and BT during this selected period. Unsurprisingly, the degree of contributions or degree of influences, i.e. energies, are almost equal between BW and BT.

Finally, utilizing both normalized BW values and average BW and BT, the author has constructed two predicted FPG formulas as follows:

First predicted FPG
= normalized present BW * previous FPG

Second predicted FPG
= normalized present (BW+BT)/2 * previous FPG

He has achieved extremely high prediction accuracy (> 99%). However, their correlations are not satisfactory (only 45%-48%). This means that its predictability can be trusted and utilized for a longer time but not for a shorter period or from the present time instant to the next time instant.

2. METHODS

Regarding his research methods, the first time-domain (TD 1) model uses a rudimentary physics definition of energy associated with a wave that is directly proportional to the square of wave amplitude. The second time-domain (TD 2) model uses the summation of the input wave's amplitude as the relative energy level. The third space-domain (SD) model utilizes the hysteresis loop area of the time-dependent strain-stress curve with viscoelastic and viscoplastic engineering material behaviors. The fourth frequency-domain (FD) model uses his defined new variable of strain (output) multiplying with stress (stress input is the strain change rate multiplying with the normalized viscosity input) and the fast Fourier transform (FFT) operation of wave theory in physics. The calculated area underneath the FFT transformed frequency curve indicates the relative energy level. From the author's research, he has identified that all of these 4 energy ratios are following a similar pattern, i.e. high energy versus lower energy. However, the results of TD 1 (squared average) and FD (stress*strain) are close to each other, while the results of TD 2 (sum) and SD (stress-strain hysteresis loop area) are close to each other. Obviously, the results from both TD 1 and FD have an amplification effect.

The following defined stress and strain equations are used to establish the VGT stress-strain diagram in the space domain (SD):

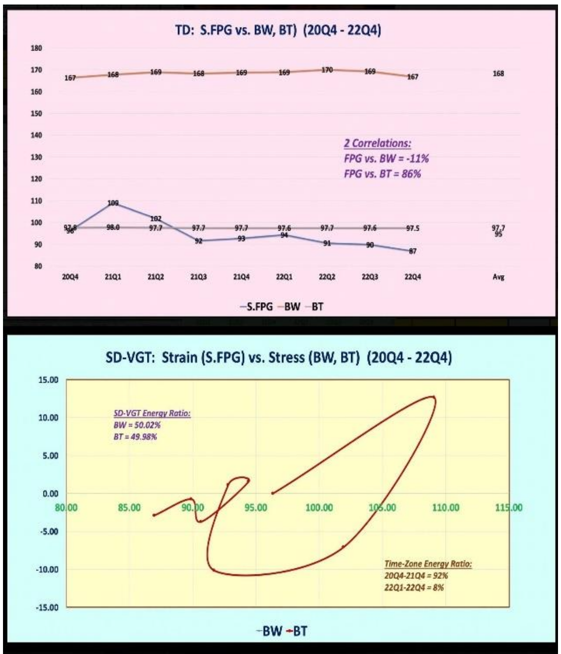
VGT strain
= ε (FPG)
= individual FPG at the present time

VGT stress
= σ (based on the change rate of strain, FPG, multiplying with a viscosity factor, BT or BW)
= η * (dε/dt)
= η * (d-strain/d-time)
= (viscosity factor η using individual BT or BW at present time) * (FPG at present time - FPG at a previous time)

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

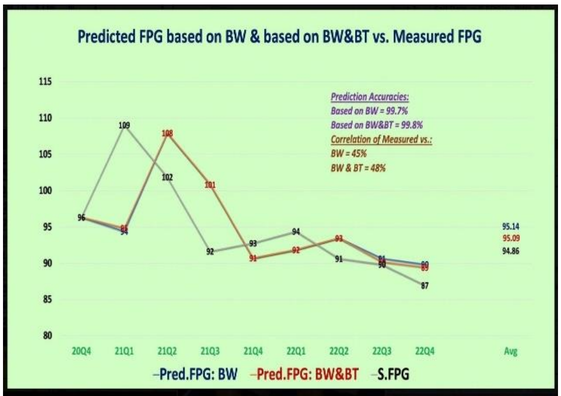
Figure 1 shows the data table, TD, and SD results.



Correlation	100%	-11%	86%	/ 170	/98.6	Strain Rate	Strain	Stress 1	Stress 2	Height 1	Height 2	Area 1	Area 2	FD 1	FD 2	SD
	S.FPG	BW	BT	N. 1	N. 2	S.FPG Rate	S.FPG	BW	BT	BW	BT	BW	BT	BW	BT	Time-Zone
20Q4	96	167	97.8	0.98	0.99	0.00	96.34	0.00	0.00	0.00	0.00	0.00	0.00	0	0	20Q4-21Q4
21Q1	109	168	98.0	0.99	0.99	12.73	109.07	12.57	12.65	6.29	6.32	80.04	80.51	1372	1380	288
21Q2	102	169	97.7	0.99	0.99	-7.17	101.90	-7.13	-7.11	2.72	2.77	-19.51	-19.87	-727	-724	92%
21Q3	92	168	97.7	0.99	0.99	-10.23	91.67	-10.14	-10.14	-8.63	-8.62	88.33	88.19	-929	-929	
21Q4	93	169	97.7	0.99	0.99	1.13	92.80	1.12	1.12	-4.51	-4.51	-5.09	-5.09	104	104	
22Q1	94	169	97.6	0.99	0.99	1.63	94.43	1.62	1.61	1.37	1.37	2.24	2.23	153	152	22Q1-22Q4
22Q2	91	170	97.7	1.00	0.99	-3.77	90.66	-3.77	-3.73	-1.06	-1.06	4.06	4.00	-342	-339	27
22Q3	90	169	97.6	1.00	0.99	-0.77	89.89	-0.77	-0.76	-2.27	-2.25	1.75	1.73	-69	-69	8%
22Q4	87	167	97.5	0.98	0.99	-2.92	86.97	-2.87	-2.89	-1.82	-1.83	5.31	5.33	-249	-251	
Avg	95	168	97.7	0.99	0.99	-1.04	94.86	-1.04	-1.03	-0.88	-0.87	157.12	157.02	3869397	3889626	314
Sum	TD1-Avg:	50.0%	50.0%	8.91	8.91		TD2-Sum:	50.0%	50.0%		SD-E: %	50.02%	49.98%	49.9%	50.1%	FD-E: %
	1.98						17.82				SD-E #	314.14			7759023	FD-E #

Figure 1: Data table, TD results, and SD results.

Figure 2 displays two predicted FPG curves with the data table.



	S.FPG	BW	BT	(BW+BT)/2		Pred.FPG: BW	Pred.FPG: BW&BT	S.FPG
20Q4	96	0.98	0.99	0.99	20Q4	96	96	96
21Q1	109	0.99	0.99	0.99	21Q1	94	95	109
21Q2	102	0.99	0.99	0.99	21Q2	108	108	102
21Q3	92	0.99	0.99	0.99	21Q3	101	101	92
21Q4	93	0.99	0.99	0.99	21Q4	91	91	93
22Q1	94	0.99	0.99	0.99	22Q1	92	92	94
22Q2	91	1.00	0.99	1.00	22Q2	93	93	91
22Q3	90	1.00	0.99	1.00	22Q3	91	90	90
22Q4	87	0.98	0.99	0.99	22Q4	90	89	87
Avg	94.86	0.99	0.99	0.99	Avg	95.14	95.09	94.86
Accuracy						99.7%	99.8%	
Correlation						45%	48%	100%

Figure 2: Two predicted FPG curves with data table.

4. CONCLUSION

In summary, there are 4 key findings from this study.

(1) In TD and SD analysis results, all of the normalized stresses, and hysteresis loop areas are almost identical to each other. This shows that both BW and BT have an almost equal contribution to FPG. However, the correlation between FPG and BT is 86% while the correlation between FPG and BW is -11%.

(2) The SD-VGT energy ratios are BW = 50.02%; BT = 49.98%. For comparison, the TD-summation energy ratios are BW = 50%; BT = 50%. The TD-squared average energy ratios are also: BW = 50%; BT = 50%. The FD-FFT energy ratios are BW = 49.9%; BT = 50.1%.

(3) The SD-VGT time zone energy ratios are 20Q4-21Q4 = 92%; 22Q1-22Q4 = 8%. This means that most of the contribution from BW and BT on FPG happened during the first year of 2021, not 2022.

(4) Two predicted FPG waves have achieved 99.7% and 99.8% of prediction accuracies, but

with low correlations of 45% and 48%. This means that this kind of simple estimation method needs further improvement on their waveform correlations.

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.

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(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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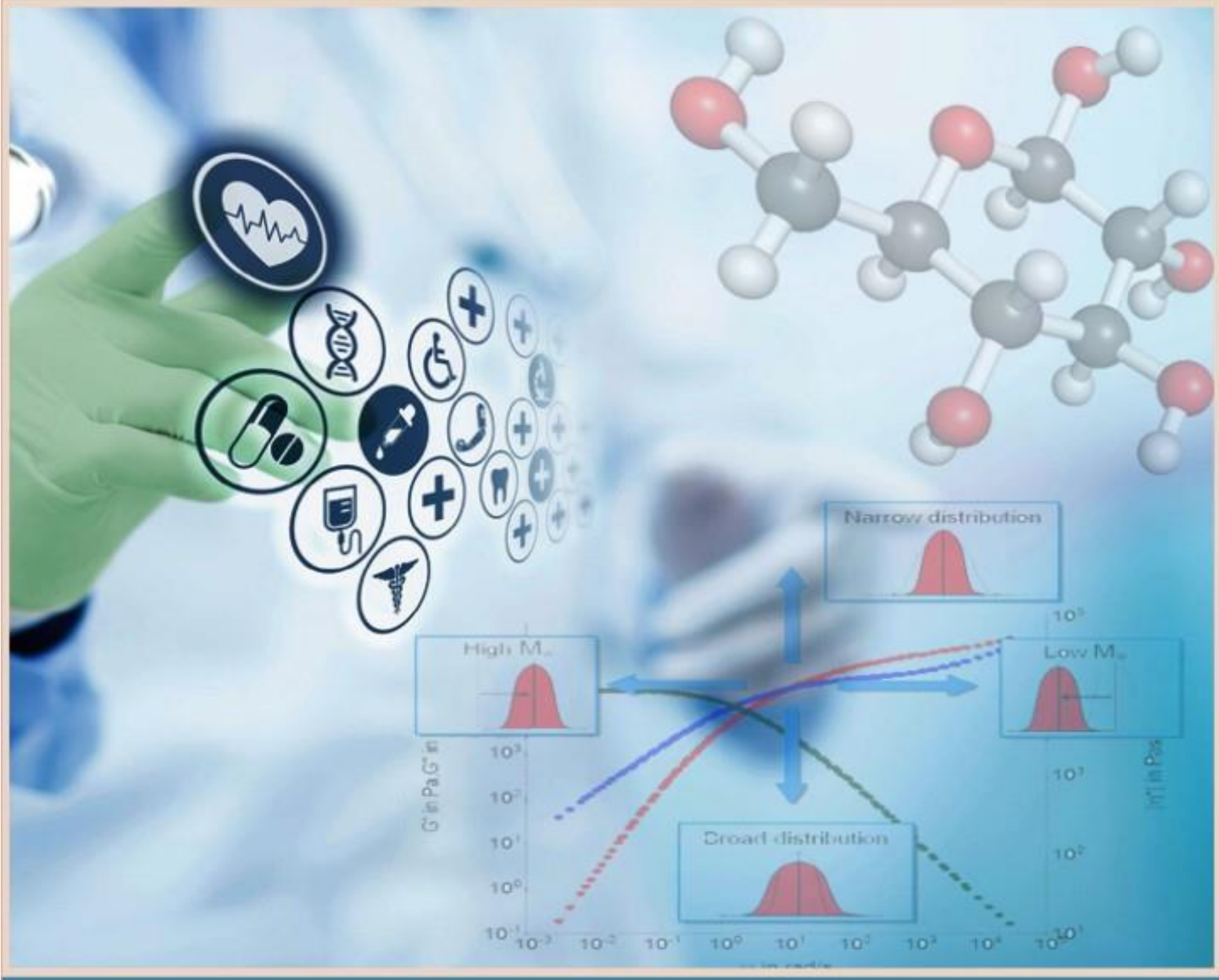

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