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A Biophysical Study of Relationships Among Nutrition, Glucose, and Neuroscience via Ppg Waveform Differences between Liquid Egg Meals and Solid Egg Meals Using Gh-Method: Math-Physical Medicine (No.294)

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ABSTRACT

In this paper, the author describes his 2+ years (801 days) research results, from 5/5/2018 through 7/14/2020, using his 171 special meals glucose data. Initially, he researched the detailed postprandial plasma glucose (PPG) data resulting from both food intake and post-meal exercise via 97 solid egg meals (74 pan-fried and 23 hard broiled) and 74 liquid egg meals (egg drop soup). Based on his findings, he adopted a statistical method of "decision making via elimination" to search and verify a hypothetical neural communication model between the brain's cerebral cortex and internal organs, such as the stomach, intestines, liver, and pancreas.

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The significant PPG differences between these two food types can be easily observed, the solid egg meals curve is consistently higher than the liquid egg meals curve.

Let us list the results in the following short table in the format of "Peak / Average / Start / (Peak-Start) / Peak's time instant (minutes)":

Solid:	136/130/123/13/45min
Liquid:	120/117/114/6/45 min
Solid-Liquid:	16/16/6/7/0 min

From a neuroscientific point of view, the author has utilized his developed math-physical medicine methodology (MPM) and his learned biomedical knowledge ***to "trick" the cerebral cortex of the brain by instructing the liver to produce or release a "lesser" amount of PPG***, without altering or decreasing the needed food nutritional balance. If this idea works, by just changing the cooking method, it can then help many T2D patients to lower both their peak PPG and average PPG levels without reducing or changing their food nutritional contents. ***Their HbA1C could be reduced by 0.8% to 0.9% without any medication intervention or lifestyle change***. Of course, T2D patients must avoid overeating food with high carbohydrates and sugar contents at all times.

By sharing these findings with other medical research scientists, he hopes that they can provide some better explanations, more proof, or further justifications by using a different or traditional research methodology, such as the biochemical medicine (BCM) approach.

Introduction

In this paper, the author describes his 2+ years (801 days) research results, from 5/5/2018 through 7/14/2020, using his 171 special meals glucose data. Initially, he researched the detailed postprandial plasma glucose (PPG) data resulting from both food intake and post-meal exercise via 97 solid egg meals (74 pan-fried and 23 hard broiled) and 74 liquid egg meals (egg drop soup). Based on his findings, he adopted a statistical method of "decision making via elimination" to search and verify a hypothetical neural communication model between the brain's cerebral cortex and internal organs, such as the stomach, intestines, liver, and pancreas.

Method

In References 1 through 4, the author described his partial research notes from various experiments and research work between 9/25/2019 and 6/5/2020 regarding the same subject using multiple meals data of both egg drop soup, pan-fried egg, and other vegetables. By now, he has further collected a total of 171 experiments data, including 74 of egg liquid food (egg drop soup) and 97 egg solid food (74 pan-fried egg plus 23 hard broiled egg).

He collected his glucose data via a continuous glucose monitor (CGM) sensor device from 5/5/2018 through 7/14/2020 at ~80 glucose data per day. After the first bite of his meal, he measured his PPG data every 15 minutes for a period of three hours (180 minutes). In total, he collected data from 2,403 meals with 31,239 PPG.

He focused on the relationships between different food inputs, such as meal nutritional contents (mainly carbs/sugar amount), cooking methods, physical states, PPG outputs (both finger-piercing measured and CGM sensor collected), and complete PPG waveform behaviors (i.e. curves patterns). When he observed those different physical phenomenon of glucose waves between liquid food and solid food, he wondered why the two meals with varying cooking methods would yield two different PPG values

and waveforms with identical nutritional ingredients input (only 0.76 gram of carbs/sugar per meal which generates ~1.4 mg/dL of glucose). Many of his medical associates in the fields of internal medicine and food nutrition have mentioned to him that food nutritional components, particularly carbohydrates and sugar amount, and exercise influence PPG values. In addition, his own research has already identified 19 influential factors on PPG. It should be mentioned that in order to single out the impact from diet, he has kept the intensity and duration of his post-meal exercise at about the same level. Therefore, he can simplify his research efforts, particularly in the area of figuring out a suitable mathematical model.

After eliminating the factors of diet and exercise, their only missing influential factor is "what" decides the amount of glucose production and release. The author has a master's degree in biomechanics which is related to the muscles, tendons, and bones. On 2/11/2020, he remembered one of his previous neuroscientific and biomechanical experiment several years ago which involved the development of a customized semiconductor chip to detect the neuro-message (brain wave) being sent by the brain to the leg muscles. Therefore, he came up with a neural communication hypothesis between the brain and certain internal organs via our nervous system. He tried to verify this neural communication model which has a path of "sending message from stomach and small intestine to the brain and then forwarding a marching order by the brain to the liver and pancreas". Now, he wants to determine the PPG production level at different time instances by using a bigger size of his experimental database.

On 5/27/2020, there was an interesting article published on Pittsburgh Post-Gazette, which was written by David Templeton (Reference 5).

Here is an excerpt

Published May 18 in the Proceedings of the National Academy of Sciences, an important world first, a study co-authored by Dr. Levinthal and Dr. Peter Strick, both from the Pitt School of Medicine, University of Pittsburgh, has explained what parts of the brain's cerebral cortex influence stomach function and how it can impact health. Dr. Peter Strick is a world leader in establishing evidence that internal organs are strongly modulated at the highest levels by the cerebral cortex. It's been traditional in biology and medicine that the internal organs are self-regulatory through the autonomic nervous system, largely independent of higher brain regions. Dr. Strick's previous research, for instance, also showed that similar areas of the cerebral cortex also control kidney and adrenal function. That course of research now could extend to "the heart, liver and pancreas to discover more about how the brain coordinates control of internal organs," said Mr. Sterling who holds a Ph.D. in neuroscience. When it comes to trusting your gut, it already is well-established that the stomach and gut send "ascending" signals to the brain in a way that influences brain function. But the study has found that the "central nervous system both influences and is influenced by the gastrointestinal system." What people haven't understood to date, Dr. Strick said, is that the brain also has "descending influences on the stomach" with various parts of the brain involved in that signaling, including those areas that control movement and emotions. Those areas control the stomach "as directly as cortical control of movement. These are not trivial influences."

This article described exactly what the author, for almost a year, hypothesized about the neural communication model between the brain and other internal organs. By training, he is a mathematician, physicist, and engineer, but not a medical doctor or a neuroscientist; however, during the period of 9/15/2019 to 7/14/2020, he believes the ascending messages from the stomach and small intestine to the brain regarding food entry, food physical state, and nutrients absorption status allows a descending message from the brain to the liver and pancreas regarding glucose and insulin amount of production and release. At first, he observed, measured, and examined those biophysical phenomena and data extremely carefully, then utilized a few mathematical simulation models, and finally tried to verify these models by using his big data analytics.

Initially, he used certain selective words, such as *hypotheses*, *guess*, and *might be*, to describe his findings, but now he has found more academic support and medical proof from the research work conducted by other neuroscientists and brain experts (Reference 5).

In 2020, he published a few articles along this line of thought by using various food and glucose data. Thus, he will forgo some explanations and go directly into the same conclusion but based on a relatively "bigger" size of his experimental data.

Results

In this particular study, he focused on the following two specific meal categories which only involved eggs. The main difference between these two "egg alone" meals is the cooking method that ends with different physical "state" (look and feel) of cooked food.

From Figure 1, one large egg contains mainly proteins (6.3g), fat (5g), small amount of carbohydrates (0.38g), and sugar (0.38g).

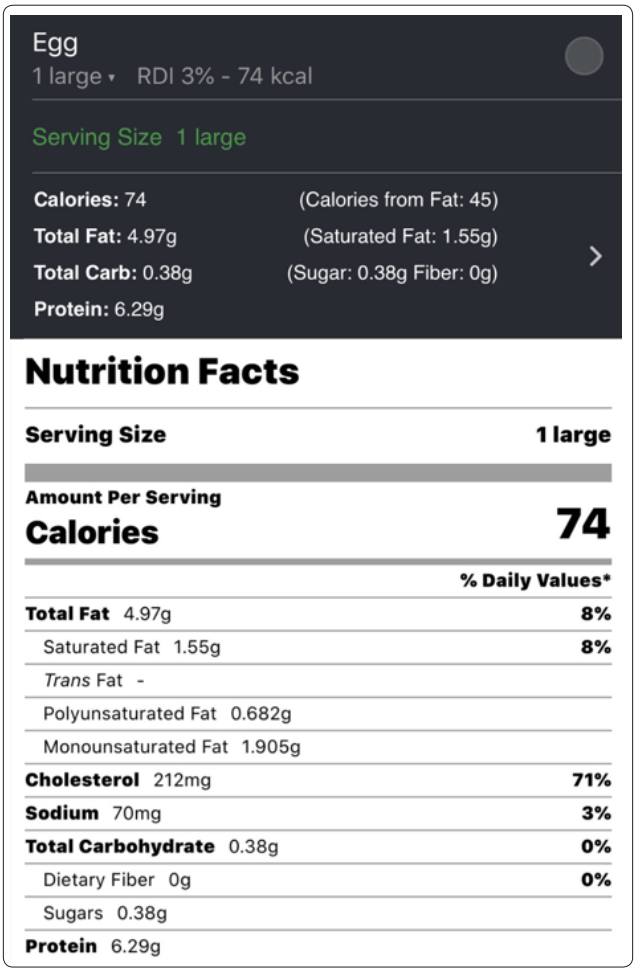

Figure 1: Nutrition ingredients of one large egg

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In his solid meals, he ate 74 pan-fried egg "solid shape" without any other food contents with significant carbs/sugar ingredients, such as small amount of olive oil with zero gram of carbs/sugar. This "solid state" of pan-fried eggs has an average carbs/sugar amount of 3.0 grams (sometime with a small amount of carbs coming from chopped spring onions). His average post-meal walking steps is 4,714. His average solid finger PPG is 112 mg/dL and solid sensor PPG is 132 mg/dL (18% higher than finger and 20 mg/dL of PPG difference). Recently, he has eaten 23 hard broiled egg "solid meals" without any other contents with carbs/sugar ingredients. This "solid state" of hard-broiled eggs has an average carbs/sugar amount of 2.2 grams. His average post-meal walking steps is 4,515. His average solid finger PPG is 111 mg/dL and solid sensor PPG is 124 mg/dL (12% higher than finger and 13 mg/dL of PPG difference). On the other hand, in his liquid meals, he ate 74 egg drop soup meals (pouring mixed eggs into boiling hot water to slowly make thin layers of egg "clouds or sheets" in the soup). This "liquid state" of egg drop soup has the exact same type and amount of nutritional ingredients as the "solid state" egg meals, which contains only protein and fat without any significant carbs/sugar. This "liquid state" egg drop soup has an average carbs/sugar amount of 2.2 grams, same as hard broiled egg. His average post-meal walking steps is 4,341. His average liquid finger PPG is 108 mg/dL and liquid sensor PPG is 117 mg/dL (8% higher than finger and 9 mg/dL of PPG difference). The sample photos of these three kinds of meals are in Figure 2 and their data are shown in Figure 3.

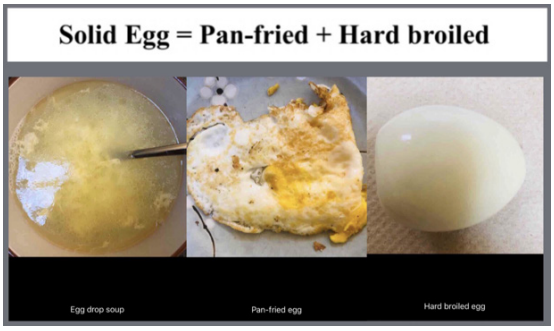

Figure 2: Three different egg meals

Average Sensor PPG	117	132	124
Post-meal Walking	4341	4714	4515
Carbs/Sugar (grams)	2.2	3.0	2.2
Finger PPG (mg/dL)	108	113	111
No. of meals	74	74	23
Sensor PPG (mg/dL)	Egg drop soup	Pan-fried egg	Hard broiled egg

Average Sensor PPG	117	130
Post-meal Walking	4341	4667
Carbs/Sugar (grams)	2.2	2.8
Finger PPG (mg/dL)	108	113
No. of meals	74	97
Sensor PPG (mg/dL)	Liquid Egg	Solid egg
0 min	114	123
15 min	116	126
30 mim	118	131
45 min	120	136
60 min	118	136
75 min	116	135
90 min	115	133
105 min	116	131
120 min	116	128
135 min	117	127
150 min	118	127
165 min	120	129
180 min	122	129

Figure 3: Two data tables of PPG comparisons of three meals (top) and two meals (bottom)

It should be noted that his personal target of post-meal walking is 4,000 steps. His post-meal exercise amounts for these two food categories are almost equal, 4,341 steps for liquid meals and 4,667 steps for solid meals. This additional 326 walking steps difference would decrease the solid egg's PPG by ~1.5 mg/dL. In other words, if their post-meal walking steps are identical, the PPG values of the solid egg should be adding 1.5 mg/dL on them. Therefore, the author can only focus on the influence from food. In this particular study, since food nutritional ingredients are almost identical, with a very small difference of 0.6 grams of carbs/sugar (liquid 2.2 grams and solid 2.8 grams) which would create ~1.1 mg/dL on solid food. By combining these two incremental PPG differences from both carbs/sugar and post-meal walking, the net impact on PPG is only a negligible 0.4 mg/dL.

It is important to examine the food and nutrient absorption and its role in the digestive system. Some carbohydrates will be absorbed in the mouth, while chewing the food and broken down by enzymes. Enzymes in the stomach further break down the food; however, most food absorption takes place in the small intestine where chyme, a thick semifluid mass of partially digested food and digestive secretions, is formed in the stomach and intestine during digestion. This process normally takes about 6 to 8 hours for food to pass through the stomach and small intestine, and to enter the large intestine, where it becomes fully digested. In term of the direct connection between food digestion and glucose generation or release, it is not so obvious by analyzing the collected sensor PPG waveform (Figure 5).

Figure 3 depicts the detailed data table of PPG waveform comparison between these 74 liquid egg meals and 97 solid egg meals. The data table results are shown in Figure 5 in a line chart. It illustrates the PPG differences between liquid and solid at every 15-minute interval. Figure 4 is the most important diagram in this article. ***The significant PPG differences between these two food types can be easily observed, where the solid meals curve is consistently higher than the liquid meals curve***.

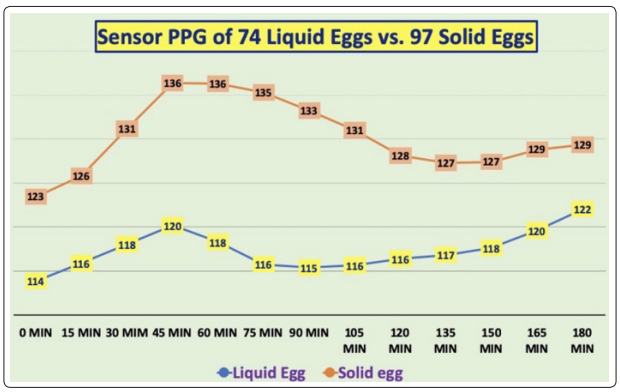

Figure 4: Comparison of PPG waveforms between 74 liquid egg meals and 97 solid egg meals

The first question is "what" kind of differences do they have? They are listed in the following short table in the format of Peak / Average / Start / (Peak-Start) / Peak's time instant (minutes):

Solid: 136/130/123/13/45min
Liquid: 120/114/117/6/45 min
Solid-Liquid: 16/16/6/7/0 min

Although the peak and average PPG of solid are 16 mg/dL higher than liquid, their peaks occur around 45 minutes. This same peak time instant rules out the influence from the chyme's different

absorption rate between liquid food versus solid food in the small intestine.

The second question is "why" do they look so different? Both food items have the same nutritional ingredient inputs; however, their different cooking methods resulting into differing physical states, liquid or solid. **Perhaps** the message (or signal) ascending from the stomach or small intestine to the cerebral cortex is not food ingredients and absorption speed, but rather the food's arrival and food's physical state. Therefore, the brain misinterprets soup as an equivalent to a cup of decaffeinated coffee or water. As a result, the brain issues a descending message to the liver and pancreas for releasing a lesser amount of glucose and insulin, respectively.

Delving deeper into the waveforms in Figure 5, the first biophysical evidence is that the stomach takes about 15 to 30 minutes to inform the solid food entry message to the brain, and during the first 15 to 45 minutes, the PPG curve's climbing speed is extremely high for solid food in comparison with liquid food. Obviously, the liquid curve is relatively flat. The second evidence is that, for both liquid and solid foods, it takes about 45 minutes for the production and release of glucose amount to reach to their peaks.

Perhaps in other types of food, the difference in PPG readings may also be affected by the absorption rates of chyme consisting of gastric juices and some leftover food. Chyme from a solid meal is relatively dense and may take more time passing through the absorptive surface area of the small intestine, while chyme from a liquid meal is mostly liquid and may pass through the absorptive surface more quickly. Therefore, the absorption speed of chyme may indeed affect the timing of peak PPG for some different foods. For this 171 egg meals experiment, the author found their peak glucose time instances are identical at 45 minutes after the first bite of food; however, their peak PPG values and PPG rising speed, i.e. peak PPG minus starting PPG values have some moderate and observable differences. This particular phenomenon cannot be explained clearly by either food nutrition or biomedical nutrient absorption rate.

It should be pointed out that these waveform differences do not seem too big because of the data collected are from the recent 2+ years period of 5/5/2018 to 7/14/2020, his especially healthy period. During this time frame, his diabetes conditions were already under control without taking any medication. This means that these results are strictly the internal biological outcomes by his stringent lifestyle management program and without any external medication's chemical intervention.

The most significant difference between the liquid egg meals and solid egg meals is the physical state of the cooked food which resulted from two completely different cooking methods. Therefore, the author decided to focus on his cooking methods and their associated ending "physical states" i.e. liquid versus solid. When the author could not locate a satisfactory explanation from viewpoints of either food nutrition or clinical internal medicine, he started to delve deeper into the source of this problem and created his hypothesis that "the production and release of glucose is controlled by the liver but this particular liver function is further controlled by the brain".

This hypothesis supports the author's thoughts on how the neural communication model exists among the cerebral cortex of the brain, stomach, intestines, liver, and pancreas regarding PPG production and release.

Conclusions

From a neuroscientific point of view, the author has utilized his developed MPM and his learned biomedical knowledge ***to "trick" the cerebral cortex of the brain by instructing the liver to produce or release a "lesser" amount of PPG***, without altering or decreasing the needed food nutritional balance. If this idea works, by just changing the cooking method, it can then help many T2D patients to lower both their peak PPG and average PPG levels without reducing or changing their food nutritional contents. ***Their HbA1C could be reduced by 0.8% to 0.9% without any medication intervention or lifestyle change***. Of course, T2D patients must avoid overeating food with high carbohydrates and sugar contents at all times [1-5].

By sharing these findings with other medical research scientists, he hopes that they can provide some better explanations, more proof, or further justifications by using a different or traditional research methodology, such as the biochemical medicine (BCM) approach.

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