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A postprandial plasma glucose (PPG) comparison study between pre-COVID-19 and during COVID-19 using GH-Method: math-physical medicine (No. 317)

Gerald C Hsu

eclaireMD Foundation, USA

*Corresponding author
Gerald C Hsu, eclaireMD Foundation, USA

Abstract
The author utilizes quantitative analysis results based on diabetes control for two periods: the pre-COVID-19 period, from 5/5/2018 to 1/18/2020, and the COVID-19 period, from 1/19/2020 to 8/24/2020, within a duration of 2.3 years. Special attention has been placed on his specific lifestyle management during the COVID-19 quarantine period from 1/19/2020 to 8/24/2020.

The COVID-19 period has a lower average Finger PPG (-6 mg/dL) along with a lower sensor PPG (-12 mg/dL). By comparing these two periods, the two glucose waveforms are similar in shape (with high correlation coefficient) and the differences between these two curves at each time instant are quite close to each other (about 12 mg/dL glucose difference). As a result, during this period, the author achieved 0.3% to 0.4% lower HbA1C value.

COVID-19 is more than 100x worse compared to the fatal respiratory illness known as severe acute respiratory syndrome or SARS that occurred in 2003, in regard to its spreading speed, fatality number, and emotional impact on the world population. People belonging to the "vulnerable" groups, such as the elderly with existing chronic diseases and history of complications require special consideration to their health conditions and lifestyle management during the COVID-19 period.

However, during this period, the author collected better results with his diabetes control in terms of both PPG and HbA1C values. The knowledge and experience he acquired in the past 10 years of medical research and his developed mathematical metabolism index model along with four diabetes prediction tools assisted him in many ways. As a result, he achieved a reduction of -6 mg/dL for finger PPG, -12 mg/dL for sensor PPG, -13 mg/dL for K-line PPG, and -0.3% to -0.4% for HbA1C. In fact, he turned the COVID-19 crisis into his health advantage!

Introduction

The author utilizes quantitative analysis results based on diabetes control for two periods: the pre-COVID-19 period, from 5/5/2018 to 1/18/2020, and the COVID-19 period, from 1/19/2020 to 8/24/2020, within a duration of 2.3 years. Special attention has been placed on his specific lifestyle management during the COVID-19 quarantine period from 1/19/2020 to 8/24/2020.

Methods
Background
To learn more about the GH-Method: math-physical medicine (MPM) methodology, readers can review the article to understand his MPM analysis method in Reference 1, along with the outlined history of his personalized diabetes research and application tools development in Reference 2.

During 2015 and 2016, he dedicated his time to research four

prediction models related to his diabetes measurement conditions such as weight, postprandial plasma glucose (PPG), fasting plasma glucose (FPG), and HbA1C (A1C). As a result, from using his own developed metabolism model and 4 prediction tools, by the end of 2016, his weight reduced from 220 lbs. (100 kg) to 176 lbs. (89 kg), waistline from 44 inches (112 cm) to 33 inches (84 cm), average finger glucose value from 280 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 medications since 12/8/2015.

Around 1850, a Japanese merchant, who traded in the rice market in Osaka, Japan, started the "candlestick charting". An American, Steve Nison brought the candlestick concept to the Western world in 1991. These techniques are currently used in the stock market by financial analysts to predict the trend of stock prices and/or aid with the required action for the investment.

On 4/17/2018, the author had an idea to study glucose behavior by using the candlestick chart as known as the "K-Line" and subsequently developed a customized software to analyze his big glucose data. These candlesticks not only provide 5 key characters of each daily glucoses but also reveal the average values and trends over a period of time when combined with the time-series analysis (References 6 and 7).

During 2018 and 2019, the author traveled to 50+ international cities to attend 60+ medical conferences and made ~120 oral presentations. This hectic schedule inflicted damage to his diabetes control, through dinning out along with exercise disruption, and on the overall metabolism status due to irregular life routines through traveling.

COVID-19
The author eluded the 2003 SARS in China and Taiwan. In early January 2020, when the rumors of a strange "Wuhan pneumonia" suddenly appeared on certain Asian news networks, he immediately recognized the danger associated with this newly found virus. The spread of this disease depends mainly on the physical contact among people. Therefore, he launched his "self-quarantine" in the United States on 1/19/2020, much earlier than the majority of Europeans and Americans who became aware of its potential damage and severity. As of today, 8/24/2020, he has been self-quarantined for 7+ months or 218 days. The timeframe of regular life pattern with home cooked meals and persistent walking exercise made his conditions on diabetes control (from his glucose results) reach to its "best" status for the past 25 years.

Data Collection
Since 1/1/2012, the author measured his glucose values using the finger-piercing method: once for FPG and three times for PPG each day. On 5/5/2018, he applied a continuous glucose monitoring (CGM) sensor device on his upper arm and checked his glucose measurements every 15 minutes, a total of ~80 times each day. After the first bite of his meal, he assessed his PPG level every 15 minutes for a total of 3-hours or 180 minutes. He maintained the same measurement pattern from 5/5/2018 until present day.

Epidemic Information
COVID-19 is a disease caused by SARS-CoV-2 virus which uses ACE-2 for cell entry (Reference 3). The current thought is that the disease is spread through respiratory droplets, though the transmission is still under investigation. Also, the virus has been found in blood and stool. In Figure 1, it shows that COVID-19 is a spectrum of diseases. Approximately 80% of confirmed cases are uncomplicated SARS-CoV-2 infection that may lead to mild pneumonia. About 15% would lead into severe pneumonia, with the remaining 5% ending up as acute respiratory distress syndrome (ARDS).
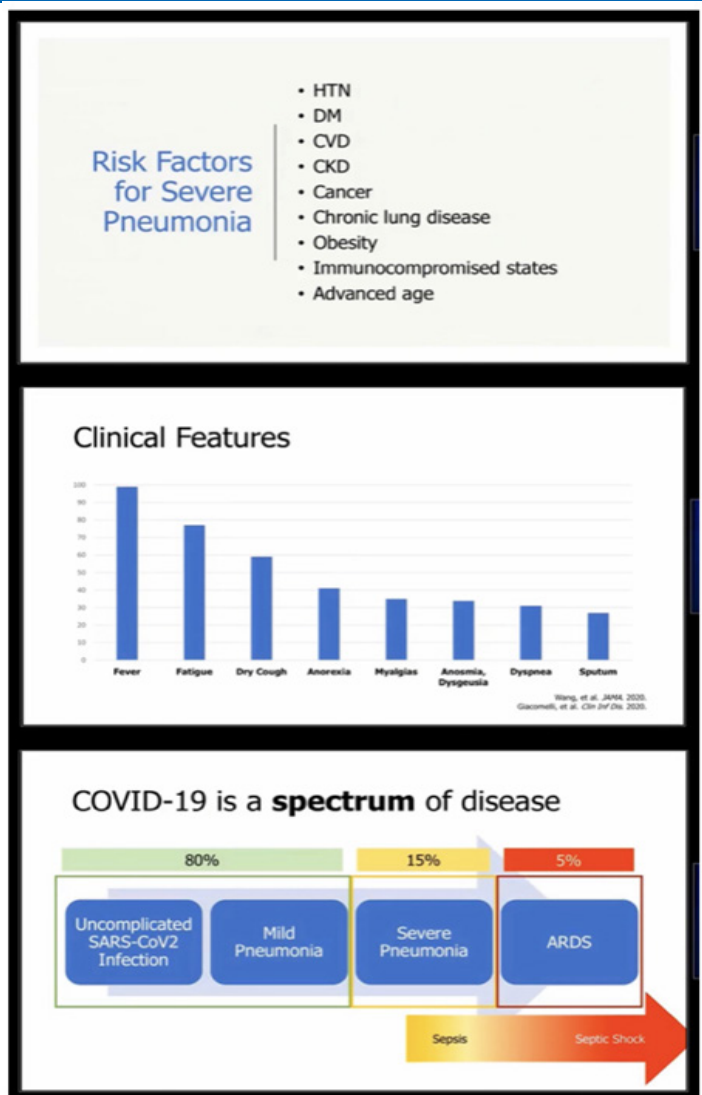

Figure 1: COVID-19 information (Reference 3)

In Figure 2, it depicts confirmed cases and number of deaths in the USA since its inception until now, 8/24/2020. This figure contains both curves in real case number and percentages. The confirmed percentage is defined as confirmed cases divided by total population of USA, while the death percentage is defined as death number divided by total confirmed cases. It is obviously that, COVID-19 is still not under control in the US; therefore, the author is mentally prepared that he will continue the existing self-quarantined life until the end of 2020 or perhaps even longer.
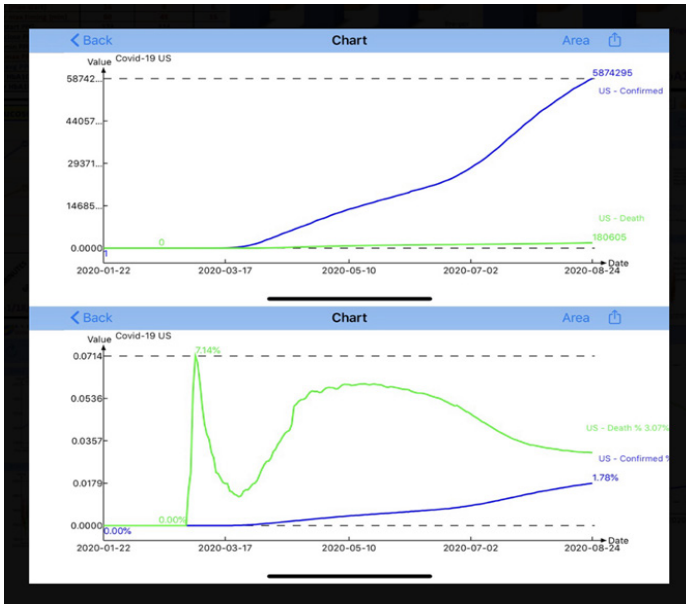
Figure 2: COVID-19 history and status in USA (7/4/2020)

Chronic Diseases and Health

As indicated in the "Linkage among metabolism, immune system, and various diseases using GH-Method: math-physical medicine (MPM)", the most effective defensive protection against COVID-19 is our *immune system* (Reference 4). The immune system is closely related to the overall *metabolic* conditions. We can safely say that metabolism and immunity are two sides of one coin. In order to strengthen our overall metabolism, we must manage our daily *lifestyle* to build up a strong and firm foundation over a long period of time (Figure 3).
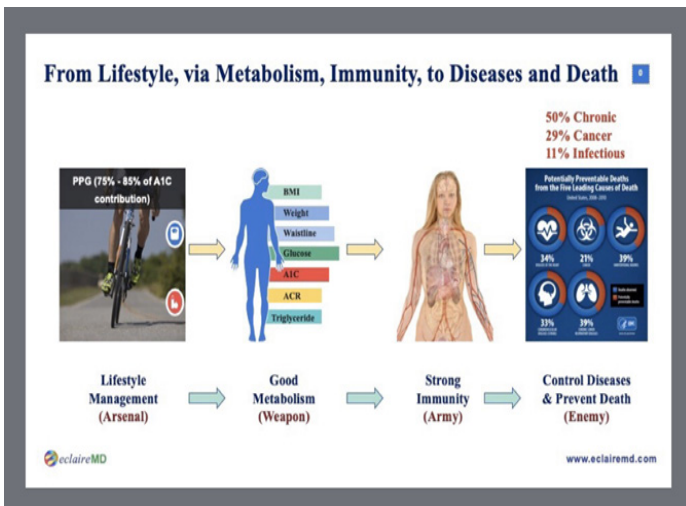

Figure 3: Relationships among Lifestyle, Metabolism, Immunity, and Diseases

In short, lifestyle is similar to the product quality and production capacity of an arsenal based on the overall educational, technological, and industrial power, whereas metabolism is similar to the effectiveness and destruction power of the weapons available to soldiers which are produced by an arsenal. Immunity is similar to the overall military strength of the armed defense force (assembly of soldiers with weapons), while diseases (chronic, cancer, and infections) are similar to an enemy's invasion force. Lastly, the study of death is similar to the investigation of outcomes of a war, which is the probability and rate of death.

Results

In Figure 4, it shows the background data table of glucose comparison between the periods of pre-COVID-19 (5/5/2018 - 1/18/2018, 623 days with 1,934 meals) and COVID-19 (1/19/2020 - 8/24/2020, 218 days with 657 meals). This data table contains PPG data and HbA1C values. The PPG data group contains three datasets, finger-piercing tested PPG, CGM sensor measured PPG, and candlestick K-line converted PPG.

	5/5/18-1/18/20	1/19/20-8/24/20	
	Pre-period	During-period	Difference
Days	623	218	
Meals	1869	654	
Meals & Snacks	1934	657	
Finger PPG	116	110	6
Carbs/Sgar (g)	14.6	12.2	
Post-meal Walking (steps)	4284	4290	
Sensor start PPG	129	123	
Sensor close PPG	131	120	
Sensor min PPG	129	119	
Sensor max PPG	145	132	13
Sensor avg PPG	136	124	12
Sensor (max-start)	16	9	6
Sensor max timing (min)	60	45	15
K-line start PPG	123	114	
K-line close PPG	131	120	
K-line min PPG	108	103	
K-line max PPG	175	155	20
K-line avg PPG	137	124	13
Finger HbA1C	6.7	6.4	0.3
Sensor HbA1C	6.8	6.4	0.4

Figure 4: Summary data table

It is obvious that the COVID-19 period has a lower average Finger PPG value (-6 mg/dL) and also a lower sensor PPG value (-12 mg/dL).

The sensor waveforms and K-line diagrams are illustrated for pre-COVID-19 and COVID-19, respectively (Figures 5 and 6).
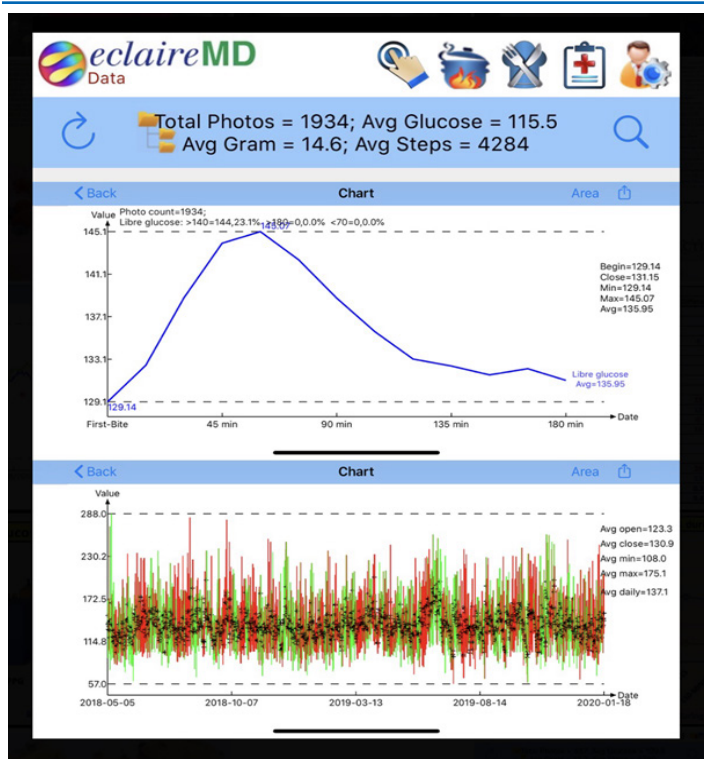
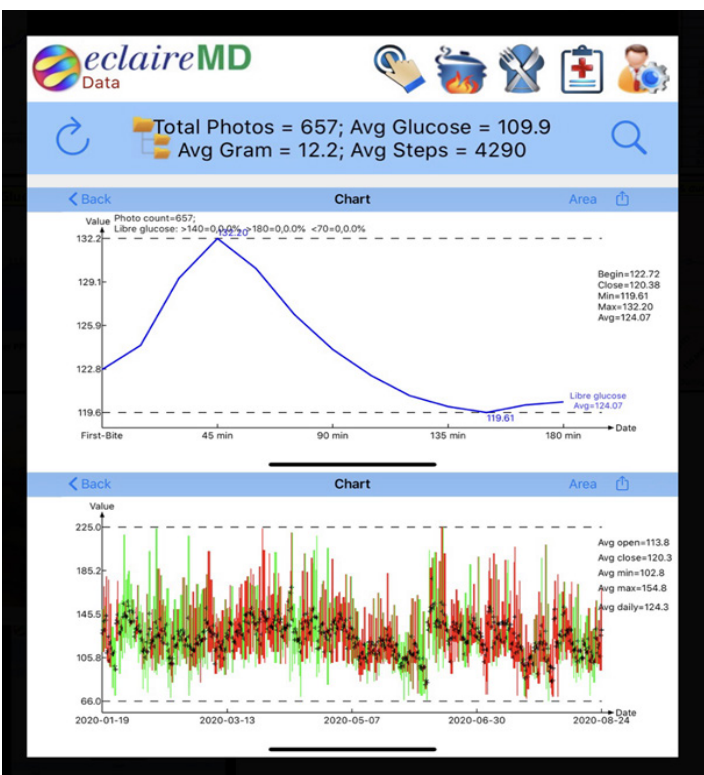**Figure 5:** PPG waveform and K-line glucoses (5/5/2018 - 1/18/2020)

Figure 6: PPG waveform and K-line glucoses (1/19/2020 -

8/24/2020)

The direct comparison between two synthesized curves with the average total of PPG curves at each time instant are depicted for pre-COVID-19 and COVID-19 (Figure 7).
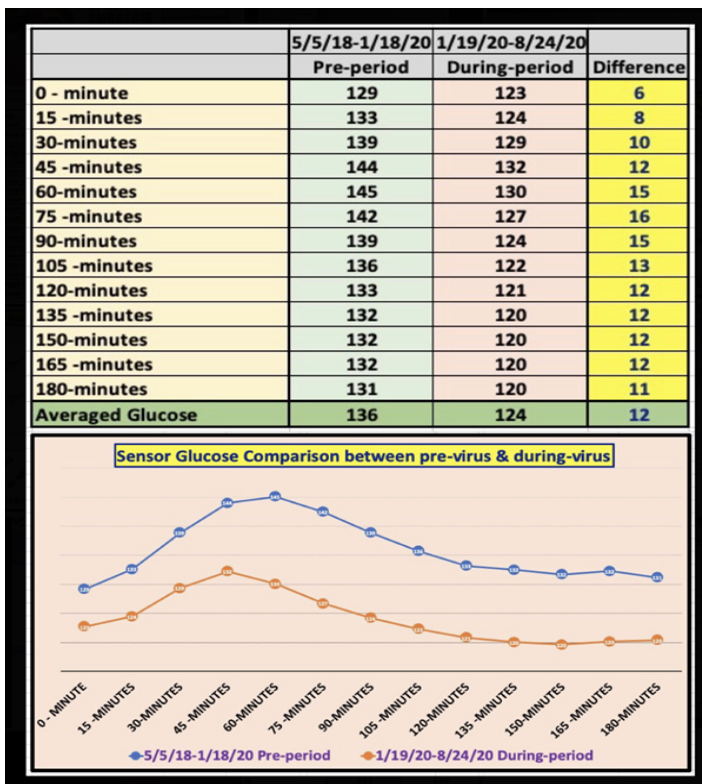
	5/5/18-1/18/20	1/19/20-8/24/20	
	Pre-period	**During-period**	**Difference**
0 - minute	129	123	6
15 -minutes	133	124	8
30-minutes	139	129	10
45 -minutes	144	132	12
60-minutes	145	130	15
75-minutes	142	127	16
90-minutes	139	124	15
105 -minutes	136	122	13
120-minutes	133	121	12
135 -minutes	132	120	12
150-minutes	132	120	12
165-minutes	132	120	12
180-minutes	131	120	11
Averaged Glucose	136	124	12

Figure 7: Comparison of PPG waveforms between two periods

It is evident that two glucose waveforms are similar in shape, with an extremely high correlation coefficient, along with the differences between these two curves at each time instant are quite close to each other about 12 mg/dL glucose difference.

The following list depicts several actual values from these two periods in the order of finger PPG value, sensor average PPG, carbs/sugar amount in grams, and post-meal walking steps:

Pre-COVID-19 Period (5/5/2018 - 1/18/2020):
116 mg/dL, 136 mg/dL, 14.6 grams, 4,284 steps

COVID-19 Period (1/19/202 - 8/24/2020):
110 mg/dL, 124 mg/dL, 12.2 grams, 4,290 steps

Here are some key findings regarding influential factors of glucose related to the author's lifestyle management during COVID-19 period:

1. Carbs/sugar amount: The difference of 2.4 grams would

contribute about 4 to 5 mg/dL glucose difference. This is mainly due to his home cooked meals without dining out during this timeframe. He also maintained high-quality protein with nutritional balanced diet.

2. Exercise: This factor can be ignored since he sustained an almost equal level of post-meal walking steps during these two periods (4,284 steps for pre-COVID-19 vs. 4,290 steps for COVID-19).
3. Weather temperature: This factor can also be disregarded since both periods cover colder temperature in winter and warmer temperature in summer.
4. No travel and jet lag during this timeframe.
5. Stress-free life during this timeframe by focusing on his medical research work and avoiding the disturbance from news associated with current politics and COVID-19 developments.
6. Sleep: He has maintained 7 to 8 hours of good quality sleep every night.

These 6 lifestyle details from above have kept his PPG within a healthy level without the involvement of medications.

In Figure 8, it shows his mathematically predicted HbA1C values for finger glucose based and sensor glucose based during these two periods. The pre-COVID-19 has HbA1C values of 6.7% to 6.8% and COVID-19 has HbA1C value of 6.4%. Therefore, the HbA1C difference between the two periods is 0.3% to 0.4% (Reference 8).
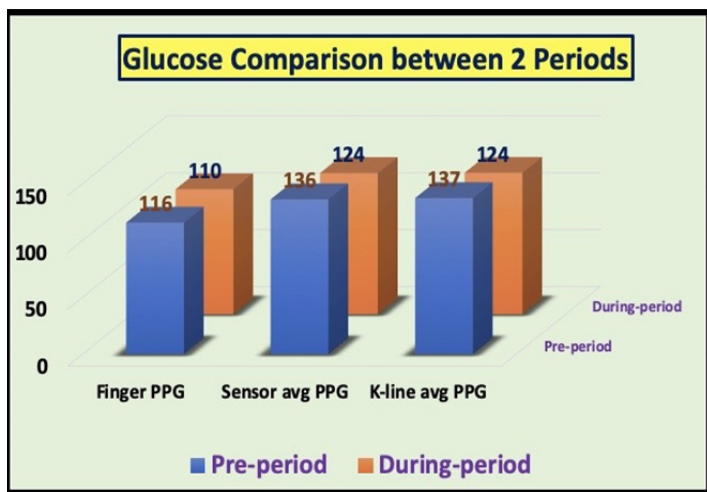

Figure 8: Bar chart of 3 PPG (finger, sensor, and K-line)

Conclusions
COVID-19 is more than 100x worse compared to the fatal respiratory illness known as severe acute respiratory syndrome or SARS that occurred in 2003, in regard to its spreading speed, fatality number, and emotional impact on the world population. People belonging to the "vulnerable" groups, such as the elderly with existing chronic diseases and history of complications require special consideration to their health conditions and lifestyle management during the COVID-19 period.
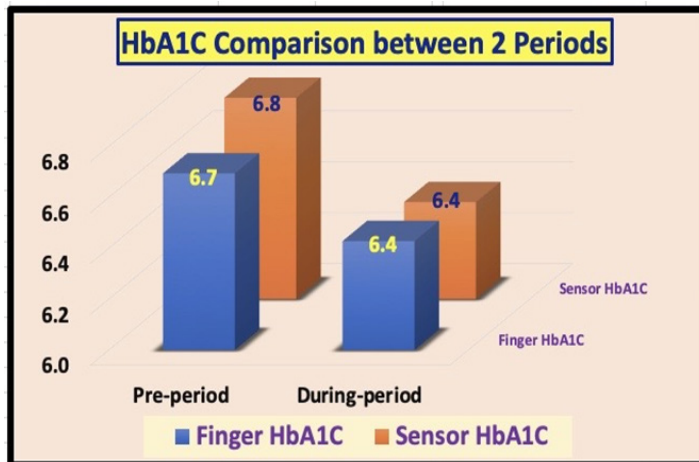

Figure 9: Comparison of two periods' mathematically predicted HbA1C values from both finger based and sensor based

However, during this period, the author collected better results with his diabetes control in terms of both PPG and HbA1C values. The knowledge and experience he acquired in the past 10 years of medical research and his developed mathematical metabolism index model along with four diabetes prediction tools assisted him in many ways. As a result, he achieved a reduction of -6 mg/dL for finger PPG, -12 mg/dL for sensor PPG, -13 mg/dL for K-line PPG, and -0.3% to -0.4% for HbA1C. In fact, he turned the COVID-19 crisis into his health advantage!

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