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Research Article

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Characteristic Pattern Study of the Glucose Waveforms using GH-Method: Math-Physical Medicine (No. 276)

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Introduction

This paper describes the research results of the waveform characteristic patterns of daily finger and sensor glucoses, postprandial plasma glucoses (PPG), and fasting plasma glucoses (FPG) over a period of 2+ years.

Methods

Since 1/1/2012, the author has 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) device on his upper arm and checked his sensor glucoses at 76.89 times each day and, by 2/19/2020, measurements were taken every 15-minute interval. He has maintained these dual glucose testing methods for 770 days from 5/5/2018 to 6/13/2020. Currently, he uses this database to conduct in-depth research on certain glucose characteristic patterns. In total, he has already collected 62,285 glucose data to be utilized for this particular study.

He applies both time-series analysis, X or Y versus time, which is similar to EKG charts, along with spatial analysis in a two-dimensional X and Y space, without "time" factor, to analyze his collected big glucose data.

In time-series analysis, when the correlation coefficient ("R") is greater than 50% (strong), then it is considered as "highly correlated". When R is between 30% and 50%, it is deemed "somewhat correlated". When R is less than 30% (weak), then it is considered as "non-correlated". It should be noted that the correlation coefficient can only be calculated for two sets of data. By using time-series analysis, the author presents his results in both daily discrete data chart and 90-days moving average data chart. The reason for including the 90-days moving average data is based on the general understanding that the HbA1C value is an average glucose for the past 90 days. Please note that these two correlation coefficients are slightly different between the daily discrete data and 90-days moving average data. This is due to the minor differences existing between collected glucose data and calculated moving average data.

In spatial analysis, if the "data cloud" is concentrated within a long and narrow band (similar to the shape of a cucumber or a football) and skewed with an angle where the slope is greater than zero, which means the *existence of correlation*, then these two sets of data are correlated. On the other hand, if the angle of the plotted data cloud is either flat or vertical, then they have an exceptionally low value of R and considered as non-correlated.

Regarding the work process of identifying correlation from spatial analysis, he first must identify the *data ranges*, which are the minimum and maximum of both X dimension and Y dimension. He then applies a visual estimation and trial-and-error process to figure out the best-fitted "slope" of a skewed "data cloud". This approach is much simpler and faster than derivation of an equation since he only needs an approximate guess from the diagram. The last step is to establish two skewed boxes as shown in his spatial analysis diagrams. The orange box indicates that data within +/- 10 % of the skewed green line of slope in the center, while the yellow box indicates that data within +/- 20 % of the center green line of slope. Each box has its different area percentage of total data contained in the colored box.

Another purpose of this study is to demonstrate the effectiveness of these two statistical tools, time-series analysis and spatial analysis, on conducting certain type of medical research work.

Results

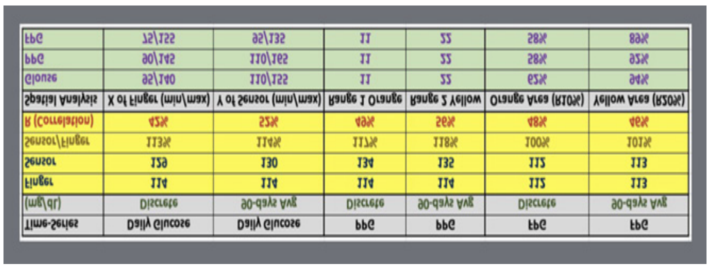
Figure 1 shows the summarized time-series analysis and spatial analysis for all three glucoses of both discrete and 90-days moving average values, including daily glucose, PPG, and FPG. Figures 2, 3, 4 are 3 respective diagrams of daily glucose, PPG, and FPG. Figure 5, 6, 7 are 3 detailed processed data of spatial analysis of daily glucose, PPG, and FPG. Figure 8 places three spatial analysis data cloud together. Figure 9 shows details of PPG waveforms which include 0-minute, 60-minutes, 90-minutes, 105-minutes, 120-minutes, 180-minutes, average and peak PPG values.

Significant Conclusions from Figure 1 Through 9 Are Listed:

1. Sensor glucose is 13%-14% higher than finger glucose, sensor PPG is 17%-18% higher than finger PPG, both sensor FPG and finger FPG are almost identical.
2. From time-series analysis results, these three glucose sets,

daily glucose, PPG, and FPG, have six correlation coefficients which are between 42% and 56%. This means that they are correlated, but not strongly correlated. His belief is that both testing methods, including finger piercing and CGM sensor, have their different product reliability issues. At times, the margin of error could reach to 25% or higher. He has written a few articles regarding this concern.

3. The three spatial analysis diagrams in Figure 8 show that all of these three data clouds are skewed with some angles. This means that the finger data and sensor data are correlated.
4. These eight curves in Figure 9 demonstrate a high similarity existing among these eight waveform patterns. This is an interesting finding because the entire 180-minutes PPG waveform pattern has been already determined and even somewhat fixed when we eat certain amount of carbs/sugar, maintain a specific exercise level, and meet specified secondary requirements.



Time-Series	Daily Glucose	Daily Glucose	PPG	PPG	FPG	FPG
(mg/dl)	Discrete	90-days Avg	Discrete	90-days Avg	Discrete	90-days Avg
Finger	114	114	114	114	112	113
Sensor	129	130	134	135	112	113
Sensor/Finger	113%	114%	117%	118%	100%	101%
R (Correlation)	42%	52%	49%	56%	48%	46%
Spatial Analysis	X of Finger (min/max)	Y of Sensor (min/max)	Range 1 Orange	Range 2 Yellow	Orange Area (R10%)	Yellow Area (R20%)
Glucose	95/140	110/155	11	22	62%	94%
PPG	90/145	110/165	11	22	58%	92%
FPG	75/155	95/135	11	22	58%	89%

Figure 1: Summarized data table

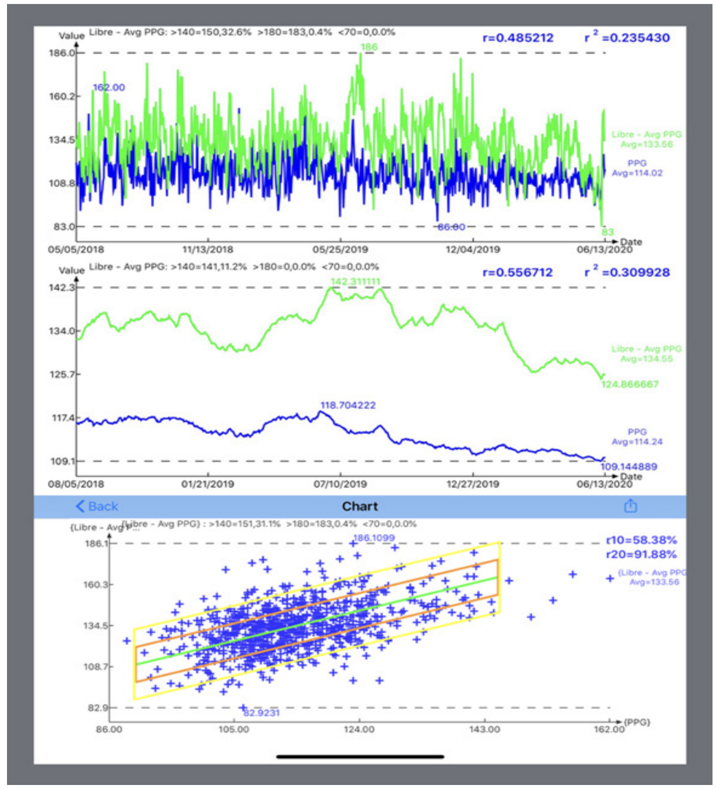


Figure 3: Time-series and spatial analysis results of PPG]

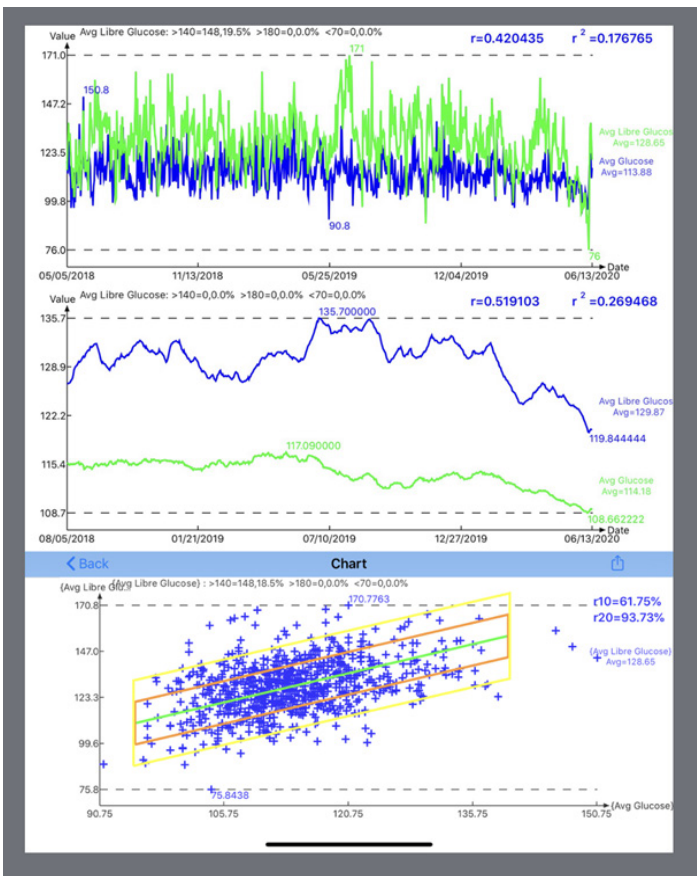


Figure 2: Time-series and spatial analysis results of daily glucose

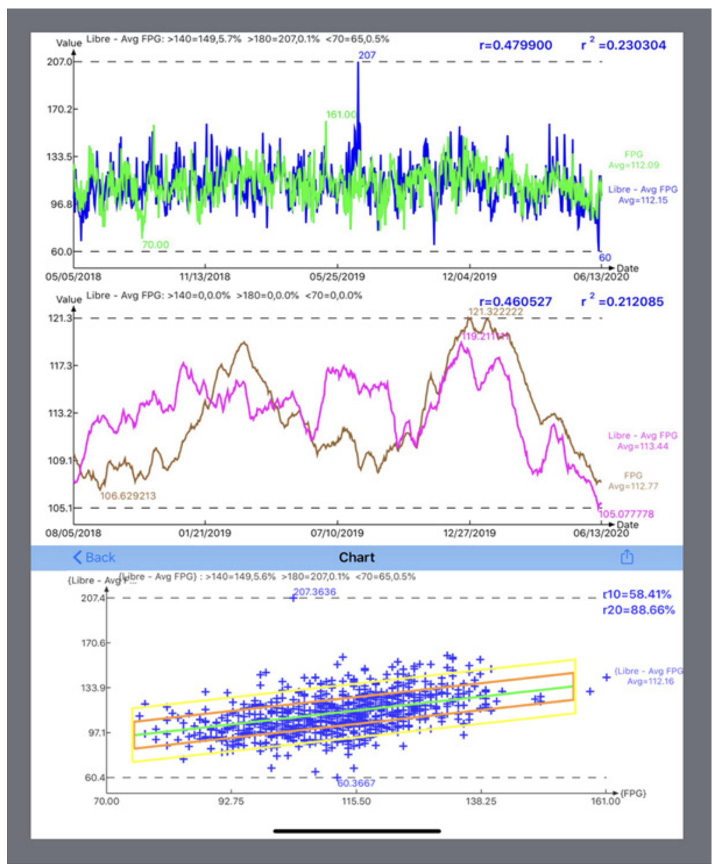


Figure 4: Time-series and spatial analysis results of FPG

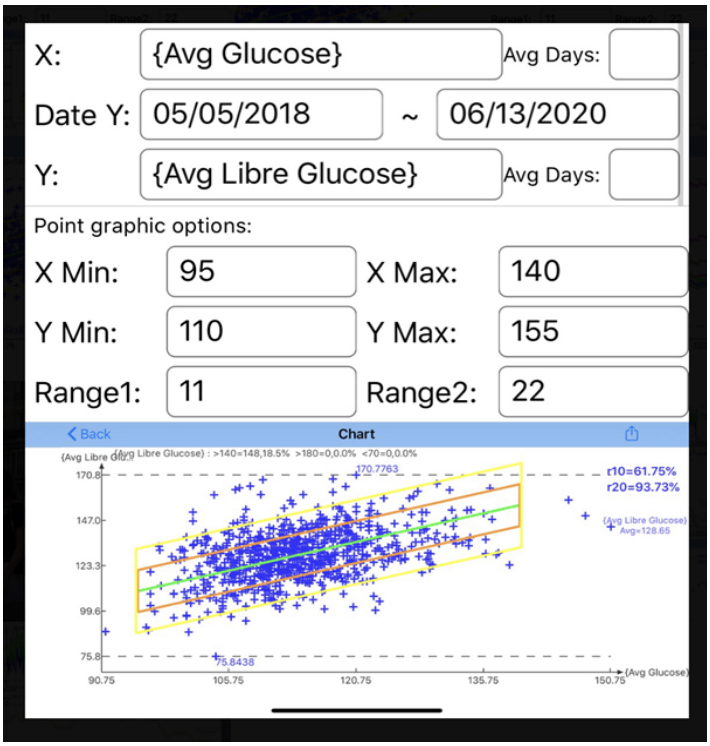


Figure 5: Spatial analysis detailed data of daily glucose

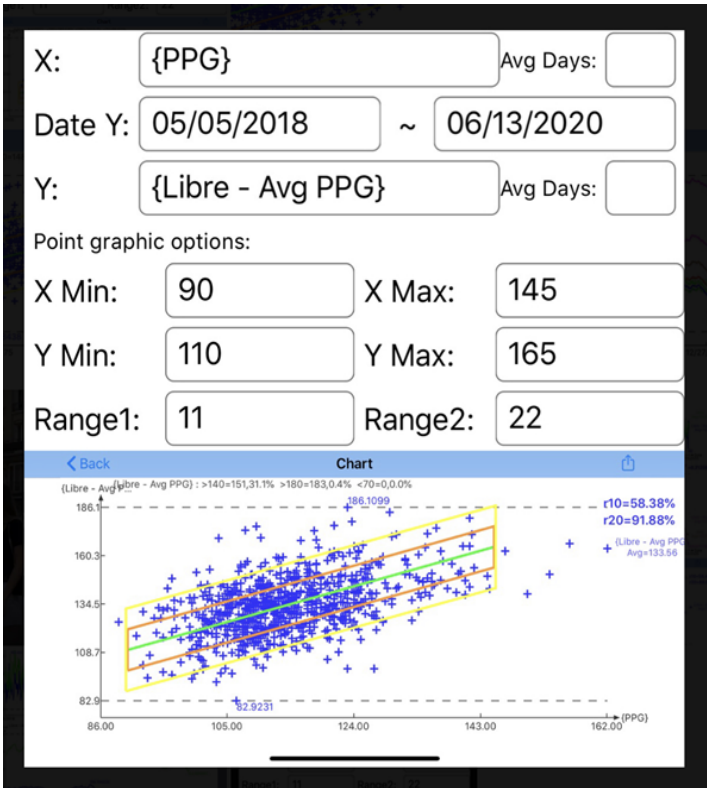


Figure 6: Spatial analysis detailed data of daily PPG

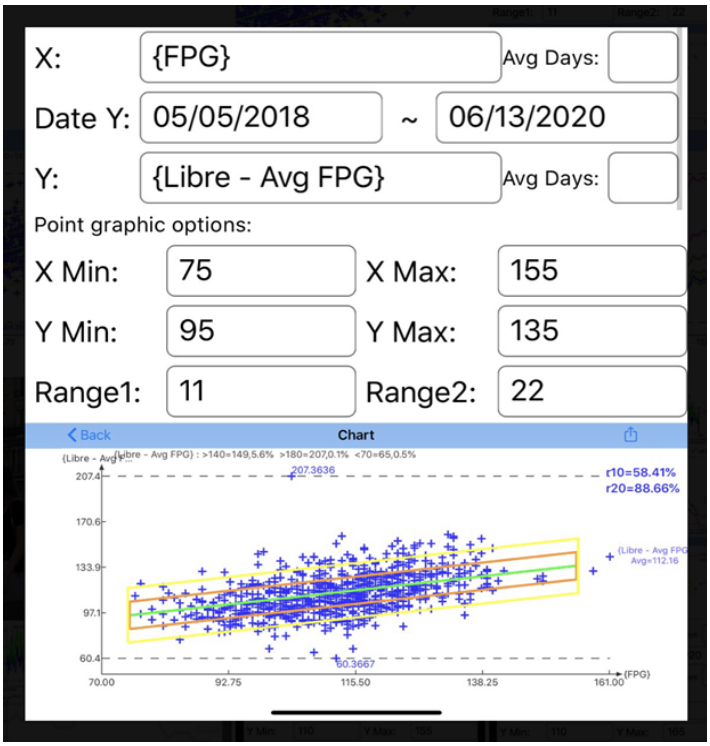


Figure 7: Spatial analysis detailed data of daily FPG

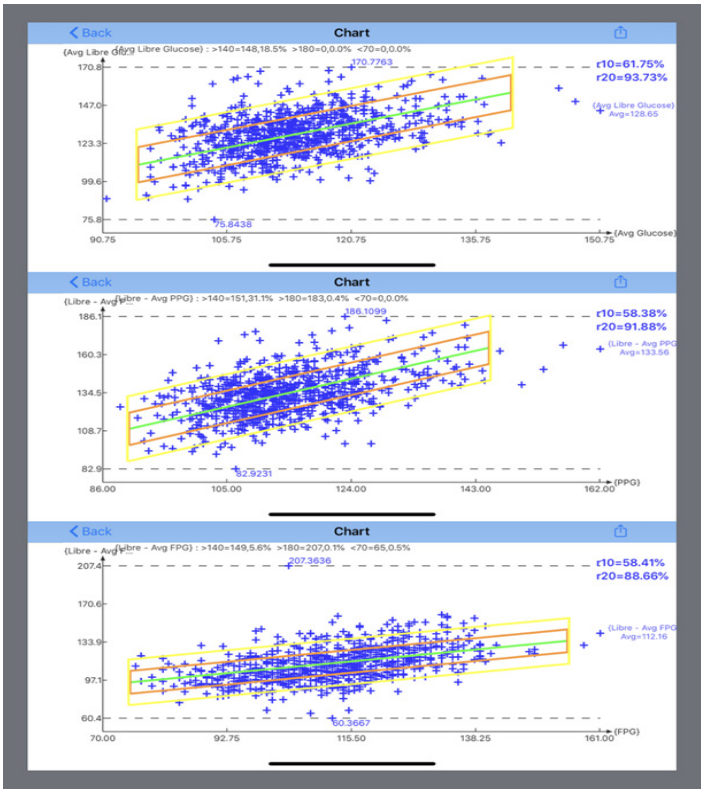


Figure 8: Spatial analysis results comparison of three glucoses

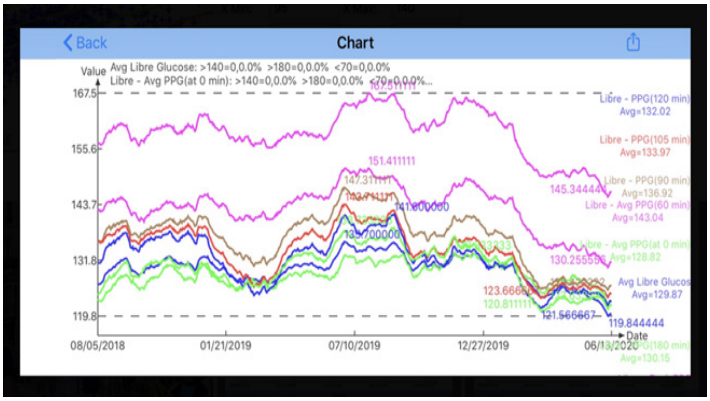


Figure 9: 8 time-series PPG curves

Conclusion

Regardless of the reliability issues from the glucose testing devices, the test results of glucoses from either finger-piercing or sensor collection would indicate a reasonable high correlation. This statement has been proven by the author using his >62,000 glucose data and two reliable statistical tools [1-6].

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