Research Article

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Journal of Diabetes Research and Endocrinology

2023
Vol. 1 No. 1: 103

Deciphering Postprandial Plasma Glucose Sensor Data through Segmentation Analysis using the GH-Method in Mathematical-Physical Medicine

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Citation: Nakajima R. (2023) Deciphering Postprandial Plasma Glucose Sensor Data through Segmentation Analysis using the GH-Method in Mathematical-Physical Medicine. J Diabetes Res Endocrinol. Vol 1(1): 103.

Received: March 09, 2023; **Accepted:** March 22, 2023; **Published:** March 30, 2023

Introduction

Analyzing and interpreting postprandial plasma glucose (PPG) waveforms, data, and crucial features in a type 2 diabetes (T2D) patient is the focus of this study. Through the application of mathematical tools, the author meticulously examines the intricate physical behaviors of glucose, utilizing the GH-Method—a distinctive approach grounded in math-physical medicine [1].

Methods and Materials

Diagnosed with T2D 25 years ago, and meticulously collected blood sugar values through a continuous glucose monitoring device (the Sensor) attached to his upper arm between 5/5/2018 and 9/28/2019. Over 481 days, a total of 35,748 glucose data points (100%) were gathered, averaging 74 collections per day. Notably, this comprehensive dataset comprised 481 fasting plasma glucose (FPG) waveforms with 5,291 data points (15% of total), 1,443 postprandial plasma glucose (PPG) waveforms with 18,759 data points (52% of total), and 11,698 pre-period glucose data encompassing both pre-meal and pre-bed measurements (33% of total) [2-4].

After meticulous data collection and categorization for analysis, the author proceeded to calculate and visualize the FPG waveform, constituting approximately 25% contribution to HbA1C, resembling a salad bowl shape. Simultaneously, the PPG waveform, contributing about 75% to HbA1C, exhibited a mountain shape. Subsequently, the author calculated average PPG values at specific time instants (0, 60, 120, 180 minutes) and during distinct sub-periods (0-60, 60-120, 60-180 minutes). Employing the OHCA (Open-High-Close-Average) model and three decomposed PPG waveform models—Himalaya, Twin Peak, and Grand Canyon—the author determined their respective average and peak glucose values.

Results and Discussion

Illustrated in Figure 1 and Figure 2 are seven daily postprandial plasma glucose (PPG) curves along with a summarized table of average glucose values. The Sensor PPG, with a daily average PPG of 136 mg/dL, exhibits an ascent from a composite opening glucose of 128 mg/dL at the initiation of the meal. Subsequently, it reaches its composite high peak value of 144 mg/dL at 60 minutes and gradually decreases to a composite closing value of 131 mg/dL at 180 minutes. Importantly, it is noteworthy that the PPG's peak occurs approximately 60 minutes after the first bite of the meal, deviating from the conventional standard of "two hours after your meal."

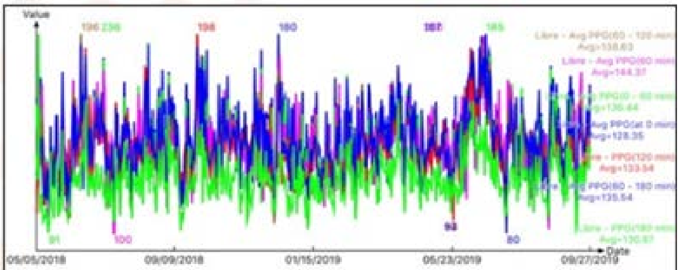
The OHCA analysis yielded results for three distinct models: Himalaya (inactivity after a meal), Grand Canyon (proper and sufficient post-meal exercise following carbs/sugar intake), and Twin Peaks (insufficient or interrupted post-meal exercise). In Figure 3, using the Grand Canyon as the 100% baseline, Twin Peaks exhibits a 7% higher average glucose (equivalent to 15% higher energy) and a 4% higher peak glucose (8% higher energy), while Himalaya shows a 1% higher average glucose (equivalent to 2% higher energy) and a 2% higher peak glucose (4% higher energy). Although the observation suggests that Himalaya would result in the worst postprandial plasma glucose (PPG) outcomes, the author's extensive knowledge of glucose and practical experiences in glucose control indicate that he adjusts his carb/sugar intake when anticipating upcoming periods of post-meal inactivity [5].

The glucose analyses highlight components with values exceeding 140 mg/dL or 180 mg/dL, representing elevated glucose levels that contribute to excessive residual energy circulating in the bloodstream. This surplus energy poses a risk, potentially causing damage to internal organs and giving rise to complications associated with diabetes.

The ascending speed of glucose from 0 to 60 minutes and the descending speed from 60 to 180 minutes. Generally, the dropping speed, measured at 19 mg/dL per hour, is approximately 60% of the rising speed, which is at 32 mg/dL per hour. Understanding the carbohydrate/sugar intake and initial glucose level at 0 minutes allows for the calculation of the peak postprandial plasma glucose (PPG) level around the peak time at 60 minutes. Similarly, considering post-meal exercise patterns and intensity, and applying the appropriate dropping speed based on the exercise amount, enables the calculation of the PPG level at 180 minutes after the first bite of the meal. These statements delineate the precise steps involved in a quantitative PPG analysis.

Conclusion

Currently, diabetes stands as a non-curable chronic ailment. While there are medications and insulin injections available to alleviate symptoms, optimal management involves addressing the root cause to prevent severe complications. Individuals with Type 2 Diabetes (T2D) seeking effective control through lifestyle management programs require healthcare professionals with a profound understanding of glucose. This understanding is a prerequisite for providing accurate knowledge, advice, and support. Armed with a comprehensive grasp of glucose, healthcare professionals can offer valuable lifestyle management guidance, encompassing aspects such as diet, exercise, and other contributing factors. The primary goal of this paper is to furnish essential quantitative and qualitative information on the fundamental concept of glucose, equipping healthcare professionals with the necessary tools to empower and guide diabetes patients effectively.



PPG x-minutes	Avg. PPG
0 min	128
0-60 min	136
60 min	144
60-120 min	139
60-180 min	136
120 min	134
180 min	131

Figure 1: PPG glucose values at different time instants.

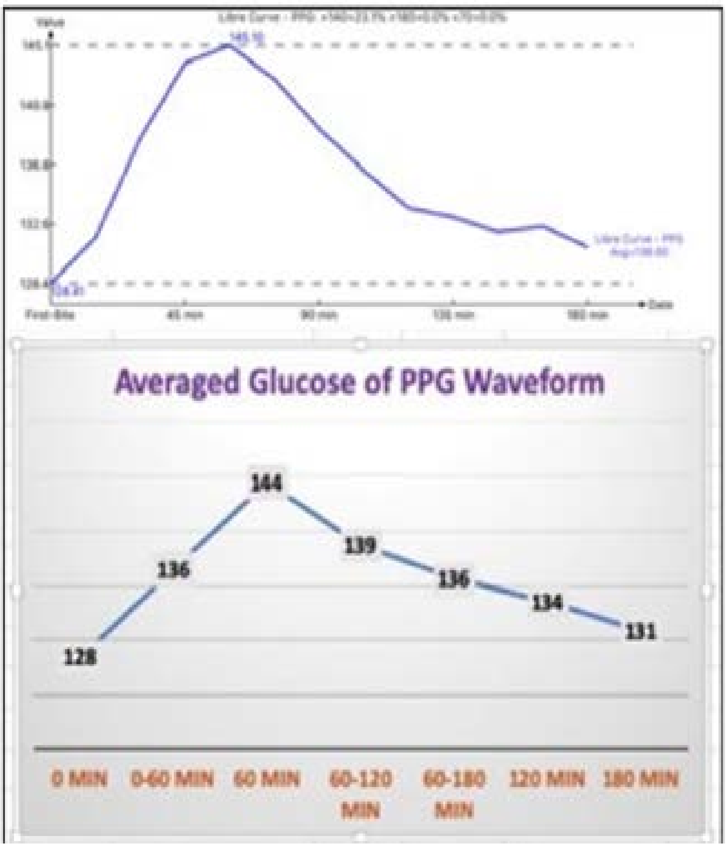
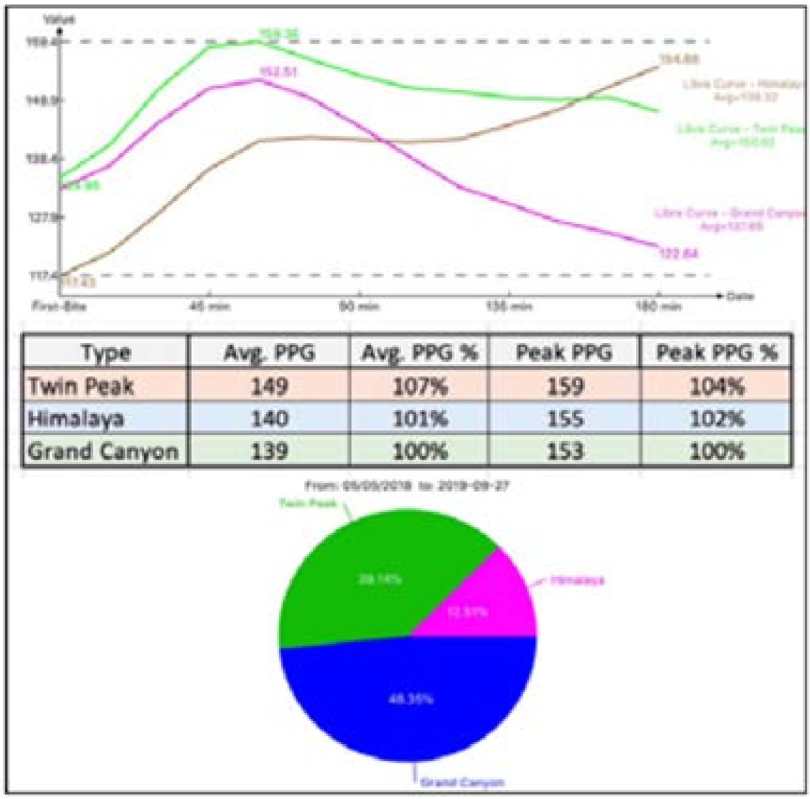


Figure 2: Two PPG waveforms based on overall data composition and assembly from 4 key time instants and 3 subperiods.



Type	Avg. PPG	Avg. PPG %	Peak PPG	Peak PPG %
Twin Peak	149	107%	159	104%
Himalaya	140	101%	155	102%
Grand Canyon	139	100%	153	100%

Figure 3: Three standardized sensor PPG waveforms.

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