Blood Glucose: A Personal Study

Abdullah Mir

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Background:

For the average, healthy person, we are generally aware of our health and if something feels off, we seek the appropriate medical care. While it is fairly easy to recognize the somatic and visual signs of something on our bodies being off such as swelling, bruising, pain, numbness, itchiness, and bleeding, far too often we are oblivious to what is happening inside our bodies. The visual and somatic signs and symptoms of diseases as previously described, usually occur long after some disturbance has already started inside our bodies. In fact, all diseases at their core occur inside our bodies with their outward manifestations being the signs and symptoms we so often associate with various diseases.

Unfortunately, the present medical paradigm is to wait until a patient is sick or is showing signs and symptoms of an illness and then treating the patient via various medical interventions like pharmaceutical drugs, surgery or others. I wholeheartedly disagree with this view from both a well-being point of view and a cost point of view. I strongly believe that the medical paradigm and indeed our own view should be one of prevention rather than cure. Why cure diabetes or heart disease or cancer via painful surgeries and other interventions if you can prevent your body from getting to that state?

The way to prevent a lot of diseases, in addition to having a healthy lifestyle of high-quality nutrition and exercise, is to be keenly aware of what is going on inside our bodies and catch any abnormalities before they become pathogenic. A lot of the money and medical research is focused on drug development and finding cures to diseases, which in my opinion is in large part because it is far more profitable for pharmaceutical and healthcare companies. However, at a societal level, it would reason to be a lot more profitable for people to not get sick at all or for the medical system to catch any internal abnormalities before they manifest as illnesses. It would certainly improve the quality of life of everyone and lessen the load on the healthcare system.

There are some companies like Galleri[1] that are working actively towards prevention and early detection of diseases such as cancer. While the lion’s share of the funding still goes towards drug development and finding cures for existing diseases, there is some evidence that more money is being funneled towards researching longevity and prevention[2,3,4]. There are also a number of scientists working on prevention of diseases and on longevity such as David Sinclair[5] and Nir Barzilai[6] among others, so the future looks hopeful. But what can we do in the meantime? How can we know what is going on inside us and then use that information to prevent diseases or stop the progression of abnormalities before they become pathogenic?

In my opinion, the best thing we can do is regular testing to apprise ourselves of our internal environment. Regular blood testing of various biomarkers such as cholesterol, vitamin D, ALT, CRP and others can keep us informed of our internal health. To that end, one of the most crucial biomarkers linked to health, longevity and general well-being is blood glucose.

I recently got a fasted blood glucose test and an HbA1C test; my fasted blood glucose was 4.5 mmol/L (81 mg/dL) while my HbA1C was 5.2%. According to the Mayo Clinic, a fasting blood glucose level less than 5.6 mmol/L (100 mg/dL) is normal. A fasting blood glucose level from 5.6 to 6.9 mmol/L (100 to 125 mg/dL) is considered prediabetes, while a fasted blood glucose of 7 mmol/L (126 mg/dL) or higher on two separate tests indicates diabetes.[7] HbA1C is a measure of how much glucose is attached to hemoglobin, which is a protein in the blood that carries oxygen; it also represents your average blood glucose level for the past 3 months. An HbA1C level of 6.5% or higher on two separate tests indicates diabetes. An HbA1C between 5.7% and 6.4% indicates prediabetes while below 5.7% is considered normal.[7]

Evidently, both my fasted glucose levels and HbA1C were well within the normal range. But I wanted to know more. I wanted to know exactly how my blood glucose levels fluctuate during the day and how various types of foods and conditions affect my blood glucose levels. To answer my questions, I bought a continuous glucose monitor (CGM), the FreeStyle Libre 2 made by Abbott (you can easily purchase one yourself for $120 CAD at Shoppers Drug Mart and $90 CAD at Costco; it does not require a prescription or any medical oversight), and decided to run a 2-week test on myself. This report is a culmination of the results of my test and a discussion of the results.

What is glucose and blood glucose:

Glucose is a simple sugar[8]. Sugar is a carbohydrate. A carbohydrate is a biological molecule that various living organisms including humans use in numerous internal biological processes[9]. Carbohydrates along with fats and proteins are the essential building blocks of all of the food that we eat. The simplest forms of carbohydrates are glucose, fructose and galactose among others. Most other carbohydrates and in fact most other foods that contain carbohydrates are built from the fundamental building blocks glucose, fructose and galactose.

When we say glucose is a simple sugar, we don't mean strictly the sweet white stuff in your pantry that we call sugar in normal everyday language. In fact, the sugar in your pantry is made of a carbohydrate called sucrose which itself is made of glucose and fructose. Essentially, glucose is the most fundamental and elemental form of a carbohydrate. When we eat carbohydrates such as a piece of cake or croissant, our digestive system breaks the food down into its foundational and elemental parts so that the energy can be released and used by the body. Glucose is extremely important for the body because glucose is the main energy source for the brain, central nervous system, and the muscles[8]. In other words, without glucose, you would be unable to function and in fact unable to stay alive.

Glucose circulates throughout body in blood where it goes to the brain, central nervous system, muscles and other cells. The organs and muscles can uptake glucose from the blood for usage. The amount of glucose in the blood is called blood glucose or blood sugar. Due to its critical importance, the body tightly regulates the amount of glucose in the blood using the pancreas, various hormones (chemicals secreted by various organs in the body that cause some biological effect) and the liver.

What is insulin and insulin sensitivity:

One of the key hormones that help regulate blood glucose levels is insulin[10]. When food or drink is consumed, the digestive system breaks it down into its foundational constituent parts and then into the basic energy molecule in the body, glucose. Once food is broken down, glucose is released into the blood stream for usage by various organs in the body. As mentioned previously, the body tightly regulates the amount of glucose in the blood. Insulin is secreted by an organ called the pancreas in response to elevated blood glucose[11].

The cells of the body cannot simply absorb glucose from the blood. The cells have gates on their outside called transporters, and there is a specific gate called the GLUT-4 which is required to absorb glucose. In other words, the main way the cells of the body can absorb and then use glucose for energy is if the GLUT-4 gate is open. Normally this gate is closed on cells but when insulin is released, it acts as a key to open the GLUT-4 gate on the outside of muscle and fat cells; once the gate is open, these cells start absorbing and sucking the glucose out of the blood. Once the cells starting sucking in glucose from the blood, the amount of glucose in the blood starts going down until it reaches your body's normal level. Once this happens, another hormone called glucagon secreted from the pancreas, closes the gates on the cells so they cannot absorb any more glucose. The body, specifically the pancreas, controls the amount of glucose in your blood by releasing insulin which opens the gates when there is too much glucose in the blood and glucagon which closes the gates when the levels of glucose in the blood return to normal.

Insulin sensitivity refers to how sensitive the cells in your body are to insulin. In other words, how easily are the cells influenced or stimulated by insulin. As an analogy, an individual who is sensitive to sunlight will burn easily if they spend some time in sunlight whereas an individual who is not sensitive to sunlight will not burn. In other words, even a little bit of sunlight affects and stimulates a sensitive person greatly whereas even a large amount of sunlight will not create a large response in a person who is not sensitive.

In a healthy individual, the cells of the body should be sensitive to insulin; when insulin is released, they should respond by opening the GLUT-4 gate and letting glucose in. Insulin insensitivity or insulin resistance is a condition in which the cells stop responding normally to insulin[12]. In other words, when the pancreas releases insulin, the GLUT-4 gates do not open as they are supposed to on the cells or they open partially, which results in the cell's inability to absorb glucose effectively. What happens as a result is that the glucose continues to remain in the blood and starts to accumulate.

Why high blood glucose levels are bad:

When blood glucose remains high, it interferes with the body's normal functions. Glucose above a certain amount is not meant to stay in the blood, but rather be absorbed by the muscles and other organs. The inability of the body to lower blood glucose due to insulin resistance is called type 2 diabetes mellitus. Chronically high blood glucose levels cause many health issues such as heart disease, cancer, eye damage, kidney damage and nerve damage[13, 14, 15]. Too much glucose in the blood binds with hemoglobin making it less effective and causes blood vessels to narrow which in turn leads to less oxygen and blood getting to the brain and other organs. This causes various ailments such as high blood pressure, heart disease, stroke and nerve damage[15]. It also impairs the body's ability to fight infections and heal wounds[15].

Why glucose spikes and crashes are bad:

In light of the above, the best option for healthy individuals and diabetics is to maintain relatively stable blood glucose levels[8]. Elevated levels of blood glucose for long periods of time leads to insulin resistance which if not fixed in time, leads to diabetes[8,10]. Blood glucose spikes and crashes are also bad as they lead to various somatic symptoms; blood glucose spikes and crashes can lead to anxiety, sleep disturbances, unstable moods, lethargy, irritability, fatigue, and weight gain[16,17]. Glucose spikes will very likely occur in all healthy individuals, so you should not be alarmed by that. However, continued sustained elevated blood glucose levels, in other words routine spikes throughout the day cause your body to release insulin to regulate blood glucose. Chronic over secretion of insulin which is what occurs with chronic glucose spikes and elevated glucose can result in insulin resistance.

Selected results:

A key aspect to note while examining the results below is that on most days, I was eating 1 meal a day and was effectively fasting for periods of around 24 hours or more. I did this to isolate the true effect of foods and various conditions on my blood glucose. For people eating throughout the day, your daily blood glucose charts may look different but in healthy individuals it should follow similar patterns of largely baseline before eating, going up after eating and returning to baseline some hours later. For all intents and purposes, most of the findings of this personal study should be applicable generally to most healthy individuals.

Units for all readings are mmol/L

<u>Establishing a baseline reading:</u>

Day 1:

Waking after 14 hours fast: 4.7
20 hours fast: 4.4
23 hours fast: 4.3
Right before eating: 4.7

Eating for 20 minutes (high protein meal)

10 minutes after eating: 5.2
20 minutes after eating: 5.7
30 minutes after eating: 7.2
40 minutes after eating: 6.9
50 minutes after eating: 7.0
1 hour after eating: 6.7
1.5 hours after eating: 5.4
2 hours after eating: 5.3
3 hours after eating: 5.6

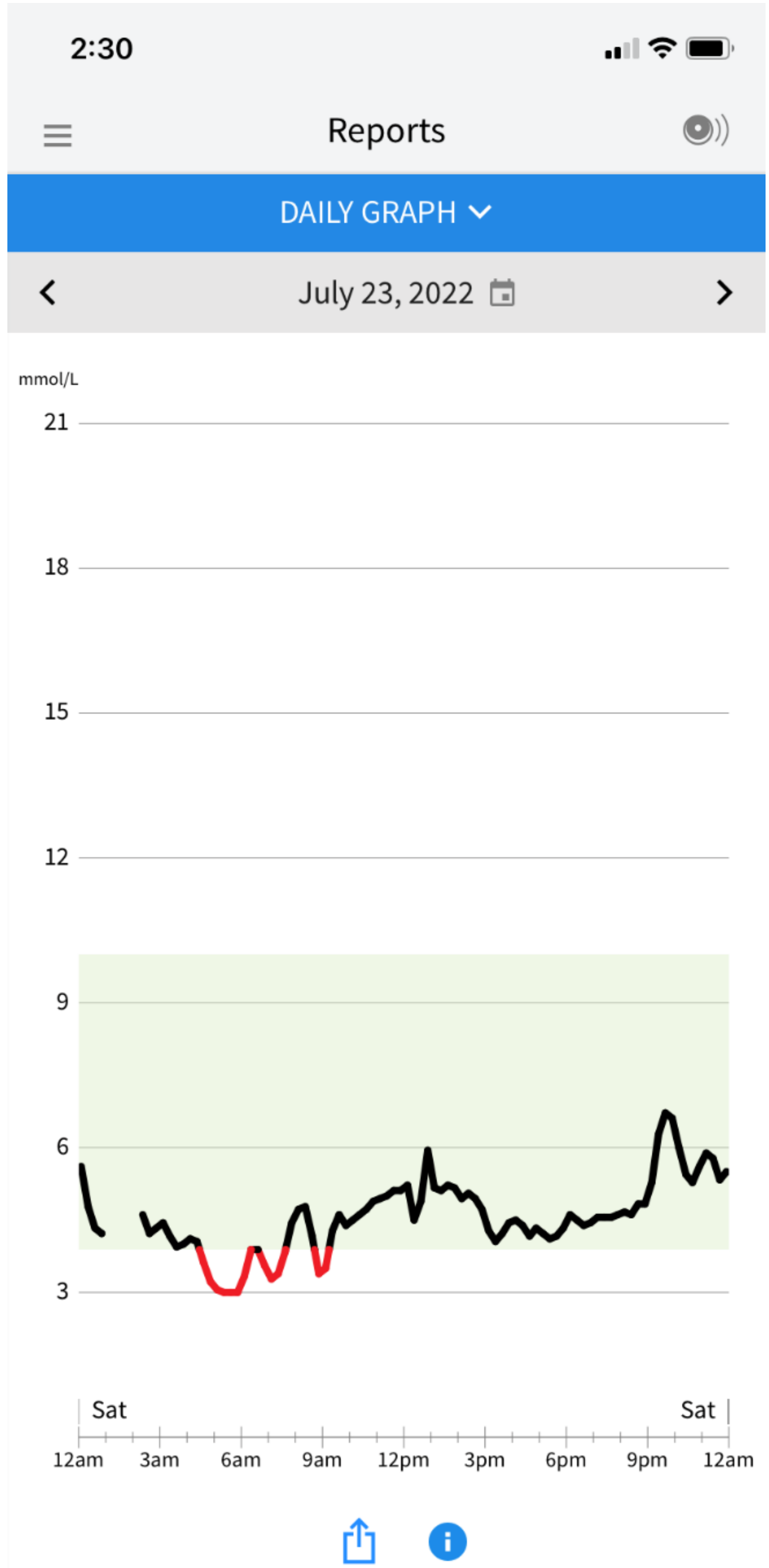


Figure 1

Day 2:

Waking after 14 hours fast: 4.8
20 hour fast: 4.5
23 hours fast: 4.2
Right before eating: 4.6

Eating for 20 minutes
(High carbohydrate meal of
tuna bagel and mango)

10 minutes after eating: 5.0
20 minutes after eating: 5.7
30 minutes after eating: 6.7
40 minutes after eating: 7.5
50 minutes after eating: 7.4
1 hour after eating: 7.7
1.5 hours after eating: 3.9 [big crash]
2 hours after eating: 6.1
2.5 hours after eating: 6.6
3 hours after eating: 5.6

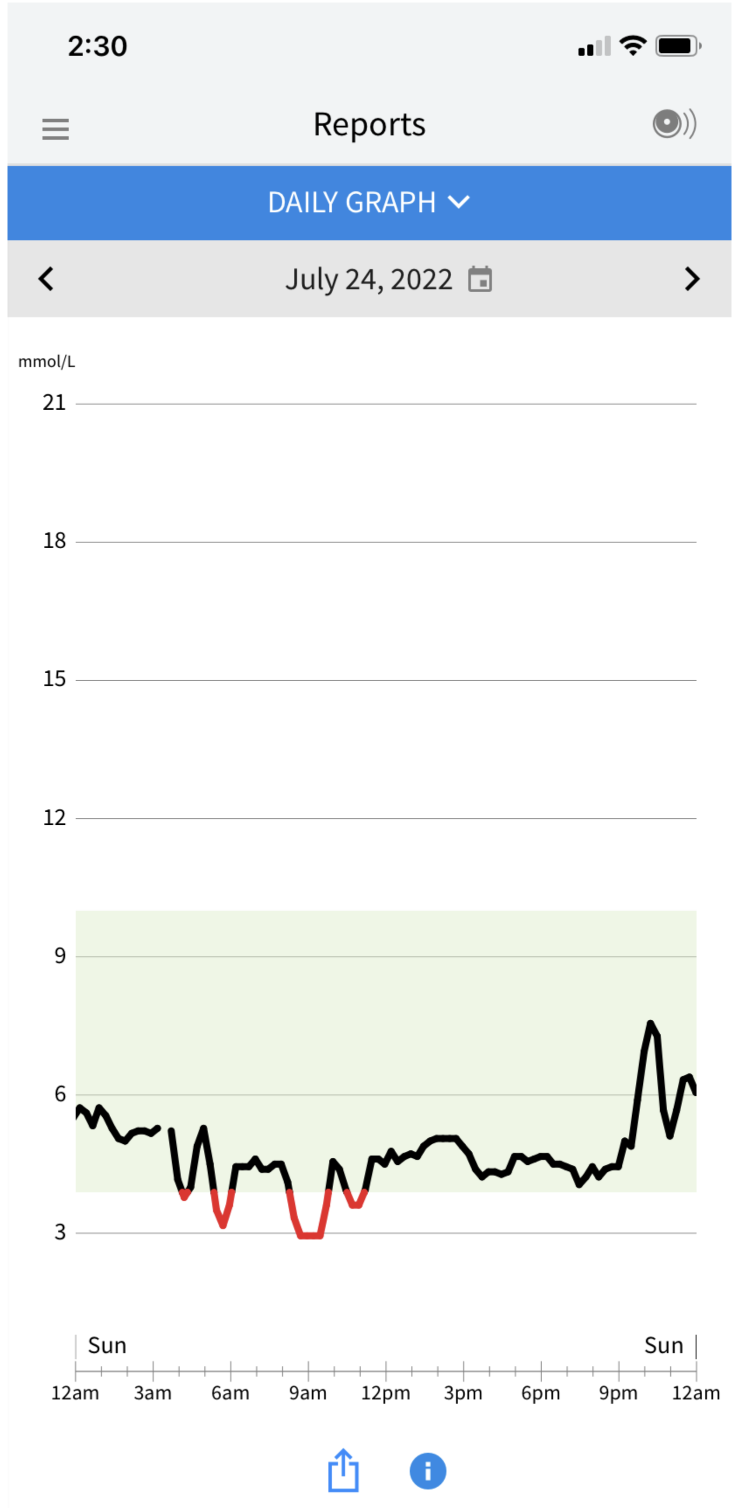


Figure 2

Exercise (80 minutes walk at 5 km/h speed):

Immediately prior to exercise: 4.9
20 minutes into exercise: 5.6
40 minutes into exercise: 5.2
80 minutes into exercise: 5.4
30 minutes after end of exercise: 4.8
1 hour after end of exercise: 4.7
2 hours after end of exercise: 4.4

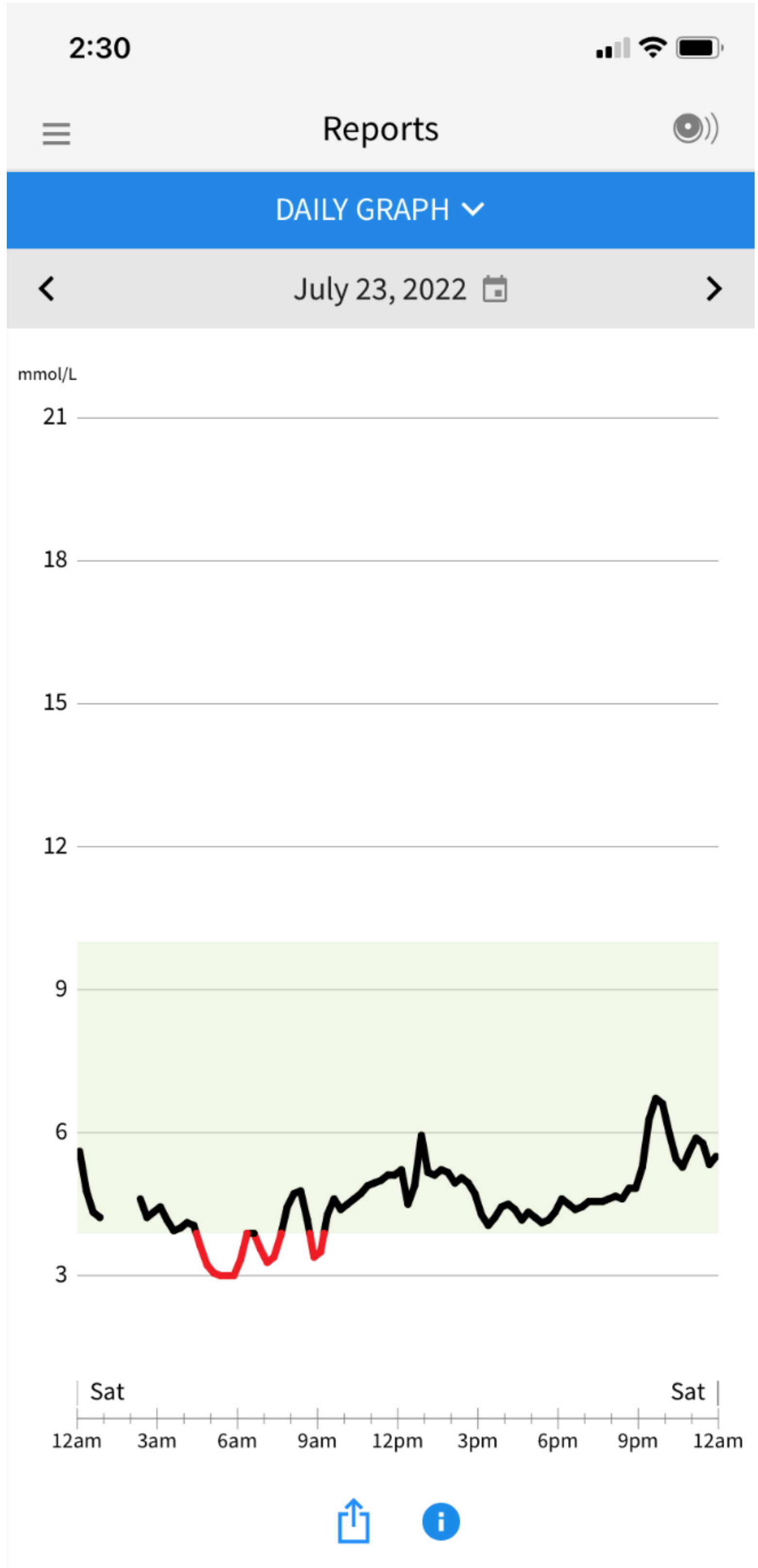


Figure 1

Exercise (75 minutes intense weightlifting):

Immediately prior to exercise: 4.6
30 minutes into exercise: 5.3
1 hour into exercise: 5.3
30 minutes after the end of exercise: 5.4
1 hour after the end of exercise: 4.8
2-hours after the end of exercise: 4.2

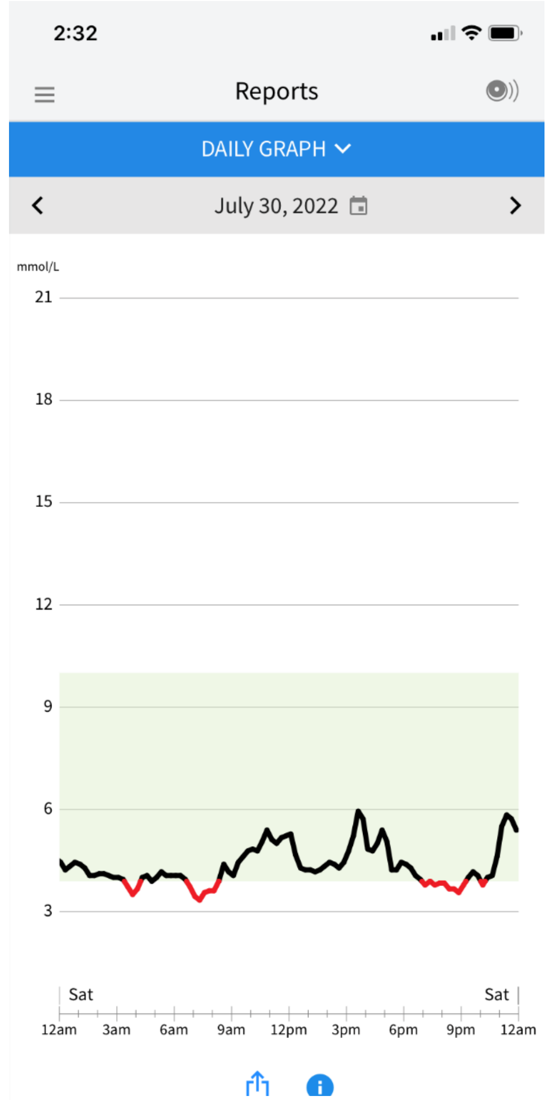


Figure 3

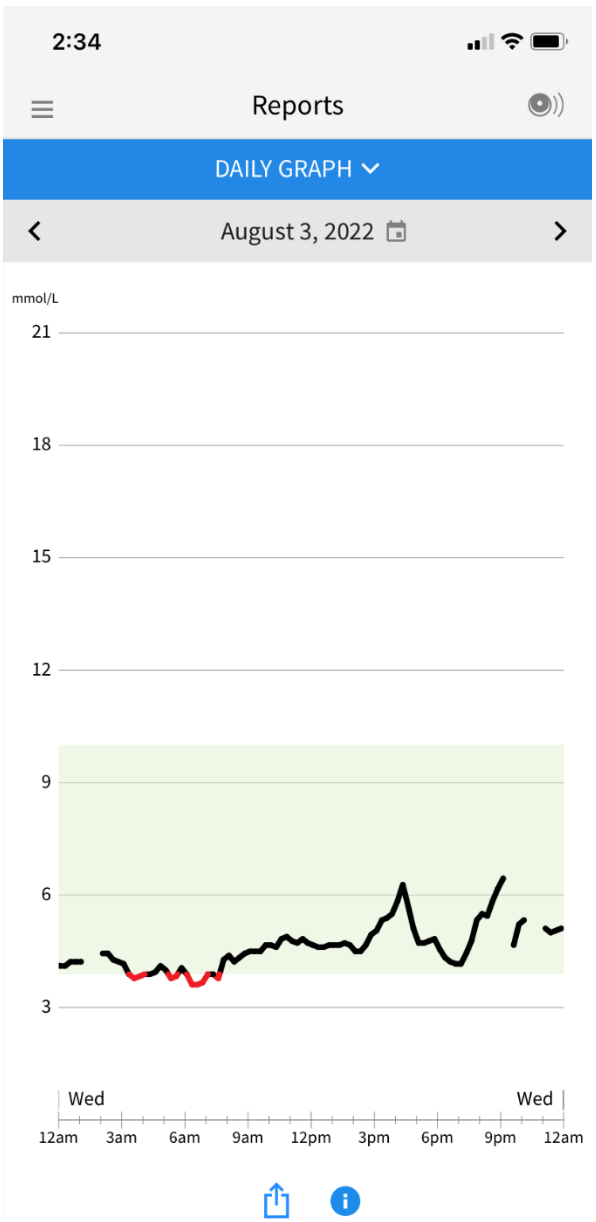


Figure 4

Exercise (60 minutes intense weightlifting):

Prior to the start of exercise: 4.6
30 mins after end of exercise: 6.8
1 hour after end of exercise: 4.6
75 minutes after end of exercise: 4.4

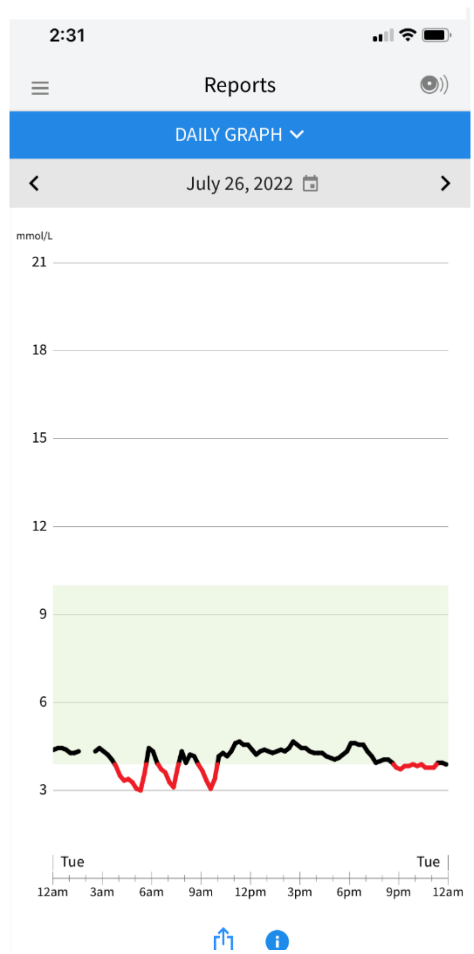
96 hours (4 days) Water Fast:

14 hours fast: 5.2
20 hours fast: 6.7 (after 1 hour in the gym, likely adrenaline and mild dehydration)
24 hours: 4.8
28 hours: 4.6
38 hours: 4.1
44 hours: 4.0
48 hours: 3.9
52 hours: 3.9
62 hours: 4.1
68 hours: 4.5 (30 minutes into a workout)
72 hours: 3.2
76 hours: 3.9
86 hours: 4.1
92 hours: 3.8
96 hours: 3.9
Right before eating: 3.9

Eating for 45 minutes
(High protein meal)

10 minutes after eating: 6.1
20 minutes after eating: 6.6
30 minutes after eating: 6.9
40 minutes after eating: 6.8
50 minutes after eating: 5.4
1 hour after eating: 4.8
1.5 hours after eating: 4.9
2 hours after eating: 5.0
2.5 hours after eating: 4.3
3 hours after eating: 4.7

Figure 5



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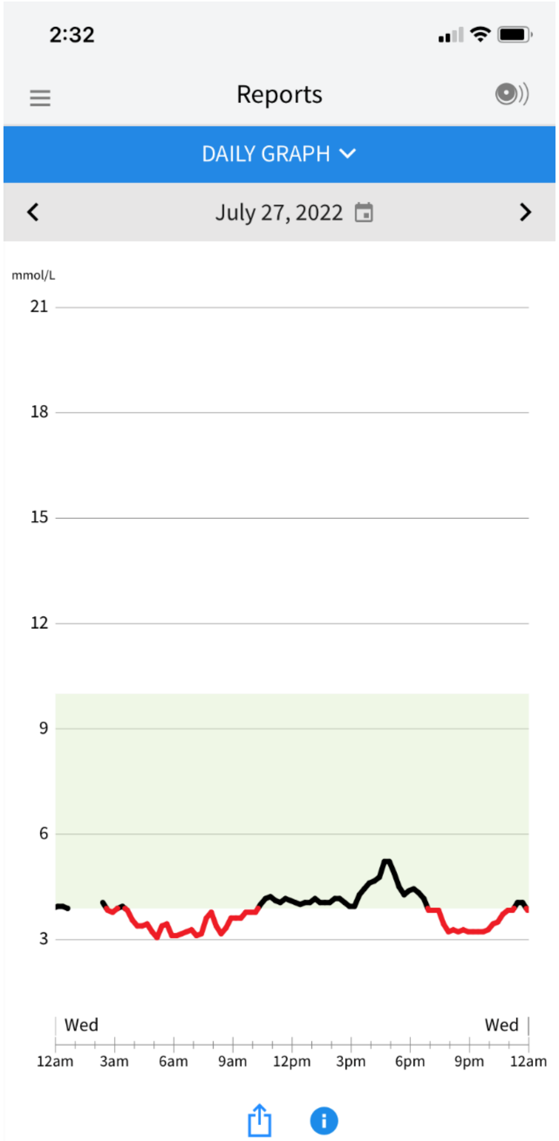

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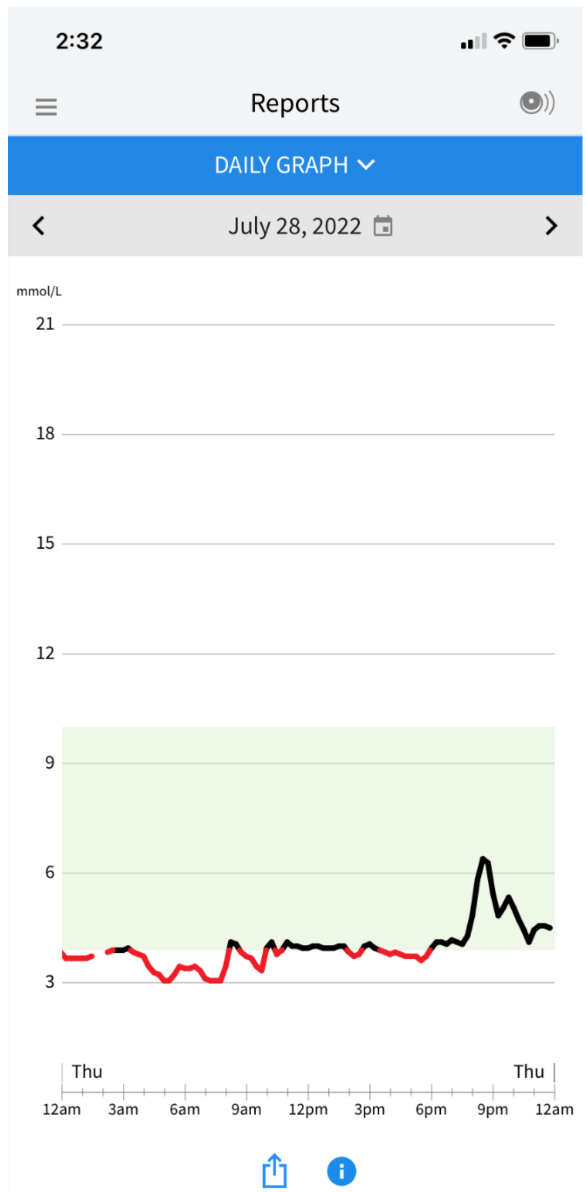

Figure 8

Low carbohydrate meal:

waking after 14 hours fast: 4.0
20 hours fast: 4.3
23 hours fast: 4.1
Right before eating: 4.1

Eating for 15 minutes

10 minutes after eating: 4.8
20 minutes after eating: 5.3
30 minutes after eating: 5.5
40 minutes after eating: 5.7
50 minutes after eating: 5.8
1 hour after eating: 5.5
1.5 hours after eating: 4.6
2 hours after eating: 5.5
2.5 hours after eating: 5.5
3 hours after eating: 4.4

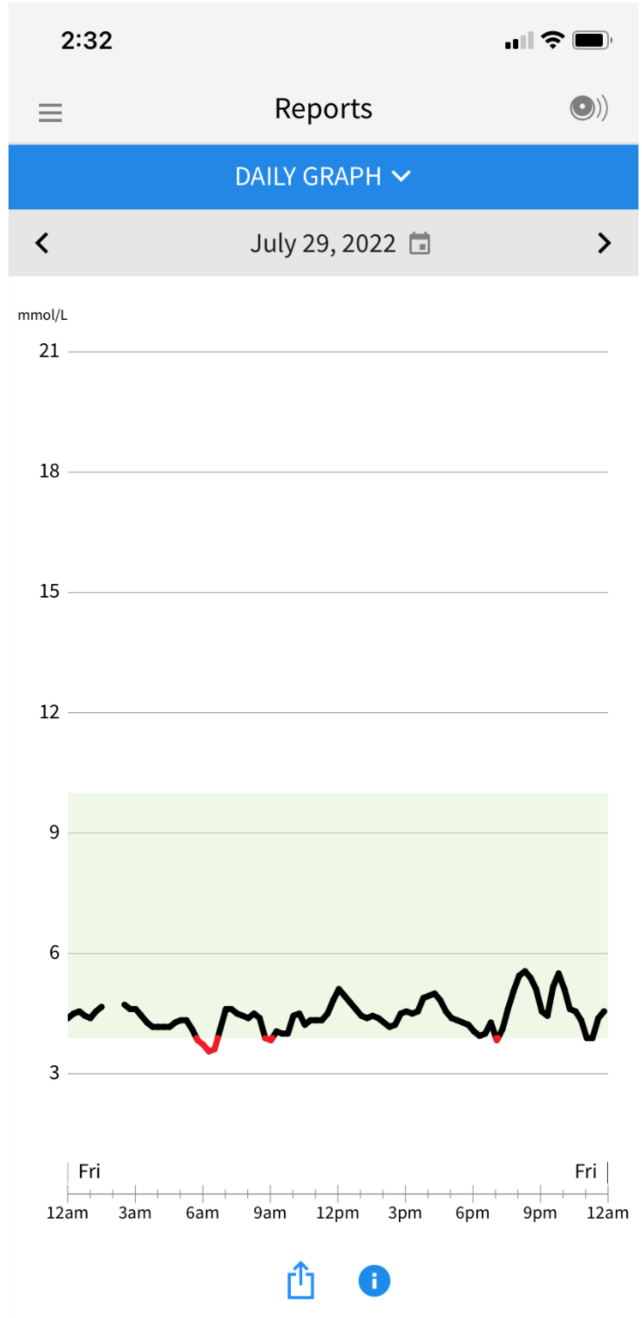

Figure 9

1 g of berberine with food:

Waking- 14 hour fast: 4.6
20 hours fast: 4.4
23 hours fast: 4.1
24 hours fast: 4.2
Right before eating: 3.9

Eating for 15 minutes (fairly carbohydrate and protein heavy meal)

1 g of berberine with food

10 minutes after eating: 5.5
20 minutes after eating: 5.6
30 minutes after eating: 5.9
40 minutes after eating: 6.0
50 minutes after eating: 5.5
1 hour after eating: 5.3
1.5 hours after eating: 5.1
2 hours after eating: 5.0
2.5 hours after eating: 4.7
3 hours after eating: 4.8

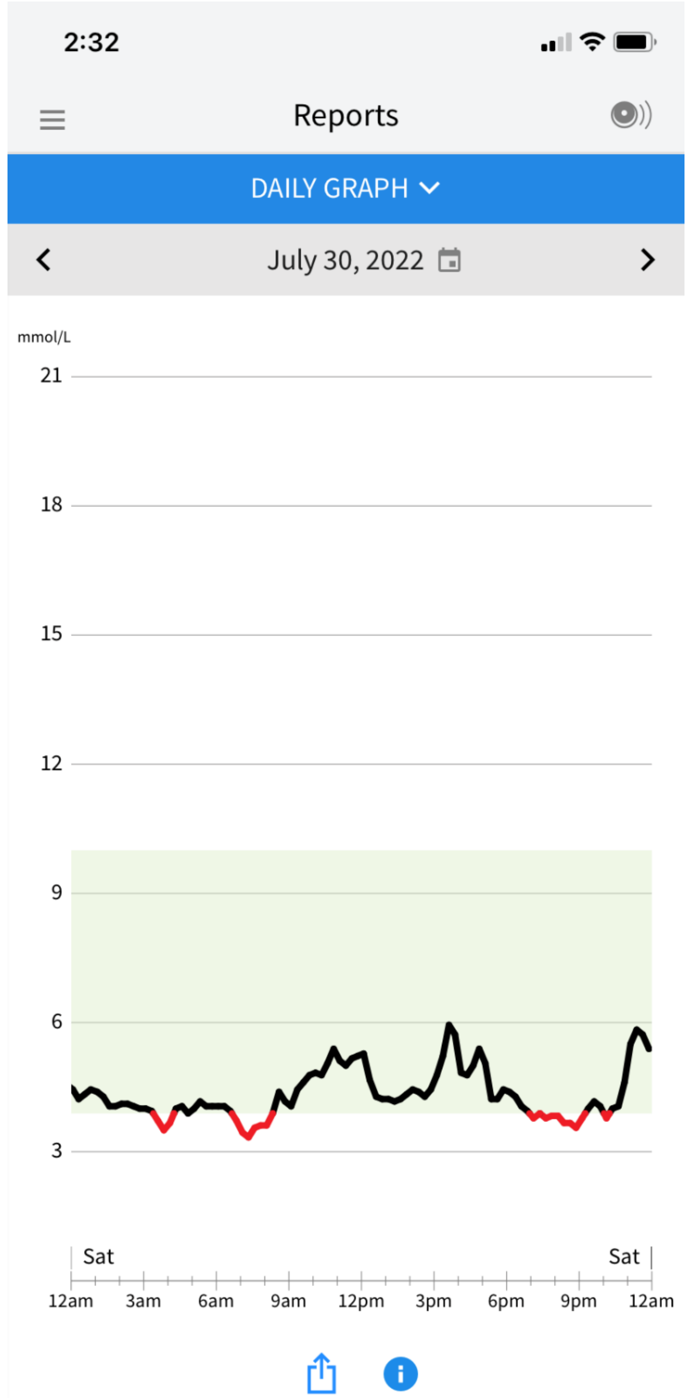

Figure 10

Very similar meal as before with slightly less carbohydrates:

Waking- 14 hour fast: 4.3
20 hours fast: 5.0
23 hours fast: 4.4
Right before eating: 4.4

Eating for 15 minutes

10 minutes after eating: 5.6
20 minutes after eating: 6.9
30 minutes after eating: 8.4
40 minutes after eating: 7.3
50 minutes after eating: 6.3
1 hour after eating: 6.2
1.5 hours after eating: 5.8
2 hours after eating: 5.2
2.5 hours after eating: 7.1
3 hours after eating: 4.3

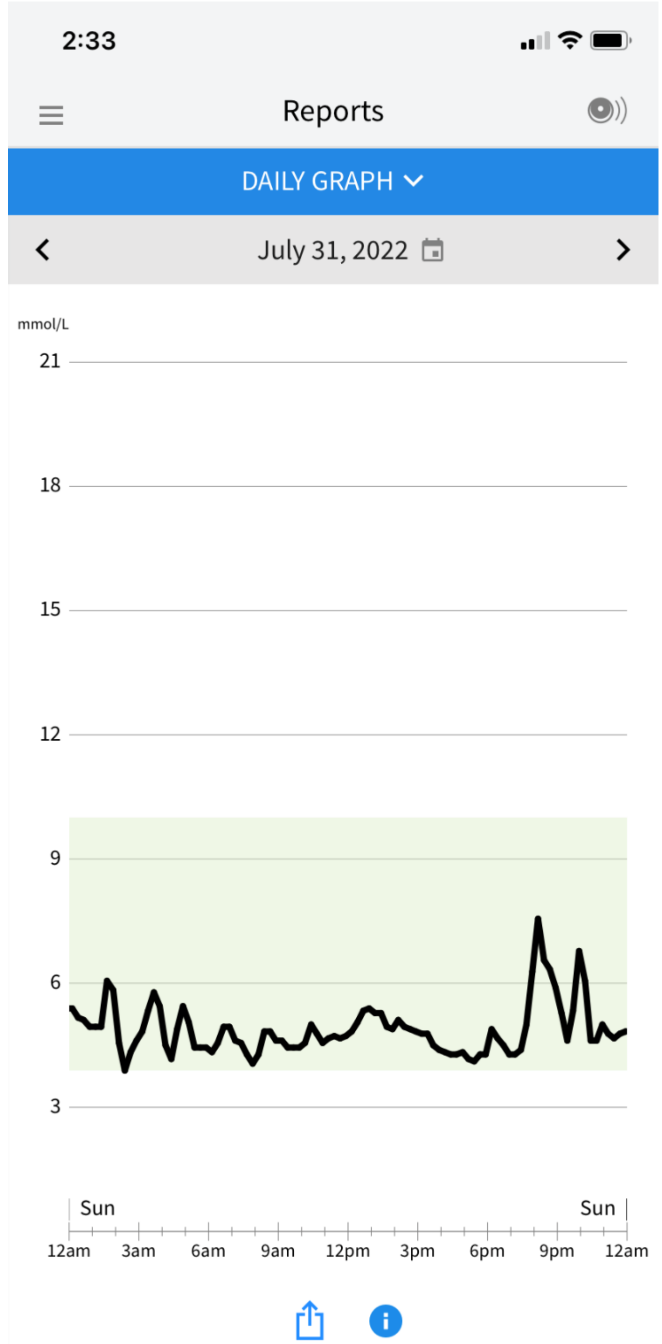

Figure 11

1.5 g of berberine with food:

waking 38 hours fast: 4.6
44 hours fast: 6.0 (during a workout)
Right before eating (48 hours fast): 4.2

Eating for 70 minutes
(High protein medium carbohydrates meal)

10 minutes after eating: 5.6
20 minutes after eating: 5.8
30 minutes after eating: 6.7
40 minutes after eating: 6.8
50 minutes after eating: 5.5
1 hour after eating: 4.4
1.5 hours after eating: 5.6
2 hours after eating: 5.5
2.5 hours after eating: 5.3
3 hours after eating: 4.9

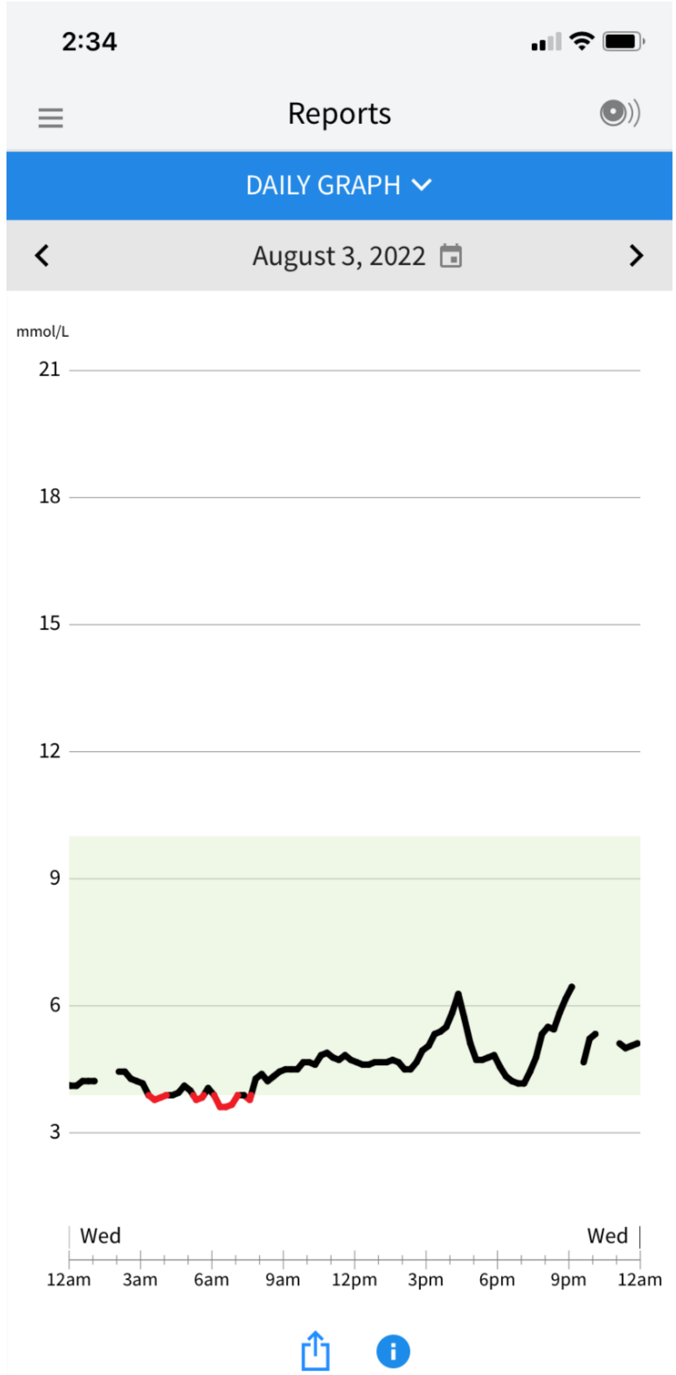

Figure 12

30 minutes walk, completed 15 minutes after eating:

Waking-14 hour fast: 4.8
20 hours fast: 5.4
23 hours fast: 4.3
Right before eating: 3.9

Eating for 45 minutes
(Protein and fruit carbs heavy meal)

15 minutes after eating: 5.6

30 minutes walk after eating
(15 minutes after the end of the meal)

Right at the end of walk: 4.6
15 minutes after walk: 5.3
30 minutes after walk: 5.6
45 minutes after walk: 5.6
60 minutes after walk: 5.8
90 minutes after walk: 5.0
2 hour after walk: 6.4
2.5 hours after walk: 5.8
3 hours after walk: 4.8

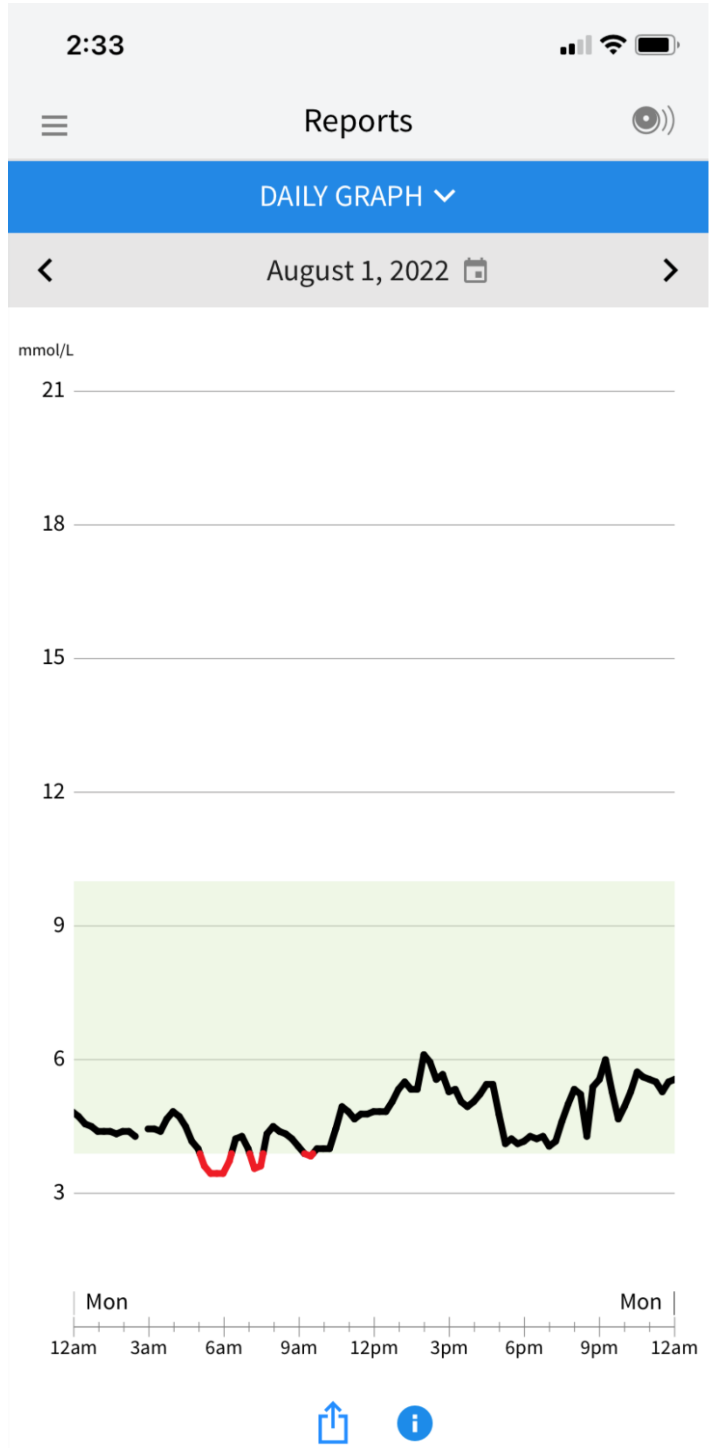

Figure 13

Average blood glucose:

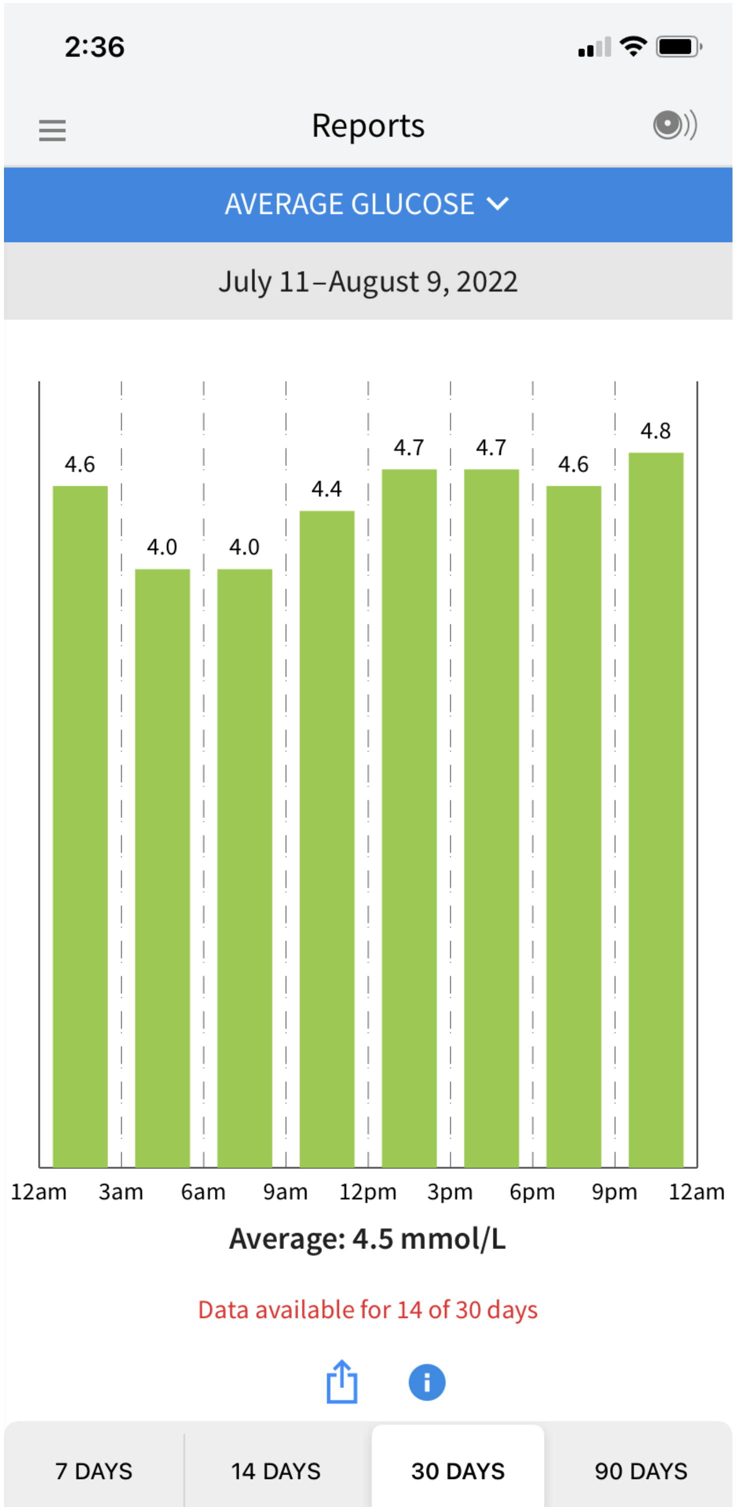

Figure 14

Discussion of results and key findings:

In Figure 1, blood glucose is relatively even during waking hours of 9 am to 9 pm until the first meal. It is relatively constrained in a narrow band between 4.3 mmol/L to 5.0 mmol/L. Around 9 pm, after eating a meal, there is a rise in blood glucose which peaks 30-50 minutes after eating and then slowly starts to come down over the next few hours. This was a high protein meal with relatively fewer carbohydrates, and the peak blood glucose was 7.2 mmol/L.

In Figure 2, there is a relatively stable blood glucose level from waking until the first meal 9 am to 9 pm. At 9 pm, I consumed a very high carbohydrate meal of tuna bagel and a ripe mango. You can immediately see a massive spike in blood glucose going as high as 7.7 mmol/L 1 hour after eating. This was followed by a massive release of insulin by my pancreas which led to a huge crash in blood glucose down to 3.9 mmol/L. This type of crash is usually what leads to feeling sleepy, lightheaded and sometimes having a headache after eating a big meal. Subsequently, my digestive system was likely still digesting the meal and releasing glucose into my blood stream, and as such you can see a rise up to 6.6 mmol/L at the 2.5 hours mark.

In Figure 1, there is a spike around 12 pm which corresponds to an 80 minutes long walk at a speed of 5 km/h. I have also noticed that after a particularly intense weightlifting session, my blood glucose has spiked as high as 6.8 mmol/L with no food intake whatsoever up to 30 to 45 minutes after the work out, as seen in Figure 3 and Figure 4. Importantly in both cases, between 75 to 120 minutes after the end of the exercise, blood glucose levels return to even lower than pre-exercise levels. The most likely explanation for these phenomena is that, during intense exercise, the body releases hormones such as adrenaline which impact the liver to pump out stored glucose into the blood stream so the muscles can actively use it[18]. Muscles naturally have an increased need for fuel when they are working harder during exercise. Subsequently, muscles work to absorb and uptake the glucose from the blood which continues even after the end of the exercise leading to improved and lowered blood glucose levels[18].

Figures 5, 6, 7 and 8 correspond to a 96-hours fast. Blood glucose levels are mostly relatively stable. There are some rises which correspond to exercise induced rises of blood glucose in most cases. There were some points during the extended fast that blood glucose dropped below the generally accepted lower end of the range of 3.9 mmol/L. However, you can note that it quickly recovered and I can report that I did not feel any somatic symptoms commonly associated with low blood glucose such as headaches, hunger or irritability. There were times when I felt low energy however that quickly subsided. The important aspect to note is that blood glucose levels remain relatively stable and low during a fast.

Figure 9 corresponds to a low carbohydrate meal. Note that my blood glucose after eating rises to a maximum of 5.8 mmol/L, 50 minutes after eating before starting to come down, eventually getting as low as 4.4 mmol/L which is as low as it would be in a fasted state.

Figures 10, 11 and 12 correspond to the consumption of berberine. Berberine is a compound derived from the roots and bark of the barberry tree and has been used in traditional Chinese and Ayurvedic medicine for various purposes[19]. Its most interesting potential use is its effect on regulating blood glucose and potentially lowering of LDL cholesterol[19].

In Figure 10, I took 1 gram of berberine before eating and I had a fairly high carbohydrate meal consisting of starchy vegetables and burgers. My blood glucose rose to 6.0 mmol/L and was quickly regulated down to fasting levels within 3 hours. In Figure 11, I had a very similar meal with the same or slightly less carbohydrates but no berberine. There was an incredible spike to 8.4 mmol/L 30 minutes after eating before crashing then rising again. Similarly, if we compare to Figure 2 when I consumed a high carbohydrate meal without berberine, my blood glucose followed a similar pattern of rising to 7.7 mmol/L followed by subsequent crashes and rises.

Figure 12 corresponds to taking 1.5 grams of berberine before eating a high protein and medium carbohydrate meal. There was a rise of blood glucose to 6.8 mmol/L, 40 minutes after eating before being regulated down to 4.9 mmol/L. I do note there were a few small spikes prior to being regulated down to fasted levels. In this personal study, I have found some evidence that berberine helped blunt the rise of blood glucose but admittedly due to time constraints with the CGM, I was unable to get completely conclusive results. Nevertheless, I find this intervention holds promise and I continue to periodically use it especially prior to high carbohydrate meals.

Lastly, Figure 13 corresponds to taking 30 minutes long walk, 15 minutes after eating. I find that the walk did lower my blood glucose levels shortly afterwards however there was a subsequent rise to 6.0 mmol/L, 2 hours after the walk. I am not sure what the cause of this rise was, and as such, I will state that the walk had only modest effect on regulating my blood glucose. Medical literature supports walking or light exercise after eating to be highly beneficial for regulating blood glucose[20,21,] and it is something I regularly do myself however, my results from a single day of testing this are inconclusive. Similar to the berberine test, I think this intervention definitely holds promise but due to time constraints of the CGM, I was unable to perform additional tests.

Conclusion:

Glucose is a simple carbohydrate (biological molecule) which is the preferred fuel for the brain, central nervous system, and various other tissues in the body like muscles. Due to its critical importance for bodily function, glucose levels in the blood are tightly regulated by the pancreas and the liver. After food is eaten, during the digestion process it gets broken down into glucose which gets released into the blood for use throughout the body. Shortly thereafter, the pancreas releases a hormone called insulin which enables various organs of the body to absorb glucose from the blood thus returning the level of glucose in the blood to baseline levels.

Chronically high blood glucose levels lead to increased secretion of insulin. Chronically high levels of insulin lead the cells of the various organs of the body to become insensitive or resistant to insulin. The side effect of this condition is an abnormally elevated level of glucose in the blood which damages blood vessels and prevents the normal functioning of various bodily functions. It can lead to heart disease, kidney damage, nerve damage, diabetes and other ailments.

The key conclusions from my personal study include that fasting, in its various forms whether it is intermittent fasting or time restricted feeding where you don’t eat for some hours during the day or multi-day water fasting, is one of the most effective interventions for regulating blood glucose. Additionally, dehydration causes elevated blood glucose due to lower blood volume and thereby increased concentration of glucose in blood. Exercise, particularly strenuous exercise such as lifting weights, is highly beneficial for regulating blood glucose. Berberine may be an excellent supplemental tool for blood glucose regulation. Walking after eating has been shown in medical literature to be an effective tool at regulating blood glucose particularly walking before blood glucose peaks 30-60 minutes after eating[21]. Lastly, avoiding refined carbohydrates and processed foods is highly beneficial for blood glucose regulation and prevention of large glucose spikes.

I encourage you to wear a continuous glucose monitor (CGM) once or twice a year to conduct your own personal study. Different foods affect different individuals in different ways based on their physiology and lifestyle. A CGM is an excellent tool to give you insight into your own body and to get an idea of how different foods and lifestyle factors are affecting your blood glucose levels. I also encourage you to go through the references at the end of this document which provide great resources for additional reading.

References:

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