International Baccalaureate

Extended Essay

In Biology

Measuring blood glucose while fasting

By

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Contents:

Introduction

In this essay I am going to investigate how the blood sugar will behave when fasting. I will test on myself and on a fellow student and I will compare the results and examine patterns and differences.

I myself am a type 1 diabetic, or Insulin-Dependant Diabetic Mellitus. I have been a diabetic for nine years, and have during that time come to learn very much about what it is all about. I believe that it is now time to explore even more what happens when I exert myself to extreme conditions, but of course under controlled circumstances. Since I am a diabetic I have access to the glucometers that will be used during the experiments.

I have consulted with my doctor how to behave when fasting. His opinion was that it is okay once or twice. He also agreed on that it is important to learn how the blood sugar reacts when I do not eat in case something happens later in life, I will then have experienced the situation once before and will be able to handle the situation. (His letter can be found in Appendix A).

It is of utter most importance that I, before I start, set the limits, and that I during the experiment is prepared to abort when the glucose level raises to high (hyperglycemia), or drops to low (hypoglycemia). I will set the lower limit to 3.0 mmol/l and the upper to 18.0 mmol/l. If the blood sugar drops under or rises above these two limits I must abort, eat and take insulin. There is an other case when I must abort the experiment and eat and take insulin, and that is when I start to produce ketons in the urine. Since insulin is needed to convert sugar into energy, there will be a problem when there is none. So if there is a lack of insulin, the body will seek other ways to get energy into the cells, and this is done by combusting fats. In this process, ketons will be produced as a by-product. This is the first warning, and I must, if this happens, take insulin. If the production of ketons continues, the insulin sensitivity will drop and the blood glucose will rise quickly and I might fall into coma, this might cause severe damages on the internal organs, like the eye, and the liver.

I will fast three to four times, in two different ways. During the first time I will not take any insulin at all, and study how long it takes for the blood sugar to start rising. The next time I will take insulin to keep the blood sugar at a constant level, when and how much will be decided from the first experiment. My goal is to be able to fast with a constant glucose level.

I will some days before the experiment is to take place check the level of my blood sugar a normal day, and adjust the insulin so that is as normal as it can be.

I will also let a friend of mine, who is a non-diabetic, do the experiment. He will fast for one day, and take blood tests and make a profile. I will then use this as a reference and compare with my profile.

Research question:

“How is the blood glucose changes while fasting – a compassion between a diabetic and a non-diabetic male student”

Theory

When I think of this experiment and try to predict what is going to happen, I more and more realize how important it really is for me. If, by any strange way, I don't get any food I must know how to handle the situation. And the only way to find out is to simulate. I also realize more and more how important it is to be careful and check my glucose level, so that nothing goes wrong.

My theory then is that my blood sugar will rise approximately at eleven o'clock to 15-20 mmol/l, maybe later. The reason for the rise is that the effect intermediate-acting insulin will decrease and I shall need more insulin.

I expect to manage to around lunchtime without insulin the first day. The next time I do the tests I will try to keep the blood glucose level down with insulin, but still no food, and see how long I can make it without any production of ketons. I believe that I will make it for about ten to twelve hours.

My fellow student Adam will also go through the same tests. In his case, since he is a non-diabetic, I think that his blood glucose level will drop to 3.0 mmol/l at ten o'clock when he hasn't had any breakfast. He will probably be tired, hungry and quite irritated. In his case I believe that the glucose level will remain rather steady. The body is supposed to work that way, but we will see what happens.

Preparations

Presentation of insulin and testing tools

Humalog©, Rapid-acting insulin

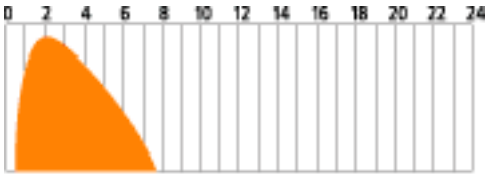
Normally, I take insulin before each meal. This is a human insulin zinc suspension, Humalog© (insulin lispro), produced by Lilly France SA. It is a synthetic humaninsulin, produced in a laboratory using DNA-method. It is closely related to normal insulin, which is produced in the pancreas. I take this kind of insulin intravenous direct or some minutes before I eat. This kind of rapid-acting insulin only works for about five hours with maximum effect after 15-45 minutes.

Monotard©, Intermediate-acting insulin

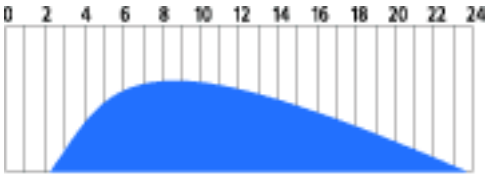
Once every night I take an intermediate-acting insulin that has a duration of 24 - 25 hours, starts working within 2.5 hours and has a maximum effect after seven to fifteen hours. It is called Monotard© and is produced by Novo Nordisk, also by using the DNA-method. It is also a human insulin zinc suspension.

This insulin-type is like a base and should be approximately fifty percent of the total daily usage of insulin. I will of course take this insulin the day before I do the tests, otherwise I would not be able to accomplish the task at all. It will make it harder, if not impossible to draw conclusions from and compare with non-diabetics because this kind of insulin does not exist naturally in the human body, a smaller amount of insulin is produced constantly, or when required. A healthy body can make that decision automatic.

Here are two graphs that show how the two insulin that I use work.



This is the Humalog©



And this is the Monotard©

My daily dose of insulin is 43U rapid-acting insulin when eating, divided on four times a day, and 38U intermediate-acting insulin every night. (100 U/ml → U-100).

The testing-tools

The two kinds of tests I take are the blood glucose test and the urine test. The first and most common one measures the level of glucose in the blood, and the apparatus I use for this is called Acutrend©.

Acutrend© (figure 1, page 6)

The unit is mmol/l, millimole per liter - a unit of concentration. You take a drop of blood and put it on a test strip. The test strip consists of an indicator that changes color with the change in concentration of glucose. You then put the strip into the Acutrend© and a laser scans the indicator and gives you the answer in twelve seconds.

There are quite a number of companies that make these glucometers. Boehringer Mannheim GmbH makes the one I use and the production name is Acutrend©. It takes twelve seconds to get the answer and the apparatus can store fifty results with date and time, a very useful function when taking profiles, especially at nights. It can measure glucose within the range 1.1 to 33.3 mmol/l. The laser has a wavelength of 660 nm and simply measures the color of the indicator.

This kind of test gives an instant hint of how you feel at the moment. The other kind of test, the urine test, reveals how the glucose levels have been for the last couple of hours. When the glucose level is above approximately 11 mmol/l the body wants to get rid of the glucose and therefor lets it out in the urine. So if you can trace how much glucose there is in the urine, you can see if you have had a high blood glucose level for a longer period of time. This is very useful, and is very often used in the mornings to check if the blood glucose has been too high during the night. The urine test also lets on you if you have ketons in the urine, so that is why I will take this test when I fast.

Keto-Diastix

Keto-Diastix® is a visual reacting-tool to determine glucose and ketons (acetoacetat) in the urine produced by Bayer Diagnostics. This method has been used for almost thirty years. The strip contains two testing fields, one for testing glucose and one for testing ketons (acetoacetat).

The field that measures the glucose consists of a two step enzymical reaction. The enzyme, glucoseoxidas, catalyses the production of gluconacid and hydroperoxide through oxidation of glucose. Another enzyme, peroxidas, is a catalyst in the next process where hydroperoxide and a calciumiodide cromogene react and the cromogene changes color from green into brown.

In the other field, the color will change from pink to purple when acetoacetat reacts with nitroprusside. The natural state is that both fields are negative, no glucose or ketons. The notation for this is ‘ - / - ‘ and this is how I will write in the table when I fast and take the tests. If sugar is traced it will be marked by the following grade: 1/10%, 1/4%, 1/2%, 1% and >2% (mmol/l), and the ketons will be graded by: 0.5, 1.5, 4, 8 and 16 mmol/l.

Here are some pictures of the tools:
1) The glucometer.
2) The test-strip for the glucometer. The yellow field in the middle is where I put the blood, and the indicator is on the backside of the strip.
3) The Keto-Diastix packet
4) The Keto-Diastix test-strip

(1)

(2)

(3)

(4)

A normal day

I will here present a table and a diagram of a 'normal' day. This is going to be used for comparison with the test-results that I will get during the experiments.

98-11-22:

Time:	Glucose:	Food / Activity / Insulin:
08.00	2.8 mmol/l	11 U, breakfast
09.00	4.3 mmol/l	
10.00	4.7 mmol/l	
11.00	3.2 mmol/l	
12.15	3.7mmol/l	
12.30		11 U, lunch
13.40	3.5 mmol/l	
14.00	3.5 mmol/l	A Coke (not diet!!!) – no insulin
14.30	5.1 mmol/l	
15.00	3.6 mmol/l	
16.00	5.3 mmol/l	

I do not know if I can say that this is a normal day, that my glucose level is like this all the time. I have got a feeling that this is too low, but on the other hand the level is probably this steady most days, and that is the most important. Note that the glucose did not rise when I had a Coke. This is probably because I take so much intermediate-acting insulin.

First experiment

without insulin

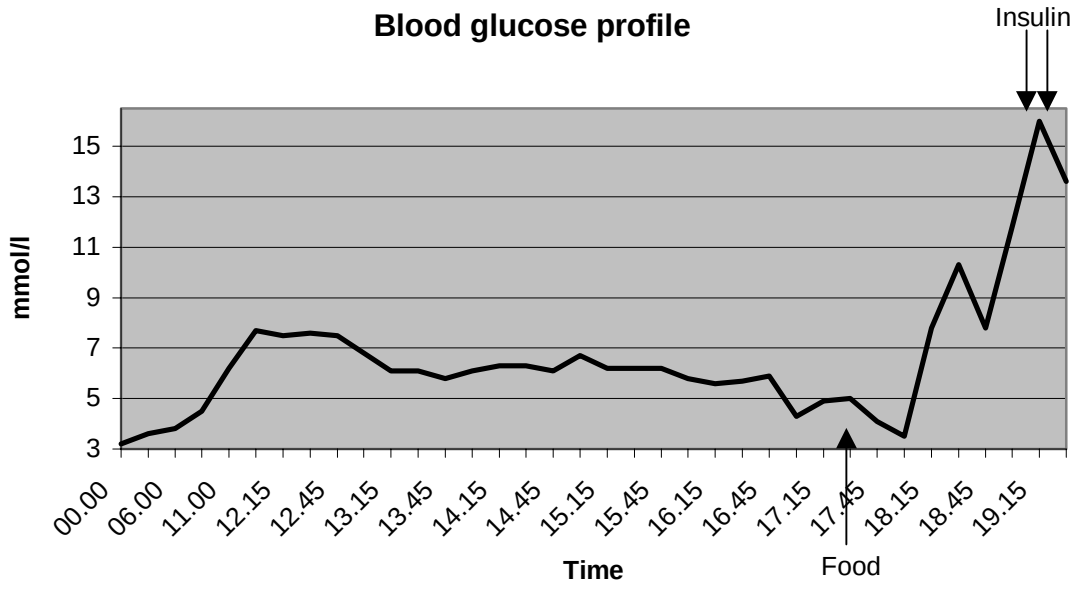
99-01-08:

Time:	Glucose:	Urine test:	Food / Activity / Insulin:
18.00 – 20.00			Very intensive sport-activity. Ate much before and during. Didn't feel well afterward, probably because drops and rises in glucose.
22.00			High glucose. Took extra insulin, 5 U.

99-01-09:

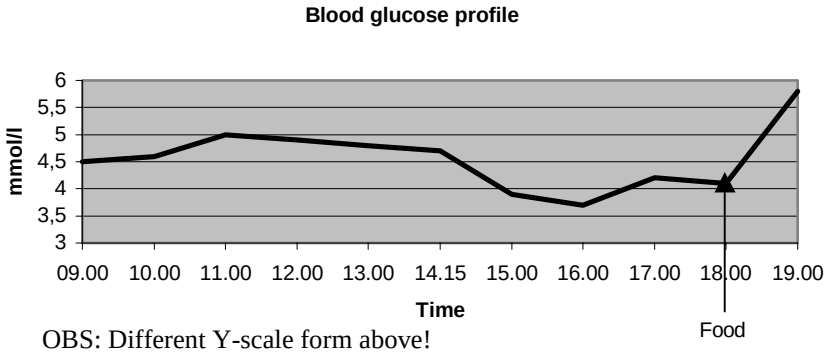
Time:	Glucose:	Urine test:	Food / Activity / Insulin:
00.00	3.2 mmol/l		Supper; tea, and three breads. 11 U. Also the intermediate-acting insulin – 38 U
02.20	3.6 mmol/l		Feeling all right.
06.00	3.8 mmol/l		
06.30	4.5 mmol/l		
11.00	6.2 mmol/l	– / –	
12.00	7.7 mmol/l	– / –	
12.15	7.5 mmol/l		
12.30	7.6 mmol/l		Very hungry!
12.45	7.5 mmol/l		
13.00	6.8 mmol/l	– / –	
13.15	6.1 mmol/l		
13.30	6.1 mmol/l		
13.45	5.8 mmol/l		
14.00	6.1 mmol/l	– / –	
14.15	6.3 mmol/l		
14.30	6.3 mmol/l		
14.45	6.1 mmol/l		
15.00	6.7 mmol/l	– / –	
15.15	6.2 mmol/l		
15.30	6.2 mmol/l		One diet coke
15.45	6.2 mmol/l		
16.00	5.8 mmol/l	– / –	
16.15	5.6 mmol/l		Not hungry any more.
16.30	5.7 mmol/l		
16.45	5.9 mmol/l		
17.00	4.3 mmol/l	– / –	
17.15	4.9 mmol/l		
17.30	5.0 mmol/l		
17.45	4.1 mmol/l		Aborting. Ate supper.
18.00	3.5 mmol/l	– / –	
18.15	7.8 mmol/l		
18.30	10.3 mmol/l		
18.45	7.8 mmol/l		
19.00	11.8 mmol/l		
19.15	16.0 mmol/l		Insulin – 8 U Humalog©
20.00	13.6 mmol/l		Insulin – 4 U Humalog©

And here is a diagram that shows 99-01-09:



I must confess that this profile really confuses me. This shows quite a normal profile. Let us compare to my fellow student, Adam's profile. It should be mentioned that neither of us made any physical work or participating in any strong activities during the day of the experiment.

Time:	Glucose:
09.00	4.5 mmol/l
10.00	4.6 mmol/l
11.00	5.0 mmol/l
12.00	4.9 mmol/l
13.00	4.8 mmol/l
14.15	4.7 mmol/l
15.00	3.9 mmol/l
16.00	3.7 mmol/l
17.00	4.2 mmol/l
18.00	4.1 mmol/l
19.00	5.8 mmol/l



OBS: Different Y-scale form above!

It should be noted that Adam took the glucose test once an hour, while I took every quarter of an hour. This could have the effect that his profile looks straighter. But it is any way a very interesting study. How come my glucose level could keep so low, without insulin?

One answer might be that the Monotard©, the intermediate-acting insulin that I took the night before held it down. That insulin should work for about 25 hours with decreasing effect, and the dose is supposed to be approximately 50% of the total insulindose of a day. The idea is that this insulin should cover the basic need, and the conclusion of this test is that it actually does, it keeps the glucose down, and the only time I need insulin is when I want to eat. When I later talked to Dr. Johansson, he said that he had met two American diabetics that some two times a year used to fast to adjust the intermediate-acting insulin.

Another reason might be that I still have insulin production. This could be a reason why; at 13.00 the glucose level drops about two mmol/l, and also keeps the glucose level down during the afternoon when the intermediate-acting insulin stops working.

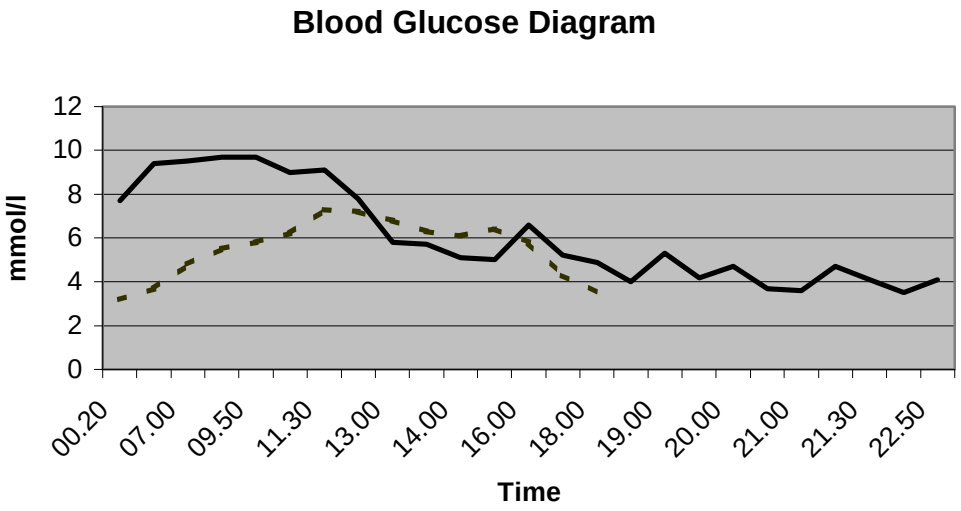
Third possible reason may be the physical activity the night before. The effect of any physical activity is that I become more insulin-sensible, the same amount of insulin will have a greater effect on the glucose level. This is of course not good for the experiment. But it shows that it is good to exercise, it will keep the blood glucose down and you don't need to take that much insulin.

Well, I must confess once again that I am very confused and surprised about the test-results, but it gives me a major problem; what am I going to do in the next experiment? I was going to take insulin, but according to this profile, I can't, there is no need to take any insulin, the glucose level is already low. So I decided to once again do the same experiment, to verify the diagram.

Now, over to Adam's profile. I'm a little confused that the glucose level rose around ten o'clock. In my opinion and prediction, it should drop and stay low, since he didn't eat and needed no energy. He told me that he had been working all day long, of course he was a little tired and hungry, but he managed to do quite a lot.

A very interesting observation is that the profile of my fellow student has a decrease around four o'clock. The most probably reason is that the body usually get food at that time, so it starts to produce insulin to take care of the not coming food.

Here follows a diagram of the blood glucose the second experiment, data on next page. You can see the Day one experiment diagram as the dots.



Second day

without insulin

99-01-13:

Time:	Glucose:	Urine test:	Food / Activity / Insulin:
00.20	7.7 mmol/l		
03.40	9.4 mmol/l		
07.00	9.5 mmol/l	- / -	
08.45	9.7 mmol/l		
09.50	9.7 mmol/l		
10.50	9.0 mmol/l		
11.30	9.1 mmol/l		
12.40	7.8 mmol/l		
13.00	5.8 mmol/l		
13.30	5.7 mmol/l		
14.00	5.1 mmol/l	- / -	
14.30	5.0 mmol/l		
16.00	6.6 mmol/l		
17.10	5.2 mmol/l		
18.00	4.9 mmol/l		
18.30	4.0 mmol/l		
19.00	5.3 mmol/l	- / -	
19.40	4.2 mmol/l		
20.00	4.7 mmol/l	- / -	
20.30	3.7 mmol/l		
21.00	3.6 mmol/l	- / -	
21.15	4.7 mmol/l		
21.30	4.1 mmol/l		
21.40	3.5 mmol/l		
22.50	4.1 mmol/l		11 U, Supper

This was a normal day for me. I went to school as normal, but did not manage to keep concentrated all the time. The trend is the same as in the last example, rise about noon and then falling down towards 4.0 mmol/l and stayed there. This experiment only verifies the last one, although I did not exercise as I did last time.

Conclusion

So, now I have fasted for two days, and taken about 70 – 80 glucose tests, and the result was, for me compleately unpredictable, and so also for my doctor who I consulted. He even said that he wanted to send the data to an international famous scientist, Johnny Ludvigsson, who is a professor in Linköping.

Then, what is the conclusion? Well, first of all I am surprised that I got this far. I never thought that I would make it through a whole day without direct-insulin or food. Now I know that in case of emergency, I can handle a situation like this. I have also come to the conclusion that it is very important to take the intermediate-acting insulin every night. If I forget to take it, it will mean that the whole system is changed and that can lead to devastating results.

An interesting detail that I noticed was that the body can get used to certain patterns, like meals. It was quite clear on my fellow student's diagram that about four o'clock, when he used to eat, the body started to produce insulin and the blood glucose dropped.

Although it was difficult and sometimes annoying to do this experiment, I found that it was important to have experienced it once. I have come to learn much about my diabetes and how the body works and doesn't work. I believe that I will be able to apply the knowledge that I have gained in real life.

Contact-addresses and references

to the companies that have been mentioned:

Lilly France SA, Rue du Colonel Lilly, 67640 Fegersheim, France. www.lilly.com

Novo Nordisk A/S, 2880 Bragsvaed, Denmark. www.novo.dk

Bayer Diagnostics: Bayer Sverige AB, Diagnostica, Box 5237, S-402 24 Göteborg, www.bayerdiag.com

Boehringer Mannheim GmbH, Wissenschaftliche Abteilung, Diagnostica, Sandhofen Strasse 116, D-6800 Mannheim 31, www.boehringer-mannheim.com

Dr. Calle Johansson, Barn- och ungdoms medicin mottagningen, Länssjukhuset Ryhov, Jönköping

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