Blood Glucose Testing

Diabetes makes many demands on the individual, not least of which is the need for frequent testing of blood glucose levels. In the early days, blood glucose testing was usually advised only for people with Type 1 diabetes. Nowadays, since the importance of blood glucose control has been fully realised, all people with diabetes are recommended to monitor their blood glucose levels at home on a regular basis.

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The Importance of Blood Glucose Monitoring

The main characteristic of diabetes is a higher than normal blood glucose level. This may cause distress and suffering in the short term, and can have a devastating effect over the long term.

The responsibility for your day-to-day diabetes care lies in your hands. The ONLY way that you can accurately* assess how well your treatment plan is working is to measure your own blood glucose levels at certain times throughout the day and, occasionally, in the night.

You will need commitment and a certain level of understanding. Testing your blood glucose should not be painful, but you may find it a nuisance; it is so often tempting not to bother. Frequency of blood testing is positively correlated with improved diabetic control so your perseverance should reward you with improved general well being and reduced risk of long term complications.

*HbA1c is often preferred by health professionals as the main indicator of blood glucose control in people with Type 2 diabetes, and especially those on no medication or on metformin only. See the blog post “Finger-prick blood glucose testing for Type 2’s” for further discussion.

Terminology

Blood samples

Blood is pumped around the body by the heart. The major vessels that take blood away from the heart are called arteries. The major vessels that take blood back to the heart are called veins. Between the two networks are many tiny blood vessels called capillaries. The composition of the blood in the three types of vessel varies slightly.

When a blood sample is taken by the doctor or nurse, it is taken from a vein and called a venous sample. At the laboratory, the blood may be analysed as it is, in which case it is a 'whole blood' measurement. Often the clear liquid part of the blood may be separated from the red blood cells. This yields either serum or plasma (depending on whether or not the blood sample in the tube is treated with a special reagent called an anticoagulant).

A serum or plasma measurement of glucose will give a result which is 10 - 15 % higher than a whole blood measurement.

When a home blood glucose test is performed, blood is usually taken from a finger-prick sample - this gives capillary blood. The measurement frequently used to be made on whole blood, although this has varied with the type of meter used. Now there is a move towards all meters giving plasma-calibrated results so that readings made at home and at the laboratory can be more easily compared - in other words, so they "mean the same".
Units of measurement

A blood glucose measurement will provide the concentration of glucose that is in your bloodstream; the result is given as the amount of glucose per unit volume (of whole blood/plasma/serum). Here in New Zealand, we use millimoles to measure the amount, and take a 'unit volume' of blood to be one litre. 'Millimoles per litre' is written mmol/l. In the US, and some other countries, milligrams are used to measure the amount and a decilitre is taken as 'unit volume'. 'Milligrams per decilitre' is written mg/dl. To convert from mmol/l to mg/dl, simply multiply the figure by a factor of 18.

'Normal' ranges and reference ranges

What is a 'normal range'? The simple answer would be the blood glucose levels maintained in all non diabetic people. In practise, normal ranges quoted from various sources differ. This is partly because it depends on the blood sample (see above) and partly because there is a good deal of variation within the general population and a grey area between 'normal' and 'diabetic' cut-off points.

Further confusing the issue, the figures you read may be intended as a guide to the diabetic person, rather than a definitive 'normal' range. For example, in the section 'Levels of control' it is suggested that people with diabetes should aim to keep their blood glucose tests above 4.4 mmol/l. This is not because you would be too low at 3.8 mmol/l, but because you may be sailing a little close to the wind if you are getting such results on a regular basis.

<table>
<thead>
<tr>
<th>Blood Glucose Level</th>
<th>NZ units millimoles per litre (mmol/l)</th>
<th>US units milligrams per decilitre (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good a</td>
<td>4.4 - 8.0 mmol/l</td>
<td>80 - 144 mg/dl</td>
</tr>
<tr>
<td>On the low side b</td>
<td>3.0 - 4.4 mmol/l</td>
<td>54 - 79 mg/dl</td>
</tr>
<tr>
<td>Too low b</td>
<td>&lt; 3.0 mmol/l</td>
<td>&lt; 54 mg/dl</td>
</tr>
<tr>
<td>(Hypoglycaemic)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too high a</td>
<td>&gt; 8.0 mmol/l</td>
<td>&gt; 144 mg/dl</td>
</tr>
<tr>
<td>(Hyperglycaemic)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Depends on time of test in relation to last meal and time of day (see 'Target ranges' below)

b Significant hypoglycaemia is usually 'defined' as a blood glucose level less than 3.0 mmol/l - however in practise most people will suffer symptoms at levels higher than this. The general recommendation is to treat for any reading below 4.0 mmol/l.
The Home Blood Glucose Test

Briefly, the home blood glucose test is performed by pricking the finger with a lancet and placing a drop of blood onto a test strip. Finger pricking is usually aided with a special spring-loaded device. The strip may then be read visually, by comparing it to a colour chart provided, or it may be read by a special meter. I recommend that a meter be used - they are accurate and reliable. People who have had laser treatment for diabetic retinopathy should not rely on colour charts, as colour vision may be impaired.

Equipment and Supplies

Lancets and test strips are usually available on prescription. Meters and finger pricking devices are available from local pharmacy stores, online, or direct from the manufacturers.

Top Tips for Testing

Skip the technical information and blurb if you want to*, but remember these simple rules for safe and effective blood testing.

*That said, there is one important feature of the CareSens meters that should be reiterated - you should always hold your meter so that the strip sucks your blood up in a vertical fashion. There are a number of useful videos that you can watch - available on the CareSens website - that will ensure that you are using the right technique and getting the most accurate results possible for these meters.
Blood Glucose Meters

Choice of meters available in New Zealand

There are a variety of different meters available at a variety of prices. Some meters have a memory which may store anything from 10 to 250 readings. Many now come with the option of downloading results from the meter into your home computer; special software enables you to look at test results and display them in graphs or charts.

In New Zealand, monitors for which subsidised test strips are available are currently limited to those described below.

The Medisense Optium meter also has the ability to test for blood ketone levels. The strips for this utility are subsidised, but patients are limited to 10 strips per 3 months. If more are required they will usually need to be purchased by the individual.

Meters can be obtained either directly from the marketing company, online, or through your local pharmacy.

<table>
<thead>
<tr>
<th>Meter</th>
<th>Marketed by</th>
<th>Also available from</th>
</tr>
</thead>
<tbody>
<tr>
<td>CareSens N</td>
<td>Pharmaco Ltd</td>
<td>Pharmacies</td>
</tr>
<tr>
<td>CareSens N Pop</td>
<td>Pharmaco Ltd</td>
<td>Pharmacies</td>
</tr>
<tr>
<td>CareSens II</td>
<td>Pharmaco Ltd</td>
<td>Pharmacies</td>
</tr>
<tr>
<td>Optium Xceed</td>
<td>Medica Pacifica Ltd</td>
<td>Pharmacies</td>
</tr>
</tbody>
</table>

How blood glucose meters work

Different meters use different test systems based on different technologies. There are, however, a number of common steps involved in the measurement process:

- Blood is applied to the test strip
- Chemical reaction(s) take place
- Outcome of the chemical reaction(s) is measured
- Measurement is translated into blood glucose reading
Variables

We make decisions based on the results of our blood glucose measurements - it is therefore important to us that the readings we obtain are true. What then, other than glucose, may affect the outcome of the test?

- **System variables:**
  - Batch-to-batch or strip-to-strip variation of strips
  - Meter-to-meter variability
    (also see section on 'Calibration' below)

- **Testing variables:**
  - Environment - temperature, humidity, altitude
  - User - technique (note hands should be dry and clean before finger-pricking), timing

- **Patient variables:**
  - Blood sample - capillary or venous, red blood cell count
  - Dehydration of the patient

Extreme hypo- or hyperglycaemia (if the blood glucose level falls outside the working range of the meter a 'LO' or 'HI' message will usually be displayed)

Calibration

Each pack of test strips usually comes with a special 'calibration code'. This is a correction factor for the meter which is derived by comparing meter response with a standardised laboratory assay or 'reference method'. For accurate readings it is essential that the meter is recalibrated between batches of strips.

If you choose to check the accuracy of your meter using a 'quality control' solution then you must use one specially formulated by the meter manufacturer. It may be easy enough to make up a standard solution with known concentration of glucose; unfortunately though, such home-made standards, usually water-based, do not behave the same way as blood on the test strip.
When to Test ... and How Often

There are no hard and fast rules governing blood glucose monitoring - when and how often you test will largely depend on you, your treatment plan and your lifestyle. Understanding why you are testing your blood glucose level will help you in establishing some kind of routine.

Why test at all?

The benefits of keeping blood glucose levels as near normal as is possible can never be overemphasised. Good control will help you in both the short and the long term. Good control for many people with diabetes means avoiding hypoglycaemia as well as hyperglycaemia.

You cannot reliably judge your blood glucose levels on how you feel. Testing your urine may be convenient in some circumstances but it provides too little information to base realistic treatment decisions upon. A negative test is of no value in determining hypoglycaemia. A positive reading does not tell us how high the blood glucose level is (or was).

The only accurate way of measuring your day-to-day control is to measure your blood glucose levels.

However, it is important that you understand we do not test purely to verify that control is OK. Achieving control is an ongoing process with continuing adjustments in people with all types of diabetes.

We test to achieve and maintain control.

When to test

In relation to a normal daily routine, the important times for testing blood glucose levels are as follows:

- First thing in the morning ('fasting')
- Before meals
- 1-2 hrs after meals ('postprandial')
- At bedtime
- During the night

In addition, you should test if you have done, or are about to do, something different from your daily routine. Such circumstances might include:

- Different food types from usual
- Changed mealtimes
- Unplanned exercise
- Under unusual amounts of stress
- On holiday
If you are feeling unwell, or if you are aware of some symptoms of hypoglycaemia then you should always check your blood glucose level.

**How often to test**

The previous section suggests that you should be testing your blood glucose level every minute of every day - this is definitely not necessary! These are key times which, together, over time, provide an informative picture of your day-to-day blood glucose levels. You and your health care team should establish a pattern of blood glucose monitoring which is appropriate to you, your diabetes and your lifestyle.

**Type 1 diabetes**

People with type 1 diabetes often find that their blood glucose levels fluctuate wildly and often for no 'apparent' reason. If you fall into this category then you may find that frequent blood glucose testing may help identify lifestyle problems. At the very least, it should help you to stay on top of the situation.

Those people, who are particularly active or lead a variable lifestyle with irregular meals, will usually need to test frequently in order to avoid serious or repeated episodes of hypoglycaemia.

Bedtime tests are especially important in order to avoid hypoglycaemia during the night. The occasional test in the early hours (e.g. 3 am) is often beneficial in discriminating high morning readings:

- Some people sleep through hypoglycaemia in the night and awake to a high blood glucose; this is because the liver may eventually be stimulated by adrenaline to release stored glucose in the blood.
- Some people awake to a high blood glucose because they suffer from the 'dawn effect'. Again, this is due to the liver releasing stored glucose, this time in response to nocturnal production of hormones such as cortisol and growth hormone.

**Type 2 diabetes**

People with type 2 diabetes generally do not need to test quite so often because blood glucose levels tend not to fluctuate. Fasting and postprandial (after meal) results are important. Use blood glucose testing to find out the effects of various different foods and/or combinations - you may be surprised at the results!

For a discussion of around blood glucose testing for people with Type 2 see the blog page “Finger-prick blood glucose testing at home - for Type 2’s”.
**Illness**

If you are unwell or have an infection of some sort then you should test more frequently. Blood glucose levels can rise to dangerously high levels very quickly when the body is under severe stress from illness. Some people with type 2 diabetes may even require insulin for a short period until the illness has cleared. People with type 1 diabetes are at high risk of diabetic ketoacidosis or DKA when they are suffering from illness. It is therefore imperative that blood glucose levels are monitored closely at such times.

**Your Test Results**

**Target ranges**

What sort of levels should you be aiming for then? This will depend on a number of factors including the following:

- Your age and lifestyle and home circumstances
- Whether the reading is fasting, postprandial or at bedtime
- Whether you are pregnant
- Whether you suffer from hypoglycaemia unawareness

Together, you and your diabetes care team should determine what sort of levels you should be aiming for and when.

Here are some general guidelines:

<table>
<thead>
<tr>
<th></th>
<th>Before meals</th>
<th>1 - 2 hr after meals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceptable control</strong></td>
<td>4.4 - 7.0 mmol/l</td>
<td>&lt; 10 mmol/l</td>
</tr>
<tr>
<td><strong>Good or intensive control</strong></td>
<td>4.4 - 6.0 mmol/l</td>
<td>&lt; 8.0 mmol/l</td>
</tr>
</tbody>
</table>

Bedtime tests should ideally be between 6.0 and 7.0 mmol/l to reduce the risk of nocturnal hypoglycaemia.
Recording your test results

The value of blood glucose testing is limited unless records are kept. Ideally, your records should include accurate times of tests, in relation to the amount and timing of food, physical activity and other variables, such as stress levels or other illness.

Keeping records can be painstakingly tedious. It is easy to defer writing things down until the end of the day, the end of the week... Accurate records are essential if appropriate treatment decisions are to be based on them and for this reason I fully recommend you write down relevant information at the time; don't leave it for later if you can help it.

Using your test results

For blood glucose monitoring to be a worthwhile exercise you must learn how to use your test results to improve or maintain your diabetes control. Making a note of all the variables will help you to make sense of your blood glucose test results.

Your Diabetes Team should provide you with guidance as to how to interpret your test results and what to do about highs and lows.

- Look for patterns or trends in your blood glucose level.
- Consider the amount, type, and timing of food that you eat, in relation to medication (tablets or insulin), exercise and blood glucose level.
- Don’t worry about the occasional high or low, but try to figure out why unexpected readings may be occurring.
- Repeated patterns of highs or lows suggest that the treatment regimen needs altering. This might necessitate a change in medication or diet, or an adjustment for activity levels.