Monitoring glucose and ketones

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Monitoring glucose and ketones

Monitoring diabetes includes aspects of diet, physical activity, clinical signs and symptoms as well as glucose and ketones. Optimal glucose and ketone levels and adequate management of other cardiovascular risk factors are important for;

> reducing the risk of development of complications in people with type 1 diabetes, type 2 diabetes and gestational diabetes mellitus (GDM)
> health and a sense of well-being for the individual
> normal growth and development in children and adolescents
> normal outcomes of pregnancy
> lowering the incidence of illness and hospitalisation.

The purpose of this publication is to identify where and when it is appropriate to monitor glucose and ketones, establish guidance in relation to the use of meters, outline appropriate education requirements and offer additional monitoring methods available.

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Background
The Diabetes Control and Complications Trial\textsuperscript{1} and the United Kingdom Prospective Diabetes Study\textsuperscript{2} have provided clear evidence of the beneficial effect of intensive therapy in people with diabetes.

More recent studies have emphasised glucose monitoring as an important component of intensive therapy, particularly for people requiring or dependent on insulin and those taking oral diabetes medication that have a hypoglycaemia risk.

For patients with type 1 diabetes, monitoring glucose and ketones decrease the risk of both micro and macrovascular disease.\textsuperscript{3} The effectiveness of glucose monitoring in patients with type 2 diabetes who do not use hypoglycaemic agents is less certain.\textsuperscript{4}

Glucose - understanding the monitoring methods
Glucose can be measured in capillary or venous blood or in interstitial fluid. Capillary blood glucose (BG) measurements are most commonly used in the hospital, home and community setting for the identification of real time measurements.

Usual times for measurements in the well person with diabetes include;

\begin{itemize}
\item \textbf{fasting} - usually taken after an overnight fast of about 8-12 hours
\item \textbf{random} - taken at any time during the day
\item \textbf{pre-prandial} - taken directly before meals can be written as \textquoteleft before meals\textquoteright
\item \textbf{post-prandial} - taken approximately two hours after a meal.
\end{itemize}

In addition, BG measurements can be done at any time to identify concerns or problems (eg suspected hypoglycaemia or hyperglycaemia).

Samples

\textbf{Whole blood}

\begin{itemize}
\item Has 10-15\% less glucose than plasma because the sample contains blood cells which means less serum (thus less glucose). Meters are calibrated to provide plasma glucose equivalent results to correlate with laboratory methods.
\item Capillary whole blood samples are recommended for hospital wards or self BG monitoring tests.
\end{itemize}

Recent innovations in meter technology allow the measurement of BG from sites other than the capillary bed of the fingertip (eg forearm). However, clinically significant variations in samples obtained from the fingertips and those from the forearm have been identified.\textsuperscript{5, 6} Alternative sites to the fingertips are not recommended and should be avoided when glucose is likely to be fluctuating (eg during illness, post meal or hypoglycaemia).

\textbf{Plasma}

\begin{itemize}
\item Is obtained by centrifugation of anticoagulated whole blood and has a 10-15\% higher glucose value than whole blood because there is a greater serum volume.
\item Venous plasma is usually tested in laboratories.
\end{itemize}

\textbf{Interstitial}

\begin{itemize}
\item Continuous glucose monitors and flash glucose monitoring systems measure the glucose level of interstitial fluid. The results are reported as sensor glucose (SG) not BG.
\item Glucose levels in interstitial fluid lag behind BG values. SG lag time has been reported to be about 5 minutes with some users of the various systems reporting lag times of up to 10-15 minutes.
\end{itemize}
For more technical information about sample choices and information about interference with BG measurements visit the Australian Point of Care Practitioners Network (APPN) website.

**Capillary blood glucose monitoring**

Monitoring BG in people with diabetes in the hospital setting facilitates timely therapeutic decision making, which can improve diabetes management and conceivably shorten length of hospital stay, support discharge or prevent re admission in some cases.

Monitoring may also occur in a variety of community settings (e.g., community health, private medical practices and diabetes services, aged and disability residential care, emergency care, child care, school, workplace, sporting field, and correctional services) and at home may assist in the management of all types of diabetes.

Self-monitoring of glucose and ketones assists to reinforce beneficial health behaviours and increase adherence with medication. The real-time results identify short-term BG patterns and assists day to day decisions and in specific circumstances (e.g., hypoglycaemia, hyperglycaemia and during illness).7, 8

It is important that BG meters are used appropriately:9

> Research does not support their use in screening for or diagnosis of diabetes.
> Use in screening and diagnosis at point of care may be acceptable in some situations e.g., remote communities where laboratory testing is unavailable or delayed.
> Outside the acute clinical setting, BG meters can only be used to monitor levels in people with confirmed diabetes. BG monitoring is not recommended for people diagnosed with impaired fasting glucose or impaired glucose tolerance, nor are subsidies provided by the National Diabetes Services Scheme to these persons.
> Capillary samples should not be independently used for BG in critically ill patients with altered perfusion or conditions significantly affecting the normal ratios of plasma constituents. Poor peripheral perfusion or other factors (e.g., peripheral vascular disease, hypotension or shock, dehydration, hypothermia, hyperglycaemic and hyper-osmolar states, oedema, and vasopressor treatment) may cause capillary samples to vary significantly from venous or arterial blood. In this situation, concurrent venous sampling is recommended on a blood gas analyser or in the laboratory.

**Blood glucose meters**

There are increasing numbers of BG meters now available. Each manufacturer provides instructions and quality control recommendations specific to the meter. The manufacturer’s recommendations must be followed for reliability of results.

Many factors may affect the accuracy of results. Strategies to limit variability in BG measurements include;

> routine maintenance of equipment and performance of quality control
> correct storage of meter and protection from extremes in temperature and humidity
> correct storage of strips and protection from extremes in temperature and humidity
> use of in-date strips
> clean and dry hands
> appropriate lancet equipment
> being aware of patient specific interferences that can affect the meters accuracy (e.g., very high or low haematocrits, drugs, other substances such as triglycerides, vitamin C).
Using blood glucose meters in health care settings

Changes in diabetes management (eg diet, physical activity and medication, (tablets and/or injectables)) are made on the basis of meter results and therefore health professionals must feel confident that the equipment is part of an endorsed quality assurance program which includes internal and external quality control testing.

The Australian Diabetes Educators Association (ADEA) Position Statement states that:9, 10

> Health professionals should only use BG meters after successfully completing an education program that encompasses competency in meter operation, control testing and problem solving.

> Quality improvement programs should be implemented in all clinical settings to ensure equipment and operators meet high standards of performance and process.

All health services using meters should provide;9

> a well-defined policy and procedure
> a training program for staff performing the tests
> quality improvement procedures
> regular equipment maintenance
> external auditing of meters

> appropriate lancing devices that meet infection control guidelines (eg single use and completely disposable).

In SA Health, the choice of meter is defined by a procurement directive. In non SA Health services it is recommended that only one type of meter is available for routine use. This reduces the complexity for operators who may work in different sections of a health service.

Staff competency

Only staff trained and competent in the use of the approved meter should perform the tests.

An accreditation program may include;

> a short answer test on the use of the meter including interpretation of BG results
> an assessment of the persons technique using the meter
> accurate testing with internal quality control solutions.

Accreditation is mandatory on gaining employment within CHSA and in most health care settings. Requirements for re-accreditation each year thereafter vary.9 To find out how staff can be accredited consult your diabetes educator or diabetes resource/link staff member.

Accreditation and up skilling for CHSA staff can be accessed free of charge at the ICCnet CHSA website. The Australian Point of Care Practitioners Network (APPN) aims to provide training, certification and professional development for all point of care testing operators.
CHSA Blood Glucose Monitoring Chart (MR59H)
The Blood Glucose Monitoring Chart (MR59H) recommends BG tests according to frequency medical instructions. The target BG range is 5-10mmol/L unless modified by the relevant Rapid Detection and Response (RDR) Observation Chart. Actions are initiated according to the colour zone:

> Treat all BG less than 4.0mmol/L using the CHSA Hypoglycaemia Protocol.

> Notify medical officer when BG and/or ketones are in the red zone or two consecutive BG readings are greater than 15.0mmol/L.

> Trigger senior nurse review when BG and/or ketones in yellow zone and increase monitoring frequency.

> Obtain medical emergency team response if patient is unconscious, unsafe to swallow, or BG remains less than 4.0mmol/L after 45 minutes.

If in the event the BG was not tested before the meal, documentation must identify the actual time the BG was taken (eg 30minutes post meal).

Standard precautions
Follow standard precautions for all BG monitoring. Remember when handling body fluids, treat all fluids as potentially infective. Ensure that blood testing technique does not increase the risk of infection from blood products.
Recommendations:11

1. Perform hand hygiene as per the 5 moments of hand hygiene guidelines (Hand Hygiene SA, SA Health).
2. Wear disposable gloves when performing or teaching BG monitoring.
3. In some cases, consider the use of safety glasses when performing BG monitoring.
4. If possible, do not over squeeze the patient’s finger to produce an adequate drop of blood. If needed, allow the patient to apply gentle pressure to their own finger. Make sure the finger is pointed downwards to reduce the chance of blood squirting upwards.
5. Dispose of all sharps into sharps container.
6. **Immediately** dispose of all other materials that have been contaminated with blood into general waste.
7. Lancing devices for health service use must be fully disposable, single use and have retractable lancet.
8. Ensure work area and surfaces are cleaned and all traces of blood removed.
9. Perform hand hygiene as per Step 1.

**Quality control**

All meters are potentially inaccurate and the reliability of any test also depends upon the quality of the equipment, basic quality assurance systems and the skill and experience of the person performing the test.

Quality control management practices are therefore required and should reflect the manufacturer’s recommendations as well as organisation’s processes and procedures.

Involvement in a quality control program is an important part of any BG monitoring system. The following terms are frequently used when defining quality control and BG monitoring.

**Internal**: internal quality control using control solutions with a known value assists checking the integrity of strips and monitor reagents, operator performance, and device reliability. It is recommended the results be documented and regularly checked, and corrective action taken when necessary

**External**: external quality assurance involves testing samples of an unknown result. The result obtained is compared to results obtained using an identical sample at other sites. It is recommended that this is done once a month.9

**Accuracy**: agreement between results obtained for the sample and its true value.

**Precision**: agreement between repeated tests on the same sample.

**Acceptability**: when a test result lies within acceptable intervals (for glucose testing, this is usually + or - 20% of the true value).

**Quality assurance in an acute care setting**

In a hospital environment it is recommended that an internal quality control test be performed at the following time;9,12

- every 24 hours
- each time a new bottle of strips is opened
- if the meter is dropped
- when the batteries are changed
> LCD screen is blank or parts of the display (eg letters/numbers) are missing
> if the BG result is unexpected
> if BG results are abnormally high or low.

Internal quality control solutions are available for each type of meter and they contain a predetermined glucose concentration. The test result must be within the range specified for the meter and strips being used. The test should be documented and records of quality control records should be kept for 7 years.13 If the internal control test is out of range, the meter should not be used until the control test is back in range or a replacement meter must be sought.

A quality control policy for Country SA meters can be found on the ICCnet website. Any queries can be directed to the ICCnet office on 08 7117 0600.

**Quality assurance in a community setting**

In people who self monitor at home, quality control solutions are recommended to ensure reliable and accurate results. Support must be provided to encourage the person to maintain monitoring standards and assistance provided so that they can purchase quality control solutions from the National Diabetes Services Scheme.

Alternatively, people can request that their meter be checked periodically at their local Diabetes Service, Pharmacy or local Diabetes Australia organisation.

**Self blood glucose monitoring in hospital**

People with diabetes can be encouraged to perform self BG monitoring if they have access to a meter that they usually use at home. However, it is recommended that the:

> nurse observes and documents a quality control check of the meter
> nurse observes the patient test the BG and assess for correct technique
> patient uses a fully disposable, single use retractable lancet to prevent needle stick injuries to staff.

If the above criteria cannot be met, then patients should have their BG tested using the hospital meter. Due to the increasing number of meters and various techniques, hospital staff may not be familiar with the person’s particular meter and may be unable to access correct control solutions. Meter company representatives or the local diabetes educator can provide information to assist.

Aim for target BG range (BGL) 5.0 - 10.0mmol/L.14 For further information on blood glucose and ketone monitoring in a hospital setting, refer to the Evidence Summary ‘Hospitalisation’.

**Special circumstances**

Some meters use strip technology that is more appropriate for certain clinical situations.

In patients on peritoneal dialysis, extreme care should be taken when using icodextrin (Extraneal®) or intravenous immunoglobulin preparations such as Intragam®

Icodextrin (Extraneal®) has been identified as causing falsely elevated BG in tests strips that use either glucose dehydrogenase pyrroloquinolonequinone or glucose-dye-oxidoreductase-based methods.

Intravenous immunoglobulin preparations containing maltose such as Intragam®, CMV Immunoglobulin and Tetanus immunoglobulin (for intravenous use) can also interfere with the readings performed using test strips with glucose dehydrogenase.

It is therefore essential to consult the product information and/or the manufacturer of the meter and test strip to ensure the appropriate meter is used.
Self blood glucose monitoring in the community

For people with type 1 diabetes, self blood glucose monitoring (SBGM) is an essential aspect of self-care as it is integral to the current standard of intensive diabetes management. In type 1 diabetes, people routinely test their BG 4 to 6 times a day usually before meals.\(^{15-17}\) (NB post prandial testing is most useful if the pre-prandial value is known. Testing pre and post enables assessment of glycaemic rise related to food and their mealtime insulin dose) Testing BG allows the person to adjust their insulin therapy based on their current BG and anticipated carbohydrate intake.

In type 2 diabetes, the NHMRC guidelines suggest that self-monitoring should be considered for all people but the decision to and the frequency and timing of measurements should be individualised.\(^{18}\) For people with non-insulin treated diabetes, structured SBGM may lead to improved glycaemic control.\(^{19-21}\) There is clear benefit to support BG monitoring in people with type 2 diabetes who require insulin.\(^{16}\)

It is important to recognise that SBGM is only one part of a larger diabetes management strategy. Therefore SBGM is only valuable if there are appropriate actions that occur when the BG is out of the target range. Actions need to be not only taken by the person themselves but also the healthcare provider is responsible for appropriate and timely treatment changes.

It is clear from the research that health care professionals should have an individualised and targeted approach to SBGM. Appropriateness for SBGM should take into consideration the following points:\(^{9}\)

> type of diabetes
> co-morbidities
> age
> culture
> dexterity
> physical and intellectual capabilities
> identified glycaemic targets
> current medication regime
> potential confounders that may interfere with accuracy.

Important principles

> SBGM in the home and community setting (e.g. community health, private medical practice and diabetes service, aged and disability residential care, emergency care, child care, school, workplace, sporting field, and correctional services) can be helpful in assessing day to day glucose control.

> SBGM should be used in the management of all pregnant women with diabetes and all people on insulin therapy.

> SBGM is recommended for all people at risk of hypoglycaemia (e.g. taking sulphonylureas or insulin).
Patients with type 2 diabetes who are diet controlled or on metformin alone can be provided with the option of BG monitoring. If they choose not to SBGM then it is important that they are informed of the need for 3 to 6 monthly HbA1c tests as this will be the only measure of glycaemic control.

Patients with type 2 diabetes not using insulin can obtain an initial six month supply of subsidised blood glucose test strips on registering with the National Diabetes Service Scheme (NDSS). After six months, further access to subsidised test strips will be granted if clinically necessary (eg inter-current illness or undergoing treatment that may adversely affect blood glucose control, diabetes inadequately controlled or there has been a change to the patient’s existing diabetes management within the previous three (3) months.

Quality control solutions are recommended for use by people who self monitor to ensure reliable and accurate results. Support and resources must be provided to encourage the person to maintain monitoring standards. Alternatively people may be able to go to their local National Diabetes Service Scheme (NDSS) Pharmacy, Diabetes Australia organisation or local Diabetes Service to have their meter quality control checked.

Participation by the person has potential to increase self-responsibility therefore self-care.

It is important to ensure that the person has the correct technique when using their meter and that the meter is providing accurate results.

Patients who test their own blood should not share their lancing device with anyone else.

All people need clear BG targets and action plans for hypoglycaemia, hyperglycaemia and sick days (eg illness).

**Education for the person who wishes to self blood glucose monitor**

It is important that the person receives education and care pertaining to the;

- correct technique
- target BG levels
- self-management behaviours such as diet, physical activity, medications, stress and illness and the impact on BG
- recognition and interpretation of clinical signs and symptoms
- and when to seek help.

**Education required:**

- appropriate choice of meter
- use of the individual meter
- correct skin preparation of the testing site (eg hand washing)
- calibration and checking procedures
- care of meter and quality control procedures (as per manufacturer’s instructions)
- problem solving of meter action and function
- recording and interpretation of results
- specific frequency and times to perform blood tests and the circumstances that indicate additional testing is required
- individual target ranges for capillary BG to enable the interpretation of results
- what to do and who to notify if BG is outside of the target range
- safe use and disposal of used lancets
where and how to purchase supplies, including the NDSS
> care of blood testing strips
> additional meter features if appropriate (eg averages and electronic download)
> information on the warranty process and customer service.

‘Smart’ blood glucose meters

‘Smart meters’ may assist those treated with basal and or multiple daily injections (MDI) in determining an appropriate basal-acting insulin and rapid-acting insulin dose based on their current BG, physical activity and planned carbohydrate intake.

A variety of clinical information and parameters must be discussed by the multi-disciplinary team and entered manually into the meter.

‘Smart’ BG meters for basal-acting insulin titration require the starting basal-acting insulin dose and the following agreed information to be programmed:

> maximum titrated dose
> low end of fasting target range
> high end of fasting target range
> number of days to average for titration period
> units to add or subtract when titration occurs
> night time check hypoglycaemia limit.

‘Smart’ BG meters for bolus-acting insulin titration require the following agreed information to be programmed:

> insulin to carbohydrate ratio (ICR)
> insulin sensitivity factor (ISF), also referred to as a correction factor
> target range of BG
> postprandial rise and target range of BG
> insulin action time.

The ICR, ISF and target BG may vary for different time periods across the day.

Several key requirements must be completed prior to any person with diabetes being provided with basal or bolus insulin calculator features. These include:

> a signed medication authorisation by a medical officer or nurse practitioner
> completion of detailed carbohydrate counting education with a dietitian
> demonstration of an understanding of how the basal and bolus insulin calculator meter calculates recommended doses.

Whilst many health care professionals are competent in the use of blood glucose meters, there are many meters available. A Credentialed Diabetes Educator is recommended in the training for people with diabetes to use a blood glucose meter.
When to test blood glucose?

Fasting values reflect overnight BG control and is affected by how sensitive the liver and body cells are to insulin (insulin resistance).

Pre-lunch and pre evening meal BG are affected by factors such as diet, physical activity and diabetes medication (tablets and/or injectables). Fasting and pre-meal testing is recommended as first line monitoring as other (eg post-prandial) readings will automatically be elevated if fasting and pre-meal readings are high.

Values at two hours post-prandial reflect peak BG which is affected by factors such as carbohydrate eaten, gastric emptying, insulin resistance, medications and illness.

Indications for extra BG monitoring outside of pre-prandial (particularly before breakfast and evening meal);

> type 1 diabetes
> HbA1c being lower or higher than expected from the existing BG profile (because of possible hidden hypo or hyperglycaemia)
> unstable BG, particularly those prone to hypoglycaemia before the next meal
> hypoglycaemia, particularly in those with impaired hypoglycaemia awareness.

Blood glucose targets in the community

Regardless of whether the person is testing BG at home it is important for the health care team to determine safe glycaemic targets and ensure that the person with diabetes understands their individual target. Individualisation of glycaemic targets (HbA1c and its corresponding glucose level) is based upon the following factors;22

> type of diabetes and its duration
> pregnancy
> diabetes medication (tablets and/or injectables)
> presence of cardiovascular disease
> risk of and problems from hypoglycaemia
> co-morbidities
> elderly
> living alone
> limited life expectancy.

BG control should be optimised because of its beneficial effects on the development and progression of microvascular complications. However, the potential harmful effects of optimising BG control in people with type 2 diabetes should be considered when setting individual glycaemic targets.18

The guidelines recommend target BG as close to normal as possible and individualised on the person’s risk profile.
Type 1 diabetes

The table below is provided by the Australian Diabetes Society National Evidence-Based Clinical Care Guidelines for Type 1 diabetes in Children, Adolescents and Adults (2011).

<table>
<thead>
<tr>
<th>Time</th>
<th>Target BG Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before breakfast</td>
<td>5.0 – 7.0mmol/L</td>
</tr>
<tr>
<td>Before other meals</td>
<td>5.0 – 7.0mmol/L</td>
</tr>
<tr>
<td>2 hours after meals</td>
<td>5.0 – 10.0mmol/L</td>
</tr>
<tr>
<td>Before bed</td>
<td>6.0 – 10.0mmol/L</td>
</tr>
<tr>
<td>Before driving</td>
<td>Above 5mmol/L</td>
</tr>
<tr>
<td>3am</td>
<td>5.0 – 8.0mmol/L</td>
</tr>
</tbody>
</table>

Low BG (hypo) below 4.0mmol/L

* For most people with type 1 diabetes, it is recommended that BG be as close to normal (fasting 5.0-7.0mmol/L) as possible to reduce the risk of long term complications.

** For infants and young children with diabetes, BG targets may be set higher.

*** For patients with type 1 diabetes who are planning a pregnancy or who are pregnant, BG targets may be set lower.

**** For some people with type 1 diabetes with cardiovascular disease, hypo unawareness, older frail, or other co morbidities, BG levels will need to be modified.

Type 2 diabetes

The Royal College Australian of General Practitioners - General practice management of type 2 diabetes 2016-20 recommends BG monitoring for patients with type 2 diabetes:

- on insulin and oral hypoglycaemic agents (OHAs) that can cause hypoglycaemia
- when monitoring hyperglycaemia arising from illness
- with pregnancy and pre-pregnancy planning
- when changes in treatment, lifestyle or other conditions require data on glycaemic patterns
- when HbA1c estimations are unreliable (eg haemoglobinopathies).

<table>
<thead>
<tr>
<th>Time</th>
<th>Target BG Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting and before meals</td>
<td>6.0 – 8.0mmol/L</td>
</tr>
<tr>
<td>2 hours after meals</td>
<td>6.0 – 10.0mmol/L</td>
</tr>
</tbody>
</table>

Low BG (hypo) below 4.0mmol/L

Routine SMBG for people with type 2 diabetes who are considered low risk and using oral glucose lowering drugs (with the exception of sulphonylureas) is not recommended.
Diabetes in pregnancy

The Australian Diabetes in Pregnancy Society and SA Maternal and Neonatal Clinical Network (2014) recommends BG monitoring for women with pre-existing diabetes or gestational diabetes mellitus.

<table>
<thead>
<tr>
<th>Time</th>
<th>Target BG Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before breakfast</td>
<td>&lt;5.0mmol/L</td>
</tr>
<tr>
<td>2 hours after meals</td>
<td>&lt;6.7mmol/L</td>
</tr>
<tr>
<td>Low BG (hypo)</td>
<td>below 4mmol/L</td>
</tr>
</tbody>
</table>

For further information on diabetes mellitus and gestational diabetes, visit the Australian Diabetes in Pregnancy Guidelines and South Australian Perinatal Practice Guidelines.

People should be encouraged to talk to their doctor or credentialled diabetes educator about their individual BG targets. People need to be able to adjust the times and frequency based on their current situation and this is often the result of a joint decision of the individual and their medical practitioner, diabetes specialist and diabetes educator.

**Remember the following points when working with people who are BG monitoring at home:**

> Monitoring is only meaningful if the person knows what the BG target is.

> Monitoring is only useful as a self-management tool if people can interpret their BG results and work out what has caused high / low BG so they can take remedial action to bring BG back into target.

> The person needs to understand that how they feel is not an accurate estimate of BG and not good enough evidence on which to base self-management decisions.

> Any self-monitoring must be meaningful to the person doing it – that is they are doing it for a reason or to find out the effect of their diabetes management (food, activity, medication) and make management decisions.

> Unfortunately some health professionals, no matter how well intentioned, use ‘blaming’ language. High or low BG should be just another problem to solve. Visit Diabetes Australia website to access the [Position Statement - A new language for diabetes 2016](#).

> Reassure that out of target BG is manageable – even if it takes a while to figure out what to do.

**Supplies**

The National Diabetes Services Scheme (NDSS) scheme is funded by the Commonwealth Government and administered by NDSS community pharmacies – a partnership which provides significant benefits for people with diabetes.

The scheme provides;

> free insulin syringes

> free needles for insulin injection devices & exenatide injection devices

> subsidised BG and ketone testing strips*

> subsidised urine testing strips

> subsidised insulin pump consumables.

> education and support services.
For further information, visit the NDSS website.

Other methods of measuring glucose

BG results that have been obtained from a meter should not be used as the only evaluation of diabetes management.9

Glycated haemoglobin (HbA1c)

Glycated haemoglobin is an assessment of long term glycaemia.

Glucose attaches to blood protein. The blood protein that carries oxygen is called haemoglobin and has a life of about 120 days. Haemoglobin that normally has glucose attached to it is called glycated (glycos = glucose).

A regular monitoring schedule for glycated proteins provides information which helps to assess overall control.

Glycated haemoglobin is a laboratory test used to measure BG by reflecting long term exposure of haemoglobin in red blood cells to plasma glucose. Since haemoglobin stays in the body for some time this measurement reflects all the ‘highs’ and ‘lows’ of BG over the past 2-3 months. The higher the glycated haemoglobin, the higher the average BG.

The test can be done every 3-6 months to check overall glycaemic control.

Change to HbA1c reporting

From 2011, the routine laboratory HbA1c reporting from the National Glycohemoglobin Standardization Program (NGSP) percentage (%) units was changed to International Federation of Clinical Chemists (IFCC) units millimoles per mole (mmol/mol).

This change was adopted but can cause confusion or misunderstandings of diabetes management for people with diabetes and/or their health care professionals.
An online HbA1c converter was developed by the Quality assurance for Aboriginal and Torres Strait Islander Medical services (QAAMS).

Sources of error in HbA1c reporting

Although the international standardisation has decreased potential technical errors in interpreting HbA1c results, there are other biological and patient-specific factors that may cause misleading results:

- Red cell survival - falsely high values in HbA1c can be obtained when red cell turnover is low, resulting in a disproportionate number of older red cells. This problem can occur in patients with iron, vitamin B12, or folate deficiency anaemia. When there is rapid red cell turnover, there is a greater proportion of younger red cells which leads to falsely low HbA1c values. This problem can occur in patients with haemolysis or anaemia and those treated for iron, vitamin B12, or folate deficiency, and patients treated with erythropoietin.

- Chronic kidney disease - false HbA1c elevations may be due in part to analytical interference from carbamylated haemoglobin formed in the presence of elevated concentrations of urea, leading to false elevations in the HbA1c level with some assays. False decreases in measured HbA1c may occur with haemodialysis and altered red cell turnover, especially in the setting of erythropoietin treatment.

Type 1 diabetes

The table below from the Australian Diabetes Society Position Statement describes the situations whereby BG targets in people with type 1 diabetes should be modified.

**Position Statement**

<table>
<thead>
<tr>
<th>Specific clinical situations</th>
<th>HbA1c target</th>
<th>Rationale for recommendation</th>
<th>Level of evidence for target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrent severe hypoglycemia or hypoglycaemia unawareness</td>
<td>&lt; 8.0%</td>
<td>Severe hypoglycaemia is associated with significant morbidity and mortality: Risks of tight glycaemic control outweigh the benefits for such patients.</td>
<td>Consensus</td>
</tr>
<tr>
<td>Patients with major comorbidities likely to limit life expectancy</td>
<td>Symptomatic therapy of hypoglycaemia and avoidance of ketosis</td>
<td>Tight glycaemic control will be of no benefit, as diabetic complications take many years to develop.</td>
<td>Consensus</td>
</tr>
<tr>
<td>Pregnancy or planning pregnancy</td>
<td>&lt; 7.0%*</td>
<td>Better pregnancy outcomes (borderline significance) were achieved for intensive therapy group of DCCT (mean HbA1c of 7.0%). Observational data demonstrate a relationship between HbA1c and adverse pregnancy outcomes when HbA1c levels exceed a threshold between 5.0% and 6.0%, but there is a heightened risk of hypoglycaemia at such low levels. Therefore, for most women, we recommend a target HbA1c &lt; 7.0%.</td>
<td>II</td>
</tr>
<tr>
<td>General target</td>
<td>&lt; 7.0%*</td>
<td>DCCT/EDIC showed that achieving a mean HbA1c of 7.0% is associated with improved outcome.</td>
<td>II</td>
</tr>
</tbody>
</table>

DCCT = Diabetes Control and Complications Trial. EDIC = Epidemiology of Diabetes Interventions and Complications study.

*Achievement of HbA1c targets must be balanced against risk of severe hypoglycaemia. A target HbA1c level < 6.0% is desirable if it can be achieved safely.

1 Where practical, suggest blood glucose target level < 11 mmol/l to help minimise risk of infection.
Type 2 diabetes

The Australian Diabetes Society Position Statement\textsuperscript{23} highlights that tight glycaemic control early in the disease process is desirable and is likely to produce the greatest benefit in terms of complication prevention (eg HbA1c less than 6\%). Achieving tight control needs to be balanced against the risk of severe hypoglycaemia. The box below can be used to help individualise targets.

\textbf{POSITION STATEMENT}

<table>
<thead>
<tr>
<th>1 Recommended glycated haemoglobin (HbA\textsubscript{1c}) target ranges for adults with type 2 diabetes</th>
<th>Level of evidence for target</th>
</tr>
</thead>
<tbody>
<tr>
<td>General target</td>
<td>HbA\textsubscript{1c} target</td>
</tr>
<tr>
<td>Specific clinical situations</td>
<td></td>
</tr>
<tr>
<td>Diabetes of shorter duration\textsuperscript{1} and no clinical cardiovascular disease</td>
<td>&lt;7.0%*</td>
</tr>
<tr>
<td>• Requiring lifestyle modifications: metformin</td>
<td>≤6.0%*</td>
</tr>
<tr>
<td>• Requiring any antidiabetic agents other than metformin or insulin</td>
<td>≤6.5%*</td>
</tr>
<tr>
<td>• Requiring insulin</td>
<td>≤7.0%*</td>
</tr>
<tr>
<td>Pregnancy or planning pregnancy</td>
<td>≤6.0%*</td>
</tr>
<tr>
<td>Diabetes of longer duration\textsuperscript{1} or clinical cardiovascular disease (any therapy)</td>
<td>≤7.0%*</td>
</tr>
<tr>
<td>Recurrent severe hypoglycaemia or hypoglycaemia unawareness (any therapy)</td>
<td>&lt;8.0%</td>
</tr>
<tr>
<td>Patients with major comorbidities likely to limit life expectancy\textsuperscript{2} (any therapy)</td>
<td></td>
</tr>
</tbody>
</table>

Continuous glucose monitoring (CGM) systems

CGM and FGM can be used continuously and/or intermittently as a management tool and diagnostic instrument for people with diabetes and/or their healthcare providers. CGM and FGM can identify glucose trends during various forms of dietary intake, physical activity, stress, illnesses, steroid medications or menstrual cycles.

There is evidence to support the benefit of continuous and intermittent use of CGM and FGM as an educational motivational tool in those challenged by diabetes management and those who have poor glycaemia control as a consequence.\textsuperscript{24-26}
Real-time CGM
Real-time CGM tracks the glucose concentrations in the body’s interstitial fluid, providing near real-time glucose data.

Some CGM systems can be linked to blood glucose meters, smart phones and/or insulin pumps which can display the glucose result, recent history and alert the patient and/or carer of the glucose excursion (trend) moving above or below the glucose target.

Some CGM systems can be linked to insulin pump therapy providing sensor augmented pump technology (SAPT). SAPT can be programmed to automatically suspend insulin delivery if the glucose falls below target.27

Real-time CGM (also known as Personal CGM) is most commonly used by the person with diabetes and/or their family.

Retrospective CGM
Retrospective CGM uses similar methodology, however, the glucose concentrations are ‘masked’ until the device is removed, the data uploaded and a report is generated.

Retrospective CGM systems are owned by healthcare professionals and loaned to patients with diabetes intermittently and can be worn for up to 6 days.

Retrospective CGM (also known as Professional CGM) is most commonly used by credentialled diabetes educators (CDE) and diabetes educators (DE) in CHSA.

Flash Glucose Monitoring Systems
FGM also tracks the glucose concentrations in the body’s interstitial fluid. FGM can provide a current glucose reading, the last 8-hours of glucose history, and a trend arrow showing if glucose is going up, down, or changing slowly. Information is not automatically displayed but only after physically scanning the sensor with the reader.

FGM is most commonly used by the person with diabetes and/or their family.

Both CGM and FGM can offer the potential to:

> improve time in target glucose
> reduce hypoglycaemia
> reduce hyperglycaemia
> and improve HbA1c.24-26

Limitations of CGM and FGM
CGM and FGM systems are accurate but the level of glucose in interstitial fluid reacts slower than the level of glucose in the blood. This is because interstitial glucose result lags approximately 10 minutes behind the blood glucose result. Figure 1 identifies the variance between blood glucose and interstitial glucose.

Figure 1: Interstitial Glucose Sensor Lag Time
Although CGM and FGM can reduce frequency, capillary blood glucose monitoring is recommended:

> For calibration of the CGM. Two - four blood glucose results (depending on type of CGM system used) are required for calibration for each day. The FGM requires no calibration.

> When glucose levels are rapidly changing (eg hypoglycaemia and hyperglycaemia).

> When results do not correspond to symptoms

> To use the bolus calculation function (FGM only).

> Where the reader indicates a low glucose result (FGM only).

> To meet driving a vehicle licensing authority requirements.

> When unwell.

> On presentation to an emergency department.

> During hospital admission.\(^{24-26}\)

Patients with diabetes who wear CGM or FGM systems in the outpatient setting, when admitted to hospital can continue to wear their personal system. However, hospital blood glucose meter results will be used to make changes to their inpatient diabetes management.

For further information, please refer to the CHSA Clinical Protocol - *Continuous Glucose Monitoring (CGM) and Flash Glucose Monitoring (FGM) in the inpatient setting.*

**Ketone testing**

Both insulin deficiency and glucagon excess contribute to the development of Diabetic Ketoacidosis (DKA) which is a medical emergency.

For further information on DKA, please refer to the Evidence Summary - ‘Hypoglycaemia and Hyperglycaemia’.

In DKA, the three ketone bodies that are produced and accumulate are:

> acetoacetic acid

> beta-hydroxybutyric acid

> acetone.

Traditionally ketones have been tested in urine; however, the most accurate way of testing for ketones is to use a meter that measures blood ketone levels. Blood testing for ketones can give an earlier warning of ketones (than urine testing) and can indicate impending DKA.

Testing for ketones is essential in people with type 1 diabetes and should be performed if the person is fasting, unwell (eg nausea, vomiting) and/or BG values exceed 15.0mmol/L. Blood ketone tests should be performed as recommended above and rechecked according to the Blood Glucose Monitoring Chart (MR59H) Rapid Detection and Response Instruction with the frequency of blood ketone tests decreasing as the BG levels improve.\(^{28}\)

For further information on monitoring of ketones and its role in sick day management, refer to the Evidence Summary - ‘Hypoglycaemia and hyperglycaemia’ or the ADEA website.

**Note:** Blood ketone testing is only routinely performed if the person has type 1 diabetes or ketosis prone type 2 diabetes.
Remember the following points when working with people with type 1 diabetes who are blood ketone monitoring at home:

> Monitoring is only meaningful if the person knows what the blood ketone target is.
> Monitoring is only useful as a self-management tool if people can interpret their blood ketone results and work out what has caused high / low BG so they can take remedial action to bring blood ketone back into target.
> The person needs to understand that how they feel is not an accurate estimate of blood ketone and not good enough evidence on which to base self-management decisions.
> Any self-monitoring must be meaningful to the person doing it – that is they are doing it for a reason or to find out the effect of their diabetes management (food, activity, medication) and make management decisions.
> Reassure that DKA is preventable and out of target blood ketone is manageable if advice and action is taken early.

**Supplies**

The National Diabetes Services Scheme (NDSS) scheme is funded by the Commonwealth Government and administered by NDSS community pharmacies – a partnership which provides significant benefits for people with diabetes.

In addition to free insulin syringes and free needles for insulin injection devices, it provides subsidised blood ketone testing strips and urine testing strips.

For further information, visit the [NDSS](https://www.ndss.com.au) website.
References


12. Royal Adelaide Hospital, Modbury Hospital, The Queen Elizabeth Hospital, and Repatriation General Hospital, 2009, *Quality assurance for blood glucose meters: Personal communication*, Diabetes Outreach, Editor.: Adelaide, p. Professional communication.

13. SA Pathology (Flinders Medical Centre), 2009, *Record keeping for quality control: Personal communication*. Adelaide.


