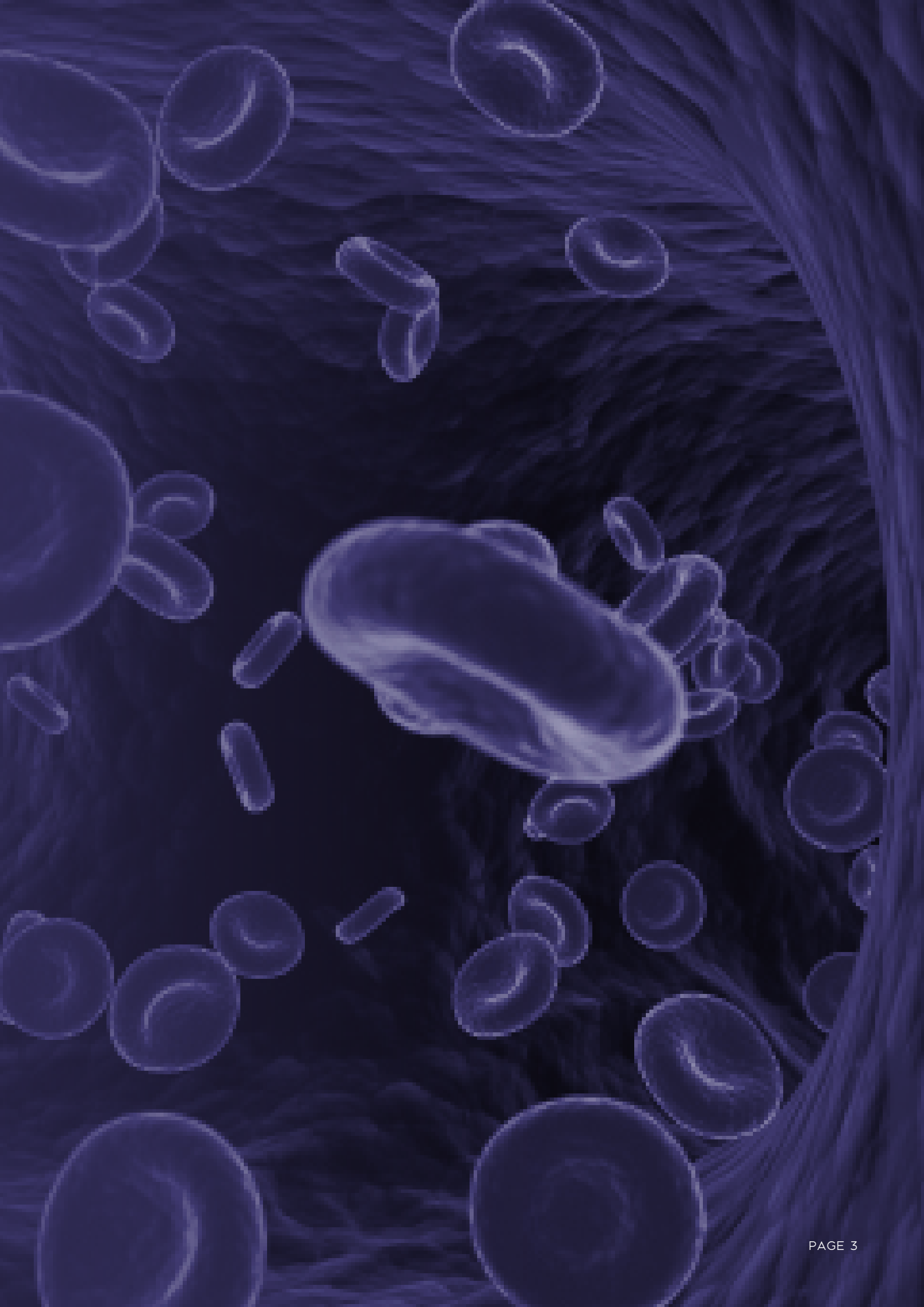
SureScreen Health

HBA1C

WHITEPAPER

Contents



When it comes to sugar, especially in a Western diet, it is part of everyday life. What many do not consider is the amount they are consuming and the impact it is having on their body long term. High glucose levels over time, known as long-term blood sugar, can affect the body so much so it damages large and small blood vessels leading to many health issues such as nerve damage, vision issues, chronic kidney disease and diabetes, making testing a necessity...

What is blood sugar?

Blood sugar refers to the amount of glucose in a person's blood, and glucose is essential for the function of cells in our bodies[3001]. Without glucose our cells and organs would not be able to produce energy and therefore would not be able to function. A good example of this is the brain - the brain is approximately 2% of our total body weight but accounts for 20% of glucose-based energy production[3002].

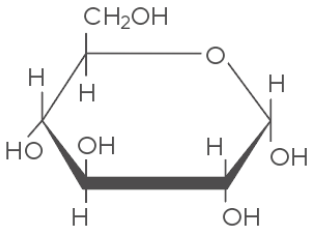
The level of glucose in our body is controlled primarily by our diet.

Diet and blood sugar?

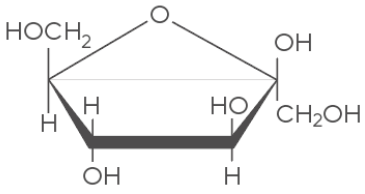
As we eat and break down food, it is absorbed into the bloodstream where it increases the level of blood glucose. The intensity and duration of these changes in glucose levels varies from food to food. Substances known as carbohydrates are the main source.

There are three main types of carbohydrate:

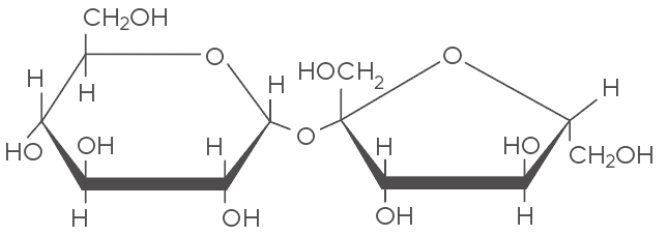
a) Simple sugars: These are the simplest form of carbohydrates and are also known as monosaccharides or disaccharides (comprised of two monosaccharides). This group contains foods such as fruit, syrups, honey and table sugar, and simple sugars can also be found in sugary food and drinks. Glucose, fructose, galactose, sucrose, lactose and maltose are all simple sugars.



glucose

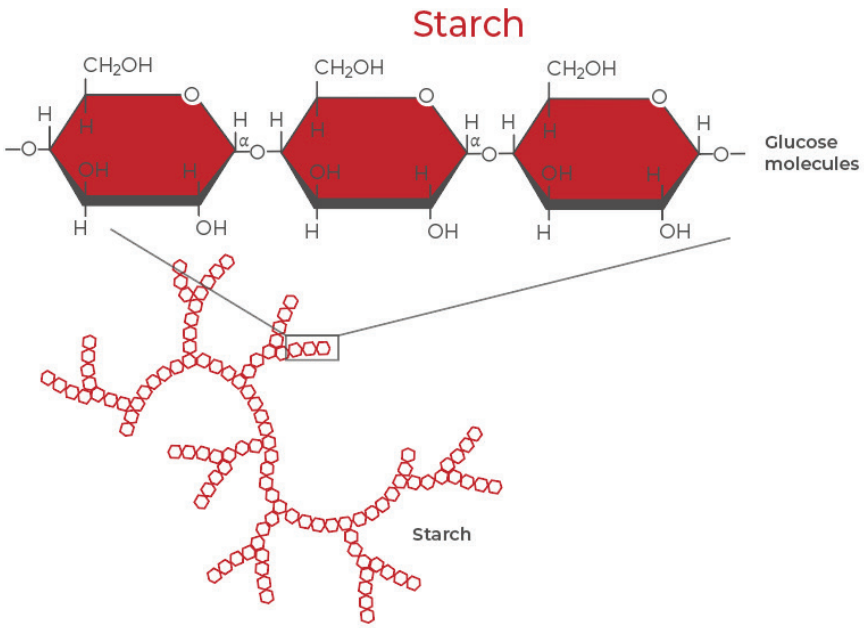


fructose



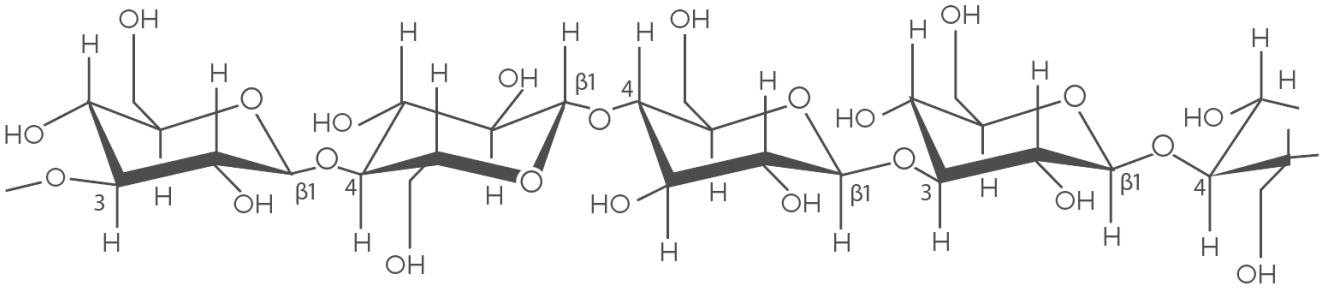
sucrose

b) Starches: These foods are also known as polysaccharides and consist of hundreds or even thousands of glucose molecules that are connected together. When eaten, these chains are broken down into their individual parts. Starchy foods include pasta, rice, bread and potatoes. These foods are more likely to cause a fast-acting, long-lasting, high glucose spike.



c) Dietary fibre: This is categorised as soluble or insoluble fibre and is defined as the structural part of a plant that cannot be broken down by the body. It can be used in several ways such as fermented by bacteria to make important compounds, bound to toxins so they can be excreted from the body or it can slow the movement of food through the intestine, delaying gastric emptying and increasing nutrient absorption. As fibre isn't absorbed it generally creates a low glucose response. Examples of fibre-rich foods include whole grains, vegetables, nuts, and seeds.

Glucose chain



A balanced diet is paramount in maintaining blood sugar. However, it is worth noting that blood sugar can be impacted by certain lifestyle habits, and some foods considered healthy can still raise blood sugar if someone is sensitive to them.

When consuming foods that raise blood sugar, our bodies release insulin (a hormone produced by the pancreas) which helps to lower those levels and then we can transport the glucose into cells that need it.

Other food groups such as fats, protein and fibre can also help lower the intensity of a rise in glucose

(sometimes called a spike). Regulated blood sugar will still have highs and lows but as it is balanced will stay in a healthy range (figure 2).

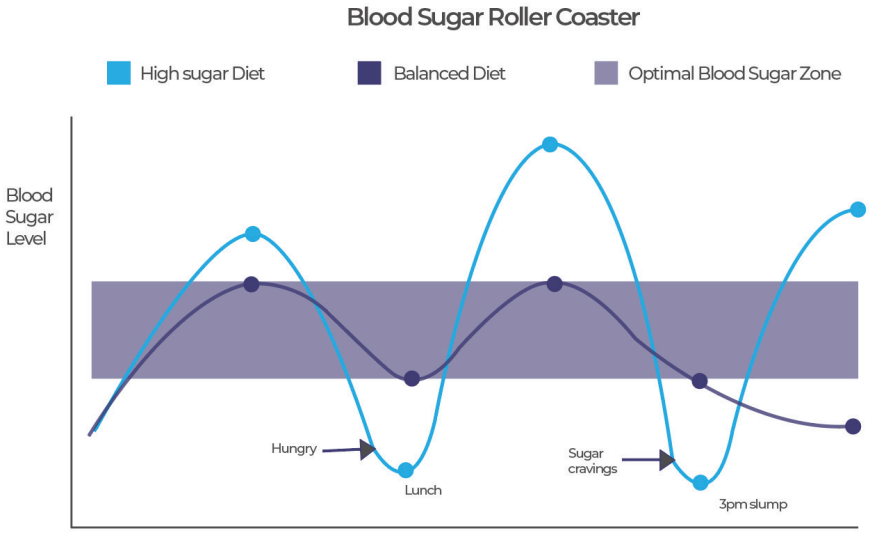


Figure 2: A balanced diet will regulate blood sugar in an optimal range (dark purple curve), unbalanced diet (consistently high amounts of carbohydrates) will create large peaks and crashes (blue curve)

An unbalanced diet may consist of lots of ultra-processed foods, few or no vegetables and fibrous pulses (nuts, seeds, etc.), and a large amount of refined carbohydrates such as white pasta, white bread, wraps and white potatoes. When these types of food make up most of a person's diet, blood sugar peaks and troughs may occur.

The red curve above is sometimes called the glucose rollercoaster. This happens because carbohydrate-heavy meals cause a large spike in glucose. Insulin is then released in large amounts to help normalise the blood glucose level. However, when too much insulin is produced, it creates a dip or crash in glucose, resulting in low energy and causing the body to crave high calorie and high carbohydrate meals, causing the cycle to repeat.

Staying on the glucose rollercoaster consistently will raise baseline blood glucose levels. This is what is tested in a long-term blood sugar test.

Movement can also positively affect glucose levels; from day-to-day movement to exercise, our bodies react, and the glucose amount will fall (although some high-intensity exercise can raise blood glucose).

Staying within a healthy blood sugar range[3106] is important, so results for 2 hours after eating should be below 7.8 mmol/L (140 mg/dL). For those who are fasting, staying between 4.0 and 5.4 mmol/L (72 to 99 mg/dL) is ideal.

When diabetes occurs

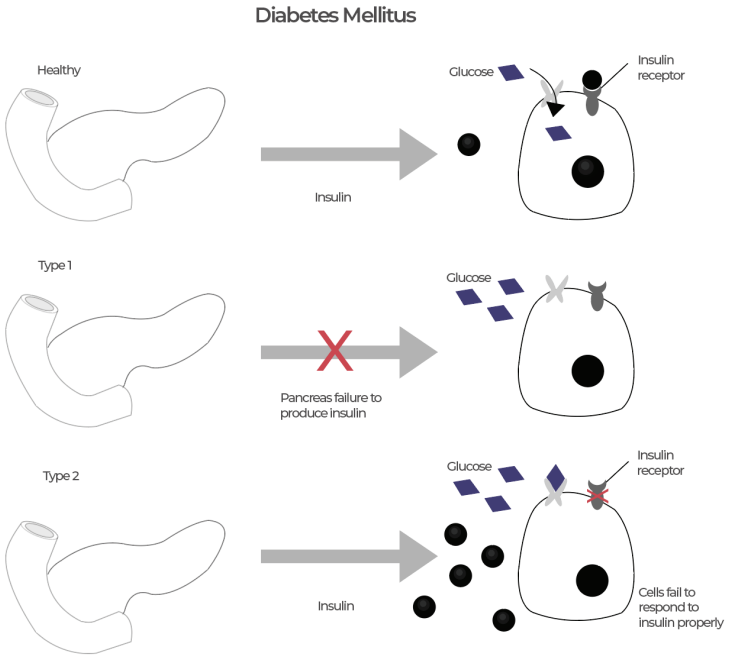
When blood sugar is consistently high, diabetes occurs and affects the whole body. There are two main types (and some rarer ones) of diabetes, type 1 diabetes mellitus (DM1) and type 2 diabetes mellitus (DM2).

Type 1

Type 1 diabetes is an autoimmune condition where T-cells destroy pancreatic beta cells. Beta cells are responsible for producing and releasing insulin, so it therefore reduces insulin levels and results

in blood glucose dysregulation.

It occurs in genetically susceptible individuals and there are several risk factors, both prenatal such as congenital rubella, maternal enteroviral infection and excessive weight gain, and postnatal, such as gut dysbiosis and early exposure to cereals, root vegetables, egg and cow's milk. Progression of the disease can be promoted by high levels of fructose, dietary nitrates and a high glycaemic load, as well as being overweight and chronically stressed[3107], so implementing a healthy diet and lifestyle habits is advisable. However, diet and lifestyle alone cannot control DM1, and medication, usually in the form of insulin injections, will be necessary. In rare cases, a pancreas transplant may be considered.



Type 2

Type 2 diabetes develops over time and a primary cause is lifestyle choices including lack of exercise and a poorly regulated diet. Being overweight or obese can also increase the risk of type 2 diabetes. In fact, approximately 90% of diabetics are overweight or obese[3131].

In type 2 diabetes, insulin is produced in response to glucose but in this case the cells are less sensitive to insulin and the uptake of glucose is diminished with blood glucose levels remaining high. This is known as insulin resistance. To counter this, the pancreas works harder to make more insulin, which can eventually adversely impact insulin production.

Untreated and unregulated, diabetes can cause serious health issues such as an increased risk of heart attack and stroke, limb amputation and diabetic related blindness.

Promotors of diabetes mellitus 2 (type 2)

Whilst some key causes of type 2 diabetes include weight, and diet and lifestyle factors, the reason why diabetes develops is slightly more complex. Here is an overview...

Fatty tissue

Fat has a big impact on the body's ability to function normally. Fat can be deposited around internal organs, also known as visceral fat. In type 2 diabetes, visceral fat reduces the amount of available insulin receptors causing blood sugar to rise or stay elevated. High levels of visceral fat are generally driven by diet and lifestyle factors such as consumption of high amounts of sugar and trans fats, alcohol, physical inactivity and chronic stress.

It is also common for type 2 diabetics to have large amounts of fat on the liver. This is known as non-alcohol related fatty liver disease (NAFLD). In fact, recent figures suggest over 70% of people with type 2 diabetes have NAFLD[3108].

In addition, extra fat can result from high levels of glucose in the blood which may be turned into triglycerides (a form of fat) and stored. This can happen due to insulin resistance or when energy intake exceeds energy demand.

Fatty tissue also produces and releases hormones that can influence appetite, insulin sensitivity and inflammation so dysfunction of fat cells can promote inflammation and insulin resistance and has been associated with metabolic diseases such as type 2 diabetes[3109].

The glucose trap

If our body is not getting the energy it needs because of insulin resistance or other factors, it will try and create the fuel for this energy itself. Gluconeogenesis is a process where new glucose is produced primarily in the liver, and to a lesser extent in the kidneys. Low blood glucose and the subsequent release of glucagon from pancreatic alpha cells, triggers gluconeogenesis to raise blood glucose levels. However, when blood glucose is high but there is a lack of insulin or insulin sensitivity to remove it from the blood, gluconeogenesis will still occur, thereby raising blood glucose levels further[3110]. The higher or more uncontrolled blood sugar levels are, the less effective insulin can be.

Cell damage

Typically damage to insulin producing beta cells (and dysfunction of alpha cells), in the pancreas is a hallmark of type 1 diabetes. However, unmanaged type 2 diabetes over time can result in damage to beta cells, making symptoms worse and the management of the condition more difficult.

The environment caused by diabetes and some of its associated risk factors are toxic to cells leading the body to destroy some cells in a controlled way (known as apoptosis) and other cells in less controlled clusters (known as necrosis).

This cell death can result in serious, and sometimes life- changing, diabetes symptoms. These may include:

- Nephropathy (damage to kidneys)
- Retinopathy (damaged retina)
- Neuropathy (nerve damage)
- Urinating more than usual, particularly at night
- Tiredness/fatigue
- Itching around the genitals or repeated episodes of thrush
- Slow wound healing
- Unexplained weight loss
- Diabetic necrosis (tissue death due to reduced blood flow)
- Blindness
- Limb amputation

- Chronic Kidney disease

Who is at risk of Type 2 diabetes?

Although a high carbohydrate, low protein diet can significantly contribute to type 2 diabetes, there are many other factors that can raise a person's risk of developing it. Knowing individual risk factors is important to identify how likely a person is to develop diabetes and what they can do to mitigate the risk.

Risk factors

- Ethnicity – People of African-Caribbean, Black African, or South Asian descent are more at risk from the age of 25[3134].

- Age - As we get older, regulation and upkeep of our cells can be impaired, and this can include insulin-producing cells. If insulin production is impaired, glucose can remain elevated in the blood increasing the risk of diabetes. As a result of this, those over the age of 40 are more at risk of developing diabetes, and those over the age of 25 for ethnic groups[3008].

- Family history - Our susceptibility to developing diabetes has a high genetic component. This is why a person is often asked about family history of diabetes to determine their own risk. If parents and siblings have had or have diabetes, a person may have an increased risk of developing it themselves.

- Metabolic Syndrome (MetS) – this is a cluster of abnormalities which include abdominal obesity, high blood triglycerides, low HDL cholesterol, high blood pressure and high fasting glucose. MetS is diagnosed if a person has at least three out of five of these criteria. MetS is an independent risk factor for type 2 diabetes, and it can also increase the risk of developing other conditions such as cardiovascular disease and polycystic ovary syndrome (PCOS)[3111].

- Thyroid disease - thyroid hormones are key regulators of metabolic processes, such as converting food into energy. Thyroid conditions are therefore considered a risk factor for diabetes. Conversely, dysregulated insulin can lead to thyroid disease by altering thyroid hormone production and activity[3112].

- High blood pressure - As well as being a factor in Metabolic Syndrome, high blood pressure can be an independent risk factor for diabetes, and these two conditions are often seen together. People with high blood pressure have a raised HbA1c even without diabetes, and people with diabetes have been diagnosed with high blood pressure without it being a previous concern[3066].

- Smoking - Smoking can increase blood pressure, which as mentioned above is a risk factor for diabetes. This is because smoking results in blood vessels being more susceptible to forming plaques, which causes them to narrow. Several studies have indicated that stopping smoking lessens the risk of developing diabetes over 5 years and even more so over 10 years[3092].

- Drinking alcohol – Whilst there is conflicting evidence on the risk of moderate alcohol consumption and diabetes[3113], chronic, heavy alcohol consumption can impair glucose regulation, and promote an exaggerated insulin response, potentially leading to insulin resistance[3114].

- Sleep - In addition to being associated with dysfunctional glucose regulation[3115], shortened sleep has also been shown to be associated with appetite dysregulation[3116]. A reduction in leptin, which is responsible for feelings of satiety and an increase in hunger-promoting ghrelin, has been shown to occur because of sleep deprivation, thereby reducing a person's ability to control their eating behaviour. Unsurprisingly, there is considerable epidemiological evidence that shows an association between lack of sleep and a higher BMI[3117], a risk factor for diabetes.

- Stress – Stress (both mental and physical) stimulates the adrenal glands to produce stress hormones, with one of their functions being the release of glucose from fat stores to produce enough energy for fight or flight. If someone is chronically stressed, the repeated cycle of glucose release and subsequent insulin release to remove glucose from the blood could contribute to lowered insulin sensitivity and insulin resistance[3016].

- Sedentary behaviour – Lack of physical activity has been associated with an increased risk of diabetes. This is because the more active we are the more energy we use, and hence the more glucose we need either from the blood or fat storage. Therefore, exercise has the potential to both reduce blood glucose and excess weight.

Pregnancy and diabetes

Type 2 diabetes is the most prevalent diabetes type but there are fewer common types that can still cause problems. Gestational diabetes is triggered by pregnancy. Usually after pregnancy, blood sugar will return to normal. However, there is up to ten times increased risk of developing diabetes in the future (both type 2 and gestational)[3098]. If blood sugar does not return to normal after the pregnancy, the person is diagnosed as having type 2 diabetes.

- 4-5% of pregnancies in the UK are affected by gestational diabetes [3118].

- Diabetes during pregnancy should be managed carefully, as left unmanaged, a person can be more at risk of developing pre-eclampsia[3119]. This is a condition where blood flow to the placenta is reduced and is characterised by high blood pressure, and high levels of protein in the urine. If left untreated it can cause preterm birth, severe health complications for both mother and baby, and potentially pregnancy loss or stillbirth.

Risk of developing gestational diabetes increases if a person[3132]:

- Has a BMI over 25
- Has previously had a baby who weighed 4.5kg (10lb) or more at birth
- Has a family member who has diabetes
- Had gestational diabetes in a previous pregnancy
- Is of South Asian, Black, African-Caribbean or Middle Eastern origin (even if born in the UK)
- Is over 25
- Has polycystic ovary syndrome (PCOS)

Testing blood sugar/testing for diabetes

Methods of testing blood sugar have evolved over the years. Historically, high blood sugar was tested by physicians tasting the patient's urine. If the urine was sweet the patient had what we now know as diabetes. Fortunately, due to developments in technology physicians no longer have to do this!

Nowadays, blood sugar is more commonly measured using a glucose meter which measures the glucose in a small sample of blood from a finger prick and gives an instant reading of the person's current blood sugar level.

People also use Continuous Glucose Monitoring (CGM) devices, which attach to the body to give more regular blood glucose data.

HbA1c testing is different. Measuring HbA1c in the blood, gives an average glucose reading over 3 months[3019].

The 'long-term' blood sugar test (HbA1c test)

Haemoglobin is responsible for blood's red colour and for the transportation of oxygen around the body. Glucose in the blood can stick to haemoglobin and irreversibly change it to glycated

haemoglobin, or HbA1c.

HbA1c levels rise as blood sugar rises but cannot fall (due to its irreversible nature) until red blood cells and all their components are dismantled and reused by the body. This period is typically around 3 months (10-12 weeks).

This means HbA1c tests can give a snapshot of the last 3 months of blood sugar levels.

HbA1c Results

The results of a HbA1c test are given either as a percentage or more usually in mmol/mol. These measurements compare glycated haemoglobin (HbA1c) to un-glycated haemoglobin (Hb).

OPTIMAL	PRE-DIABETIC	DIABETIC
20-41 mmol/mol	42-47 mmol/mol	>48 mmol/mol
(4.0-5.9%)	(6.0-6.4%)	(>6.5%)

- Optimal - HbA1c is minimal, indicating blood glucose level is optimal with a low risk of diabetes. HbA1c levels below 4% may indicate other health problems.
- Pre-diabetic - Blood glucose is raised, and without change, there is a risk of developing diabetes.
- Diabetic - Blood glucose levels are high due to issues with either insulin production, insulin utilisation or possibly both. As such, there is a high risk of diabetes.
- Managing diabetes - Those who are diagnosed diabetic should aim to control their HbA1c levels to between 6.5% (47.5mmol/mol) and 7.0% (53mmol/mol).

Managing blood sugar

With effective management, blood sugar can be lowered and those with diabetes can lower to below the diabetic range - 48mmol/mol or 6.5%. If this is sustained over at least three months, without medication, it is known as **diabetic remission (Diabetes.org)**.

Making appropriate diet and lifestyle changes can help to lower blood glucose levels, increase insulin sensitivity, and decrease the risk of damage to the pancreas. Positive outcomes may include weight loss, a reduction in inflammation, more effective energy pathways, and balanced hormones.

Here are some recommendations, which will contribute towards these outcomes:

1. Limit carbohydrate intake and choose carbohydrates with a lower glycaemic index and glycaemic load: There are essentially two different methods that can be used to measure the immediate impact carbohydrates will have on blood glucose levels. One is the glycaemic index (GI) which gives food a score between 0 and 100 based on how quickly 50g of carbohydrate contained in that food is digested and absorbed. This is compared to the digestion and absorption rate of 50g of pure glucose which has a score of 100. The lower the score, the slower blood glucose will rise after consuming that food. However, the glycaemic load (GL) can be a more accurate measure of how a food will impact blood glucose as it also considers a typical serving of that food. For example, watermelon has a high GI but the carbohydrate in a typical serving is low, giving it a GL of only 4. Below is a table, which shows a comparison of the GI and GL of both refined and unrefined foods.

WESTERN REFINED FOODS			UNREFINED TRADITIONAL FOODS		
Food	Glycemic Index	Glycemic Load	Food	Glycemic Index	Glycemic Load
GLUCOSE	97	96.8	PARSNIPS	97	19.5
RICE KRISPIE CEREAL	88	77.3	BAKED POTATO	85	18.4
CORNFLAKES	84	72.7	BOILED MILLET	71	16.8
LIFESAVERS	70	67.9	BOILED BROAD BEANS	79	15.5
RICE CAKES	82	66.9	BOILED COUSCOUS	65	15.1
TABLE SUGAR (SUCROSE)	65	64.9	BOILED SWEET POTATO	54	13.1
SHREDDED WHEAT CEREAL	69	57.0	BOILED BROWN RICE	55	12.6
GRAHAM CRACKERS	74	56.8	BANANA	53	12.1
GRAPENUTS CEREAL	67	54.3	BOILED YAM	51	11.5
CHEERIO CEREAL	74	54.2	BOILED GARBANZO BEANS	33	9.0
RYE CRISPBREAD	65	53.4	PINEAPPLE	66	8.2
VANILLA WAFERS	77	49.7	GRAPES	43	7.7
CORN CHIPS	73	46.3	KIWI FRUIT	52	7.4
MARS BAR	68	42.2	CARROTS	71	7.2
STONE WHEAT THINS	67	41.9	BOILED PEAS	48	6.8
SHORTBREAD COOKIES	64	41.9	BOILED BEETS	64	6.3
GRANOLA BAR	61	39.3	BOILED KIDNEY BEANS	27	6.2
ANGEL FOOD CAKE	67	38.7	APPLE	39	6.0
BAGEL	72	38.4	BOILED LENTILS	29	5.8
DOUGHNUTS	76	37.8	PEAR	36	5.4
WHITE BREAD	70	34.7	WATERMELON	72	5.2
WAFFLES	76	34.2	ORANGE	43	5.1
ALL BRAN CEREAL	42	32.5	CHERRIES	22	3.7
WHOLE WHEAT BREAD	69	31.8	PEACH	28	3.1
FRUCTOSE	23	22.9	PEANUTS	14	2.6

Source: Cordain, L, Eades, M, Eades M (2003) Hyperinsulinemic diseases of civilization: More than just Syndrome X. Comparative Biochemistry and Physiology Part A Molecular & Integrative Physiology 136(1):95-112 DOI:10.1016/S1095-6433(03)00011-4[3130]

2. Consume fibre: Eating wholegrains and legumes can slow the release of glucose into the blood, as suggested by the lower GI and GL scores of these types of food in the table above . Fibre has also been shown to reduce HbA1c and improve insulin sensitivity[3120].

3. Include protein with every meal: Protein slows glucose release and has also been shown to lower fat accumulation in the liver, thereby enhancing insulin signalling[3121].

4. Avoid trans fats: It is suggested that trans fats found in many ultra-processed foods such as cakes, biscuits, doughnuts, fries and some spreads can elevate the risk of diabetes due to the negative impact they have on the gut microbiota, which results in immune dysregulation, chronic inflammation and insulin resistance[3122].

5. Consume healthy fats: Polyunsaturated fatty acids (PUFAs) are vital for several reasons, one being cell membrane fluidity which is relevant to diabetes as cell membrane composition influences insulin activity. Membrane fluidity can increase the number of insulin receptors and insulin's affinity to it. Monounsaturated fats such as olive oil also have a number of benefits, including their ability to improve fasting glucose levels and glucose and insulin levels post-meal[3123].

6. Eat small meals: Eating smaller meals will reduce the insulin response.

7. Keep alcohol to a minimum: Chronic alcohol use has been shown to impair the glucose response and increase the risk of insulin resistance.

8. Support gut health: A reduction in the diversity and composition of the gut microbiota (collection of bacteria and other microorganisms), known as dysbiosis, is closely associated with metabolic diseases such as diabetes[3124].

9. Regular physical activity: Exercise has several benefits in terms of insulin resistance and diabetes

10. Manage stress: Chronic stress can not only keep blood glucose levels high by triggering the release of glucose for energy, but the stress hormone cortisol can interrupt insulin signalling within cells[3125].

11. Supplementation: Consideration may also be given to inclusion of the following nutrients as supplementation to a person's diet:

    a) Chromium – chromium can help to increase insulin sensitivity, beta cell activity and the utilisation of glucose.

    b) B vitamins – B vitamins are required by cells to assist in the process of energy harvesting from fats, proteins and carbohydrates.

    c) Vitamin D – vitamin D helps to increase calcium movement in pancreatic cells, assisting in the process of insulin release.

    d) Magnesium – magnesium has been shown to increase insulin sensitivity and improve glycaemic control[3126].

    e) Zinc – zinc plays a role in beta cell function, and as such positively impacts insulin activity and glucose regulation[3127].

    f) Manganese – manganese is an important mineral for insulin activity, and research has shown that a deficiency can lead to glucose intolerance[3128].

    g) Cinnamon – cinnamon can help increase a cell's response to insulin, thereby allowing more effective entry of glucose into cells. Research has shown that cinnamon consumption has a beneficial effect on glycaemic control[3129].

Summary

Glucose in the blood is used for energy. When there is too much, it is stored as fat and this excess glucose, over a sustained period, can result in diabetes.

Type 2 is the most common diabetes type. It is a condition that is preventable, but the risk of being diagnosed with it, and its progression can worsen over time if contributory risk factors such as inactivity, excess weight and dietary factors are not addressed. Some people's risk of type 2 diabetes can also rise due to unalterable determinants such as age, sex and ethnicity.

Therefore, measuring blood glucose or HbA1c (long-term glucose) is essential for diabetes screening, as it can highlight any dietary, lifestyle and supplemental changes needed to improve and/or manage blood glucose to keep it within a healthy range.

SureScreen Health, Morley Retreat,
Church Lane, Morley, Derbyshire, DE7 6DE

Tel: 01332 292003 Email: scientifics@surescreen.com surescreenhealth.com