

Introduction to Physiology – Case Study 1: Diabetes

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Written Assignment (Case Study Report)

1. Introduction

Diabetes mellitus is a long-term condition that affects the way the body regulates blood glucose, commonly known as blood sugar. Glucose is an important source of energy for the body's cells. However, its concentration in the bloodstream must be controlled carefully to maintain normal physiological function. Diabetes develops when the body does not produce enough insulin, cannot use insulin effectively, or experiences a combination of these problems. Without effective regulation, blood glucose levels can become too high, resulting in hyperglycaemia and an increased risk of long-term complications.

There are two main types of diabetes mellitus: type 1 and type 2. Type 1 diabetes is an autoimmune condition in which the immune system attacks the insulin-producing beta cells in the pancreas. Consequently, the body produces little or no insulin, and treatment with insulin is essential. Type 2 diabetes develops when body cells become less responsive to insulin, a process known as insulin resistance. Over time, the pancreas may also become unable to produce enough insulin to compensate for this resistance. Type 2 diabetes is associated with several risk factors, including family history, increasing age, excess body weight, physical inactivity and some ethnic backgrounds. However, it can affect people with different body types and lifestyles (NHS, n.d.-a; NHS, n.d.-b).

Common symptoms include increased thirst, frequent urination, tiredness, blurred vision and wounds that heal slowly. Type 1 diabetes can develop rapidly, whereas type 2 diabetes may develop gradually and remain undiagnosed for some time. If diabetes is not managed effectively, it can contribute to

cardiovascular disease, kidney damage, nerve damage and problems with vision.

This report examines the physiology of diabetes, the mechanisms responsible for maintaining blood glucose within a healthy range, and the roles of glucose and oxygen in cellular energy production. It also considers how diet, physical activity, smoking cessation, medication and appropriate monitoring can support patients in managing their condition. Understanding these processes can help healthcare professionals explain diabetes clearly and support patients to participate in decisions about their care.

2. How Blood Glucose Is Regulated

Blood glucose regulation is an essential homeostatic process. Homeostasis means maintaining relatively stable internal conditions despite changes in the external environment. Following a meal, carbohydrates are digested into simpler sugars, including glucose, which is absorbed from the small intestine into the bloodstream. Blood glucose therefore rises temporarily after eating. The body responds through hormonal mechanisms that help prevent glucose from remaining excessively high.

The pancreas plays a central role in this process. Within the pancreas, clusters of endocrine cells called the islets of Langerhans contain beta cells and alpha cells. Beta cells produce insulin, while alpha cells produce glucagon. These hormones have complementary effects on blood glucose concentration.

When blood glucose rises after a meal, pancreatic beta cells release insulin into the bloodstream. Insulin binds to receptors on target cells and activates processes that promote glucose uptake, particularly in skeletal muscle and adipose tissue. In these tissues, insulin stimulates the movement of glucose transporter proteins, especially GLUT4, to the cell membrane. This increases the movement of glucose from the bloodstream into cells.

Once glucose enters cells, it can be used to produce energy through cellular respiration. Excess glucose can also be stored as glycogen in the liver and skeletal muscles. This storage process is known as glycogenesis. Insulin also reduces the liver's production and release of glucose, helping blood glucose levels return towards the normal range. These actions demonstrate how insulin supports the body's response to a rise in blood glucose after eating.

When blood glucose falls, such as between meals or during fasting, pancreatic alpha cells release glucagon. Glucagon acts mainly on the liver, stimulating glycogenolysis, which is the breakdown of stored glycogen into glucose. It also promotes gluconeogenesis, the production of glucose from non-carbohydrate substances such as certain amino acids and glycerol. The liver releases glucose into the bloodstream, helping to supply organs that require a continuous energy source.

Insulin and glucagon therefore work together to maintain glucose homeostasis. Insulin generally lowers blood glucose, while glucagon helps raise it when necessary. Other hormones, including adrenaline and cortisol, can also influence glucose regulation, particularly during stress or illness. The balance between these hormonal responses enables the body to supply cells with energy while avoiding excessive changes in blood glucose.

In type 1 diabetes, the destruction of pancreatic beta cells results in severe insulin deficiency. Glucose cannot be regulated effectively, and without treatment it accumulates in the bloodstream. Cells may be unable to use glucose normally, even when blood glucose is high. The body may then break down fat for energy, producing ketones. Excessive ketone production can lead to diabetic ketoacidosis, a serious medical emergency.

In type 2 diabetes, insulin resistance means that muscle, liver and adipose tissue respond less effectively to insulin. The pancreas may initially compensate by producing more insulin. However, beta-cell function can deteriorate over time, leading to persistent hyperglycaemia. The liver may continue releasing glucose even when blood glucose is already elevated, further contributing to the problem.

Prolonged hyperglycaemia can damage blood vessels and tissues. It increases the risk of cardiovascular disease and may contribute to diabetic retinopathy, diabetic kidney disease and peripheral neuropathy. Effective diabetes management aims to reduce these risks while avoiding hypoglycaemia, which occurs when blood glucose becomes too low. The appropriate glucose targets depend on the individual, their treatment and their risk of complications (NICE, 2026).

3. The Role of Glucose and Oxygen in Cellular Energy Production

All living cells require energy to carry out essential functions. These include muscle contraction, active transport across cell membranes, protein synthesis, cell repair and the maintenance of normal cellular activity. The main immediate energy-carrying molecule used by cells is adenosine triphosphate (ATP). Cells produce ATP through metabolic processes, including cellular respiration.

Cellular respiration involves the breakdown of glucose and the transfer of energy into ATP. When sufficient oxygen is available, aerobic respiration is an efficient way for many human cells to release energy from glucose. The overall process can be summarised by the following equation:



This equation represents the overall chemical changes rather than every step of the process. Aerobic cellular respiration involves several stages: glycolysis, the link reaction, the citric acid cycle and oxidative phosphorylation.

3.1 Glycolysis

Glycolysis occurs in the cytoplasm of the cell and does not directly require oxygen. During this process, one molecule of glucose containing six carbon atoms is broken down into two molecules of pyruvate, each containing three carbon atoms. A small amount of ATP is produced, alongside reduced NAD, which carries high-energy electrons to later stages of respiration.

Glycolysis is important because it begins the breakdown of glucose and provides intermediates for further metabolic reactions. If oxygen availability is limited, pyruvate may be converted into lactate to allow glycolysis to continue temporarily. This pathway produces much less ATP than complete aerobic respiration.

3.2 The Link Reaction and Citric Acid Cycle

When oxygen is available and the cell's metabolic conditions permit aerobic respiration, pyruvate enters the mitochondria. It is converted into acetyl coenzyme A during the link reaction, releasing carbon dioxide and producing reduced NAD.

Acetyl coenzyme A then enters the citric acid cycle, also called the Krebs cycle, in the mitochondrial matrix. Through a series of chemical reactions, the acetyl group is broken down and carbon dioxide is released. Reduced NAD and reduced FAD are also produced. These molecules transport high-energy electrons to the next stage of cellular respiration.

The citric acid cycle is important because it transfers energy into electron carriers that support the production of ATP. It also provides intermediate compounds that can be used in other metabolic pathways.

3.3 Oxidative Phosphorylation

Oxidative phosphorylation takes place across the inner mitochondrial membrane. Electrons from reduced NAD and reduced FAD pass through a series of protein complexes known as the electron transport chain. The energy released is used to pump protons across the membrane, creating an electrochemical gradient.

As protons move back across the membrane through the enzyme ATP synthase, energy is used to convert adenosine diphosphate (ADP) and inorganic phosphate into ATP. Oxygen acts as the final electron acceptor in the electron transport chain. It combines with electrons and protons to form water. Without sufficient oxygen, this process cannot continue normally, and ATP production through oxidative phosphorylation is severely reduced.

Aerobic respiration produces far more ATP per glucose molecule than glycolysis alone. The ATP generated supports the activities required for survival, movement, growth and tissue repair (Clark et al., 2018).

3.4 The Relationship Between Diabetes and Cellular Metabolism

Diabetes affects the way the body manages glucose, but it is important to distinguish high blood glucose from the ability of individual cells to use glucose. In type 1 diabetes, insufficient insulin limits normal glucose uptake in insulin-sensitive tissues and reduces the body's ability to store and use nutrients appropriately. In type 2 diabetes, insulin resistance interferes with normal metabolic regulation.

Some cells, including red blood cells, can take up glucose without insulin through insulin-independent transport mechanisms. Other tissues have different requirements and responses to insulin. Therefore, it would be inaccurate to state that glucose cannot enter any cells in a person with diabetes.

When insulin is insufficient or ineffective, the body may increase fat breakdown and protein breakdown to provide alternative fuels and metabolic substrates. In type 1 diabetes, severe insulin deficiency can lead to excessive ketone production. In both major types of diabetes, prolonged high blood glucose can contribute to cellular and tissue damage.

Oxygen remains essential for aerobic respiration, but diabetes is not simply a condition in which the body lacks oxygen. Instead, it primarily involves problems with insulin and glucose regulation. Understanding this distinction helps healthcare professionals explain why diabetes treatment focuses on controlling blood glucose, supporting normal metabolism and reducing the risk of complications.

4. Lifestyle, Monitoring and Diabetes Management

Effective diabetes management combines appropriate medical treatment with education and individualised lifestyle support. Healthcare professionals should explain the condition in accessible language and consider each patient's circumstances, preferences, cultural background and ability to follow a care plan.

A balanced diet can support blood glucose management. Patients may benefit from choosing high-fibre foods, vegetables, whole grains and suitable sources of protein, while reducing excessive consumption of sugary drinks and highly processed foods. Carbohydrate quantity and timing can influence blood glucose, particularly for people using insulin or certain glucose-lowering medicines. Dietary advice should be personalised rather than based on the assumption that one eating plan is appropriate for everyone.

Regular physical activity can improve insulin sensitivity, support cardiovascular health and assist with weight management where appropriate. Muscle contraction also increases glucose uptake by skeletal muscle, including through mechanisms that are partly independent of insulin. Patients should be encouraged to choose activities that suit their abilities and health needs. People using insulin or medicines that can cause hypoglycaemia may need advice about checking glucose and adjusting food intake or treatment around exercise.

Smoking cessation is also important. Smoking increases cardiovascular risk, and people with diabetes already have an elevated risk of cardiovascular complications. Healthcare professionals can offer supportive advice and direct patients towards appropriate smoking cessation services.

Medication is another important part of care. People with type 1 diabetes require insulin. Treatment for type 2 diabetes may include lifestyle changes, tablets, injectable medicines or insulin, depending on individual needs and the progression of the condition. Patients should understand the purpose of their medication, how to take it correctly and what adverse effects or warning signs to report. Medication should not be stopped or changed without appropriate clinical advice.

Monitoring helps patients and healthcare professionals assess how effectively diabetes is being managed. HbA1c is a blood test that reflects average blood glucose over approximately the previous two to three months. It is used to assess longer-term glucose control and to help review treatment. The frequency of HbA1c testing and the target level should be agreed according to the person's clinical circumstances.

Self-monitoring using a finger-prick blood glucose meter or a continuous glucose monitoring device may be appropriate for some patients, particularly those using insulin or at risk of hypoglycaemia. However, routine finger-prick testing is not necessary for every adult with type 2 diabetes. NICE recommends individualised decisions about monitoring based on treatment, risk and clinical need (NICE, 2026).

Keeping records of relevant readings, meals, activity and symptoms can help identify patterns. For example, repeated high readings after meals may prompt a review of food choices, medication or the treatment plan. Low readings may indicate a risk of hypoglycaemia and require appropriate action. Patients must be taught how to interpret results and when to seek professional advice.

Healthcare professionals should also explain warning signs requiring urgent assessment. Severe hypoglycaemia can cause confusion, seizures or unconsciousness. In people with diabetes, vomiting, abdominal pain, deep or rapid breathing, dehydration or unusual fruity-smelling breath may indicate diabetic ketoacidosis and require emergency medical care. Clear information about warning signs can improve safety and help patients understand when self-management is not sufficient.

NICE (2026) emphasises individualised care, appropriate glucose targets, healthy living and regular review. Supporting patients to participate in their care can improve understanding, encourage treatment adherence and help reduce the risk of complications.

5. Conclusion

Diabetes mellitus is a condition in which the body's normal regulation of blood glucose is disrupted because of insulin deficiency, insulin resistance or both. Understanding the functions of the pancreas, insulin and glucagon explains how the body normally maintains glucose homeostasis and why this process becomes impaired in diabetes.

Glucose and oxygen are also essential to aerobic cellular respiration, through which cells produce ATP to support normal physiological functions. Although diabetes primarily affects glucose regulation rather than oxygen availability, poor glucose control can disrupt metabolism and contribute to long-term damage to blood vessels, nerves, kidneys and eyes.

Healthcare professionals have an important role in helping patients understand their condition, treatment and lifestyle choices. Individualised advice about nutrition, physical activity, smoking cessation, medication and appropriate glucose monitoring can support safer and more effective diabetes management. By combining an understanding of physiology with clear communication and person-centred care, healthcare professionals can help patients make informed decisions and improve their long-term health outcomes.

References

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