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“Specific Health Complications Among Diabetics”

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Introduction

Diabetes Mellitus is a disease where the body cannot sufficiently lower the amount of blood glucose. Insulin is the only hormone that the body produces which can lower blood glucose; if that stops it will cause serious complications to a person's health.

Diabetes has been known about since ancient times but only in the last 125 years has it been linked to the pancreas, and the discovery of insulin was only made 93 years ago in 1921 at the University of Toronto, Canada. Insulin was discovered due to a collaboration between 4 people: "Surgeon Frederick G Banting (1891-1941), His student assistant Charles H Best, The Biochemist James B Collip and the physiologist JJR Macleod (1876-1935)" (Bilous and Donnelly. 2010)

Diabetes and the complications that come along with it are a massive drain on the NHS (National Health Service) in England and Wales. It is estimated that it costs £14 billion a year to treat people affected by diabetes. This equates to about £25,000 a minute; that's is a massive 10% of the NHS's yearly budget. (*Cost of Diabetes*, no date)

It is estimated that over 90% of people with diabetes are Type 2 and the other 10% are Type 1. This is based on geographical location and varies depending on it as well. Usually ranging from a split of 95% Type 2/ 5% Type 1 to a split of 85% Type 2/15% Type 1.

An investigation into how design and technology can reduce complications of Diabetes later in life will be carried out through general research and a questionnaire to discover more about how Diabetics live and cope in modern

times. The aim is to further knowledge and have a greater understanding of diabetes and how instruments used in the treatment of the disease work.

The structure of this dissertation will start with a chapter looking into the causes of type 1 and 2 diabetes, leading onto the prevention of type 2 and then rounding off the chapter with a questionnaire and analysis.

The second chapter will include history of insulin with the discovery of it and administration of it leading onto the history of blood glucose monitors and concluding with an engineering analysis of the Novo Nordisk FlexPen, showing the exact functions of this piece of equipment.

The Final chapter will look at new technologies being used to treat diabetes as well as predictions and ideas of what will happen with diabetes and its treatment over the next 20 years. The summary of chapter three will include a discussion of the recent breakthroughs in finding a cure for type 1 Diabetes and what it means for people suffering from the ailment.

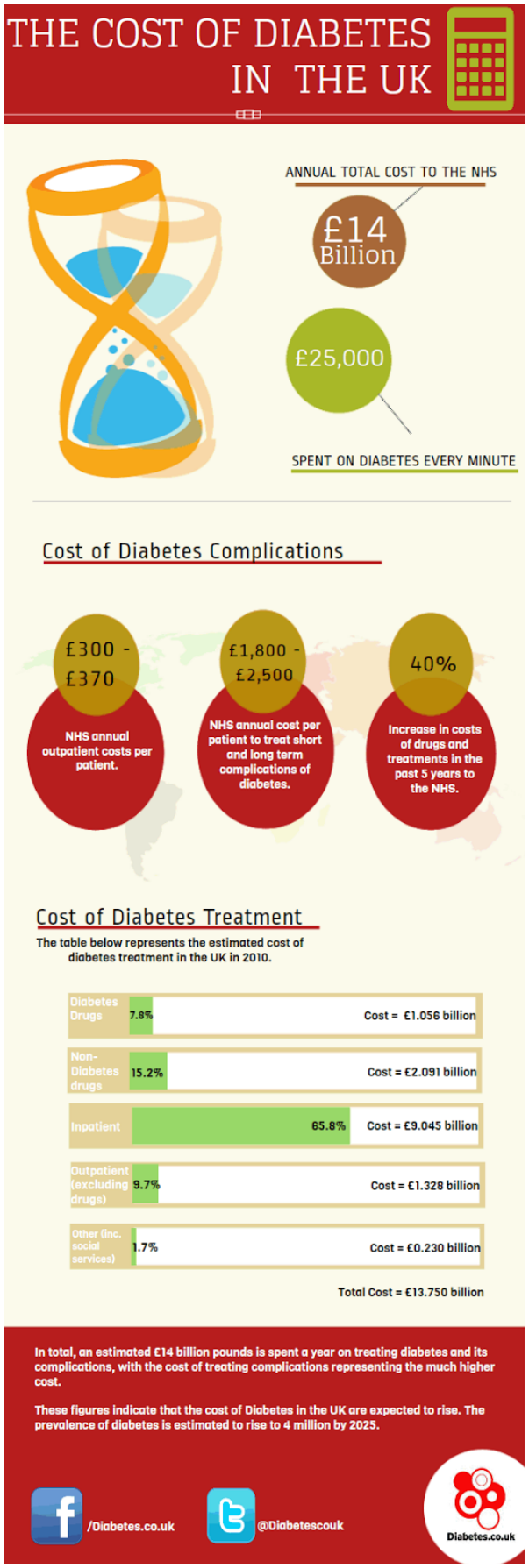


Figure 1: The cost of Diabetes Infographic

CHAPTER 1

Diabetes and its causes

2.0 Chapter 1 – Diabetes and its causes

2.1 Causes of type 1 and type 2 diabetes

Type 1 Diabetes falls into two categories. There is Type 1A which autoimmune diabetes. This is where the *autoimmune* system destroys beta cells which cause the pancreas to stop producing insulin. Type 1B diabetes is Idiopathic, this means that the destruction of beta cells is unknown and no evidence cannot be seen or provided to back it up (Flood, Jabbour & Simon, 2010).

"Type 2 Diabetes Mellitus is a heterogeneous condition due to both genetic and environmental factors." (Dunning and Ward, 2008, pg 7). These include resistance to insulin, impaired tolerance of glucose and insulin secretion. If the body builds up a resistance to insulin it then starts to produce more to combat against the resistance, so insulin secretion goes up as well. This also applies to tolerance of glucose. These can manifest for years before Type 2 Diabetes becomes evident in a person. With Type 2 Diabetes there are also environmental factors that come into play; factors such as being overweight and being of an older age can result in a much higher risk to Type 2 diabetes, although people who are not overweight are still susceptible to contracting it, even if it is at a lower risk.

Diabetes can also be temporary but only in women who are pregnant. This is known as 'Gestational Diabetes Mellitus' and usually occurs after 28 weeks of the gestational period. Even though this is temporary, women who suffer from Gestational Diabetes suffer a greater risk of developing Type 2 Diabetes later

in life. It is suggested that every few years they are screened to detect diabetes to catch it sooner rather than later to avoid possible complications. Impaired Glucose Homeostasis is somewhere in between having normal glucose homeostasis and diabetes. You have a significant higher risk of developing cardiovascular disease. Approximately 3% of people with Impaired Glucose develop diabetes every year (Dunning and Ward, 2008).

Figure 2: Word cloud for diabetes

2.2 Methods to prevent the onset of Type 2 Diabetes

There are many risks factors to take into account when trying to prevent Type 2 diabetes. Some of these factors you cannot prevent such as: age, ethnicity and family background relating to genetic makeup DNA/Genes. (Can you reduce your risk of diabetes, no date) The NHS offer regular checks for older people so that doctors can diagnose it when it is in a pre-diabetes state. This is important as Dr. Edelman (TCOYDtv, 2013) discusses that in America there are around 30 Million people living with Type 2 Diabetes and approximately 80 million people with pre diabetes; around 5-10% of those cases progressing to Type 2 each year. People who are of Asian or African American origin, for example, can be a lot more susceptible to diabetes, so they have to take more precautions than someone of European origin. (TCOYDtv, 2013) The risk of diabetes is linked to family genes and ethnicity strongly. Other family members suffering from diabetes like a: mother, father, brother or sister raises the chances of Type 2. It is estimated that if both your mother and father suffer from Type 2 diabetes you almost certainly get Type 2 diabetes in your lifetime. Leading a healthy lifestyle is one of the ways to combat and reduce the risks factors that come with diabetes.

One of the ways doctors recommend reducing the risk of diabetes is through a non-pharmacological treatment. This is where there is no doctor intervention and is achieved by a complete lifestyle changes, (TCOYDtv, 2013) including:

- Healthy eating: By changing your diet and eating smaller portion sizes and less in general, can aid in the loss of weight and body fat. Avoiding foods that are sugary and sweet as well as processed foods.

- Regular exercise: Doing regular exercise recommended at 30-60 minutes a day also aids with weight loss and reduction in body fat. Exercise can include: walking, running etc. as well as anything that helps to increase heart rate in general.
- Stress Management: Managing stress through behavioural improvements and having a positive attitude can help but attention must be paid to a person's coping skills, quality of life, healthy workplace environment and family members that can provide optimal support and care. (INDIAN COUNCIL OF MEDICAL RESEARCH, 2005) All of these apply to people who are in a pre-Type 2 diabetes state and people who are currently suffering with Type 2 diabetes.

Figure 3: Diabetes Fruti Glucometer

2.3 The problems with dieting and eating healthy

Processed food only has one advantage over healthy food (which people should eat) and that is price. Companies like McDonald's, a world renowned restaurant, serves mostly fast food that is processed. It is easier for someone to buy a cooked meal at McDonald's which isn't necessarily healthy than to buy the ingredients for a healthy meal and have to use their own time cooking/preparing the food. This is one of the fundamental problems with today's society and one of the reasons that the number of people with Type 2 Diabetes is so rapidly increasing (Holin, 2011).

The NHS in the UK is running programmes to keep people active and healthy (NHS, 2013). These are programmes to help the population as a general and not just people who are diabetic or at risk to it. They offer ideas on how to keep a variety of people active including young children, people aged over 65, as well as people who work in an office and are generally sat at their desk all day. Stress is another contributing factor to peoples eating habits; if someone is stressed, they are more likely to eat junk food and not spend time cooking a healthy meal (Tran et al., 2011).

Figure 4: Diabetes Mellitus

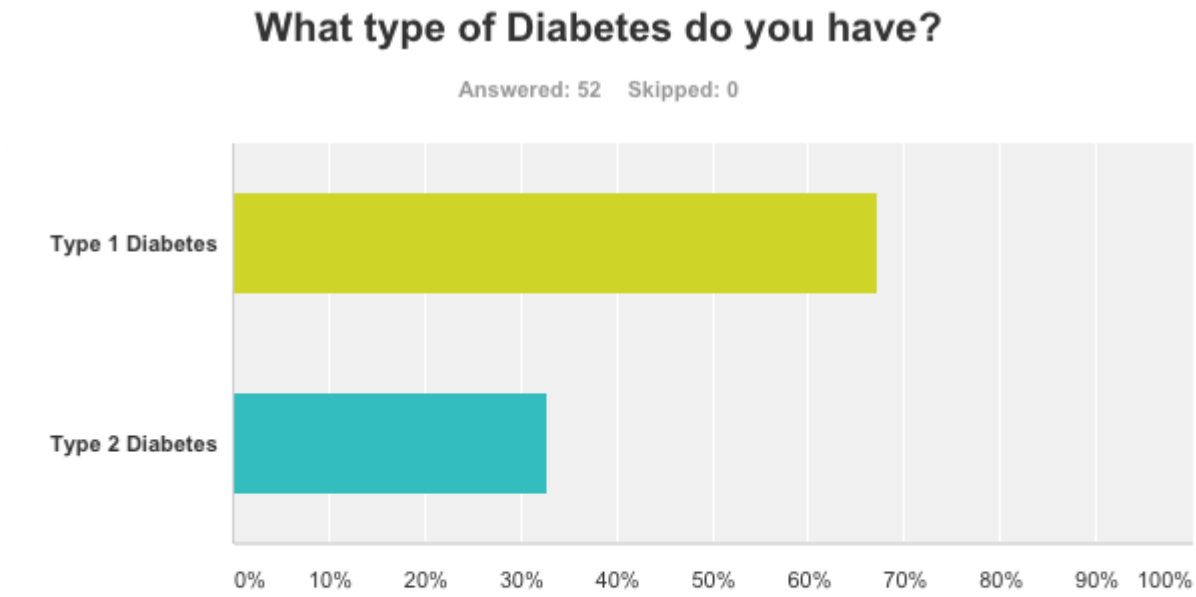
2.4 Questionnaire

In order to further knowledge and get a greater understanding of the current state of Diabetes in the UK, a questionnaire for people diabetics was created in order to gather information from a large targeted sample of people with the illness; this was achieved by posting the questionnaire to a forum for diabetics. A forum was ideal as it contains people who have either Type 1 or Type 2 Diabetes and come from different walks of life. The aim was also to target those from a variety of backgrounds, with different experiences and have had diabetes for different amounts of time; there would be people who have had diabetes for under a year and some who have had it for over 20 years. To get a high amount of responses a decision was made to make the questionnaire short with 10 multiple choice questions which would apply to both Type 1 and Type 2 Diabetes.

The questionnaire was posted for a total of 5 days in order to get a good number of responses. After 5 days, 52 people had filled out the questionnaire and the results that the questionnaire produced were very interesting and quite different from what was predicted.

Figure 5: Online Questionnaire icon pencil and que

Question 1

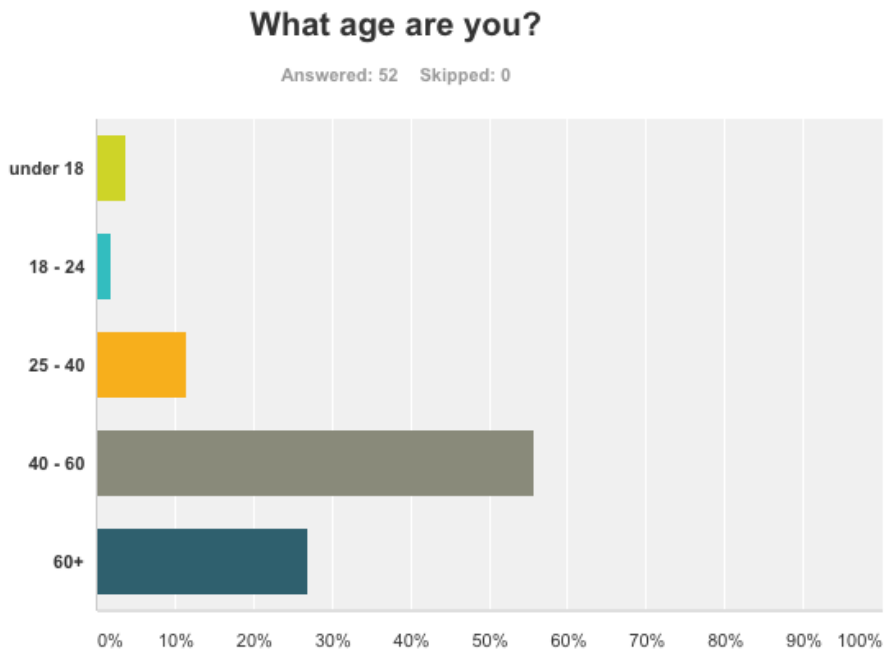


Answer Choices	Responses	
Type 1 Diabetes	67.31%	35
Type 2 Diabetes	32.69%	17
Total		52

Figure 6: What type of diabetes do you have?

Discovering what type of diabetes people on the forum had was a good starting point. Results showed that 35 out of 52 people suffered from Type 1 Diabetes and the remaining 17 suffered with Type 2 Diabetes. Looking at this result and then comparing it to the estimated 90/10% of Type 2/Type 1 (REFERENCE) split in sufferers of diabetes shows that diabetics who have Type 1 tend to use forums more. This could be for such things as help and support in living with Type 1 Diabetes as they have the burden of having to self-administer injections of insulin, whereas Type 2 can be controlled by pills and diet.

Question 2

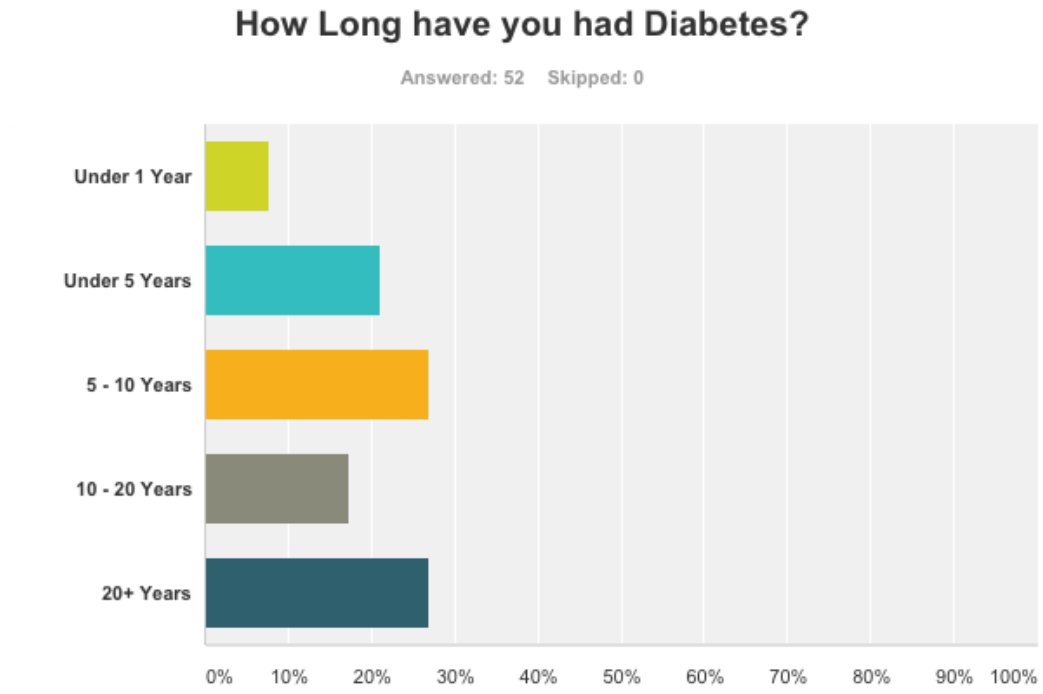


Answer Choices	Responses	
under 18	3.85%	2
18 - 24	1.92%	1
25 - 40	11.54%	6
40 - 60	55.77%	29
60+	26.92%	14
Total		52

Figure 7: What age are you?

It was also important to discover the age of forum users. Over 50% of responses were from people who are aged between 40-60 years of age. This shows a massive gap in the number of young people on the forum, with only 1 respondent being aged 18-24. It shows more needs to be done to show young people suffering with diabetes that there is support out there in forums from people going through the same thing as they are whether or not they are older. It is worth noting that it was specified that parents/carers of young people with diabetes could fill out the questionnaire as well for them.

Question 3



Answer Choices	Responses	
Under 1 Year	7.69%	4
Under 5 Years	21.15%	11
5 - 10 Years	26.92%	14
10 - 20 Years	17.31%	9
20+ Years	26.92%	14
Total		52

Figure 8: How long have you had Diabetes?

Leading on from the age range, it was also important find out how long people on the forum had been suffering from diabetes. There was a good spread in the length of time people had been suffering with Diabetes. There were four respondents who had been diagnosed under a year ago and just over 25% of respondents who had been inflicted for 20+ years.

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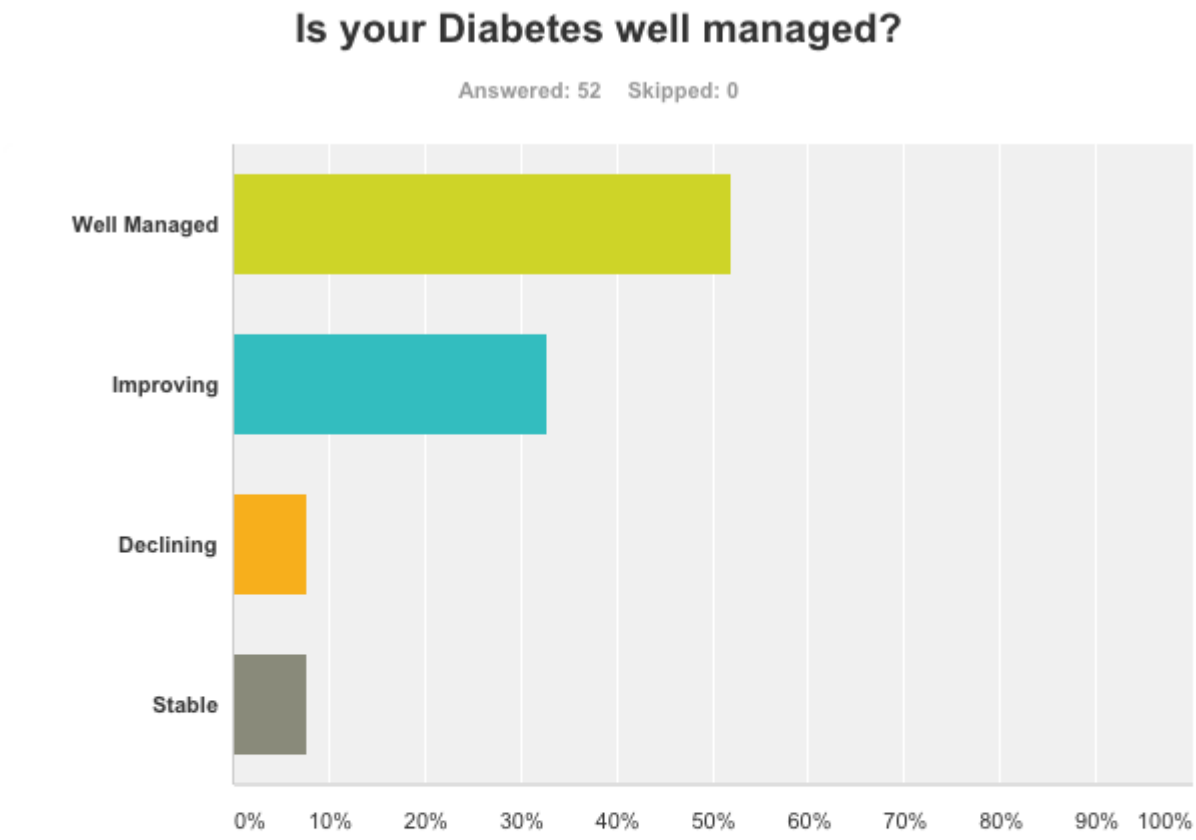
Question 4

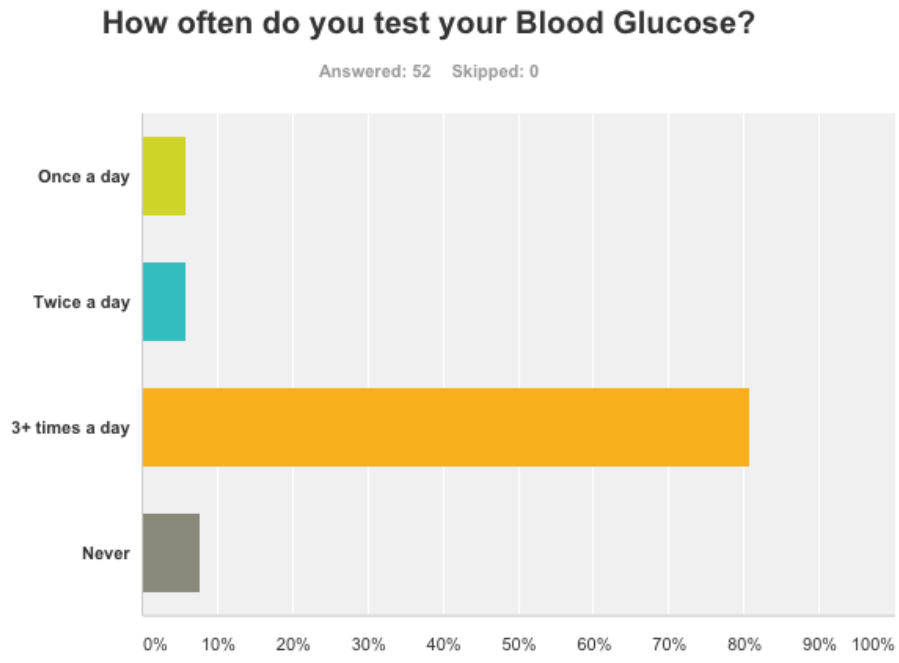


Answer Choices	Responses	
Well Managed	51.92%	27
Improving	32.69%	17
Declining	7.69%	4
Stable	7.69%	4
Total		52

Figure 9: Is your Diabetes managed well?

Just over half said that their diabetes was well managed, followed by a third of respondents who said their control over diabetes was improving. A few said their diabetes was stable or declining. This could suggest that they were seeking support and ideas from people on the forum to manage their diabetes better.

Question 5

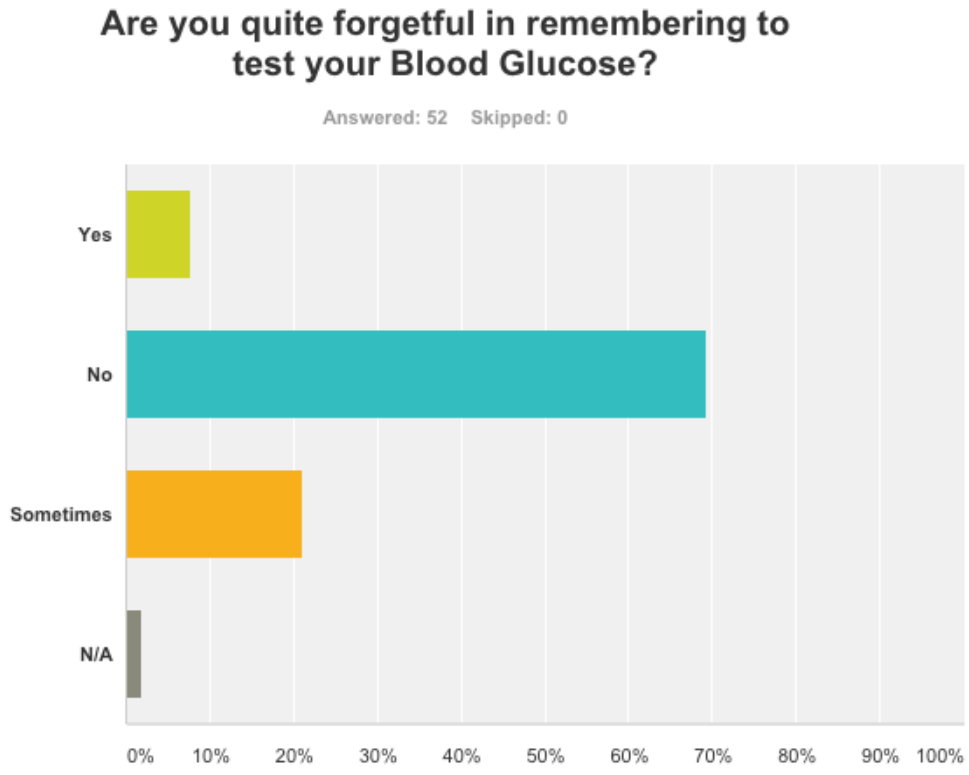


Answer Choices	Responses	
Once a day	5.77%	3
Twice a day	5.77%	3
3+ times a day	80.77%	42
Never	7.69%	4
Total		52

Figure 10: How often do you test your blood glucose

Next was to find out how many times a day respondents tested their blood glucose. The results of this question were surprising: typically a sufferer of Type 1 Diabetes is told to test once or twice a day. Over 80% of Diabetics on the forum test their blood glucose 3+ times a day. This could explain why in the previous question that over 50% of people's diabetes are well managed. These results show a positive correlation between testing 3+ times a day and well managed diabetes: to help achieve diabetes that is well managed you should test at least 3 times a day so you can compare results and make adjustments to your dose of insulin (or diet and pills in cases of Type 2 Diabetes).

Question 6

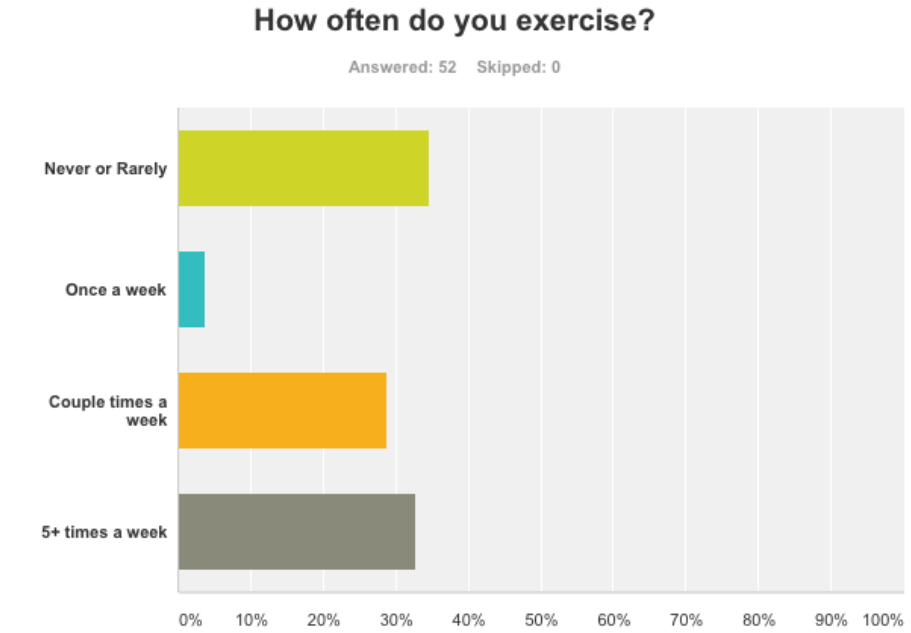


Answer Choices	Responses	
Yes	7.69%	4
No	69.23%	36
Sometimes	21.15%	11
N/A	1.92%	1
Total		52

Figure 11: Are you quite forgetful in remembering to test your Blood Glucose?

Carrying on from the blood glucose-testing question, the questionnaire followed with finding out if people were quite forgetful in remembering to test their blood glucose. From the graph it shows that just fewer than 70% do not have a problem remembering to test their blood glucose. However, there are still 21% who sometimes forget, with 4 out of the 52 people forgetting to test their blood glucose frequently. There could be more effective ways in helping people to remember to test their blood glucose, as forgetting to test can lead to a decline in diabetes management and cause complications.

Question 7

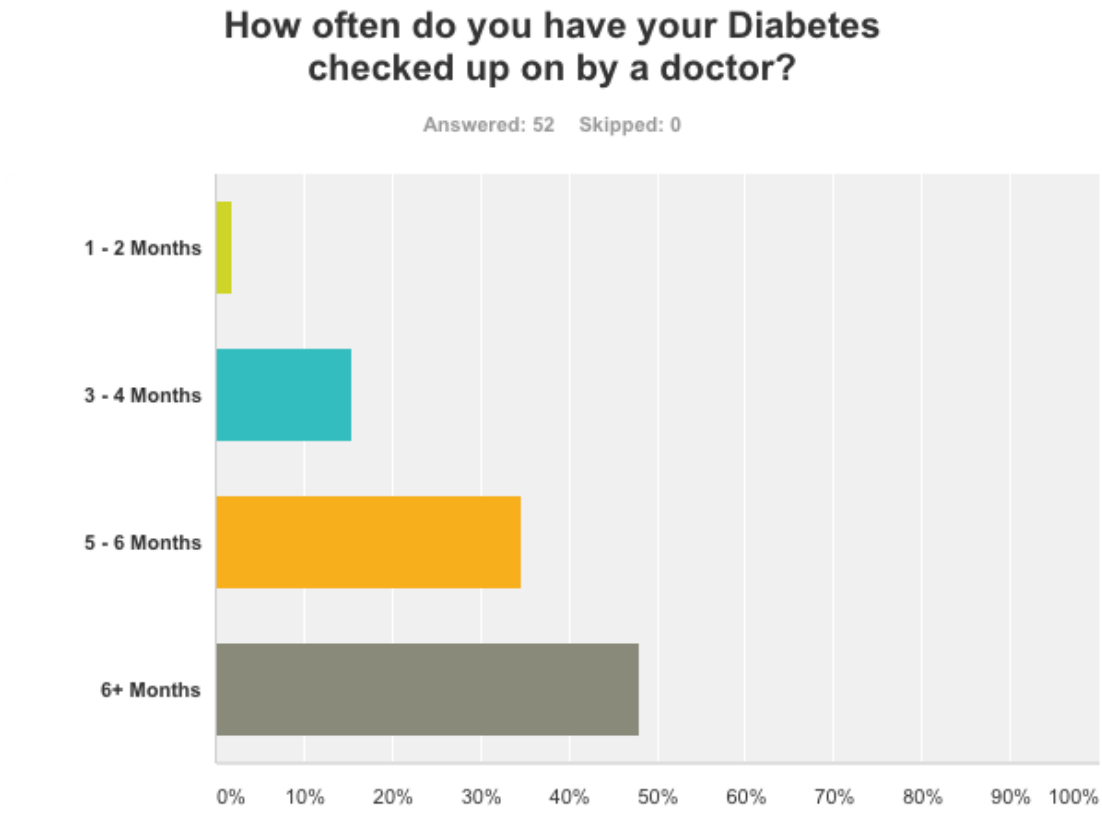


Answer Choices	Responses	
Never or Rarely	34.62%	18
Once a week	3.85%	2
Couple times a week	28.85%	15
5+ times a week	32.69%	17
Total		52

Figure 12: How often do you exercise?

One of the common factors to why people get Type 2 Diabetes is because they are overweight. Asking the forum how many times they exercise a week is a good question to gauge responses. Just under a third of people asked said they exercise 5+ times a week showing that they keep fit and active and 15 out of 52 people saying that they exercise at least a couple of times a week. But the results also show that another third of people rarely or never exercise, which could be an indicator of poorly managed health. One of the ways to live a healthier life with diabetes is to make sure that you do exercise at least a couple times a week. This is something that needs to be addressed if people want to avoid complications with their diabetes, especially in younger people.

Question 8

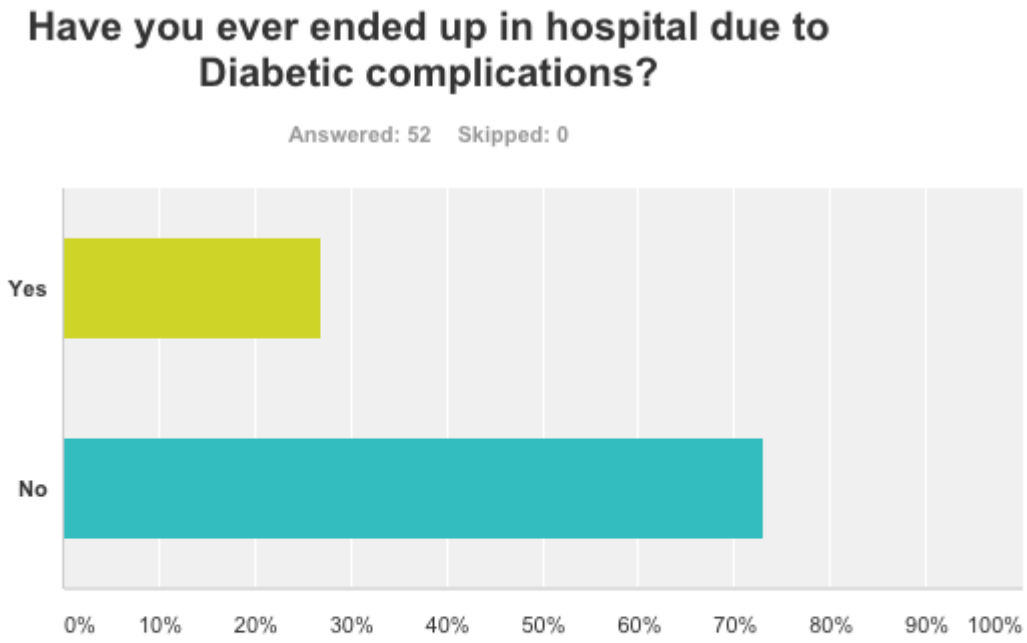


Answer Choices	Responses	
1 - 2 Months	1.92%	1
3 - 4 Months	15.38%	8
5 - 6 Months	34.62%	18
6+ Months	48.08%	25
Total		52

Figure 13: How often do you have your Diabetes checked up on by a doctor?

It is recommended that a person suffering from diabetes gets a check up with a diabetic specialist regularly (at least twice a year). Depending on a person's current state and management of their diabetes there could be more frequent checks with a Diabetic Specialist. People who are well managed usually get checked up on every 6 months whereas people who have a declining or improving management have get seen every 3-5 months.

Question 9

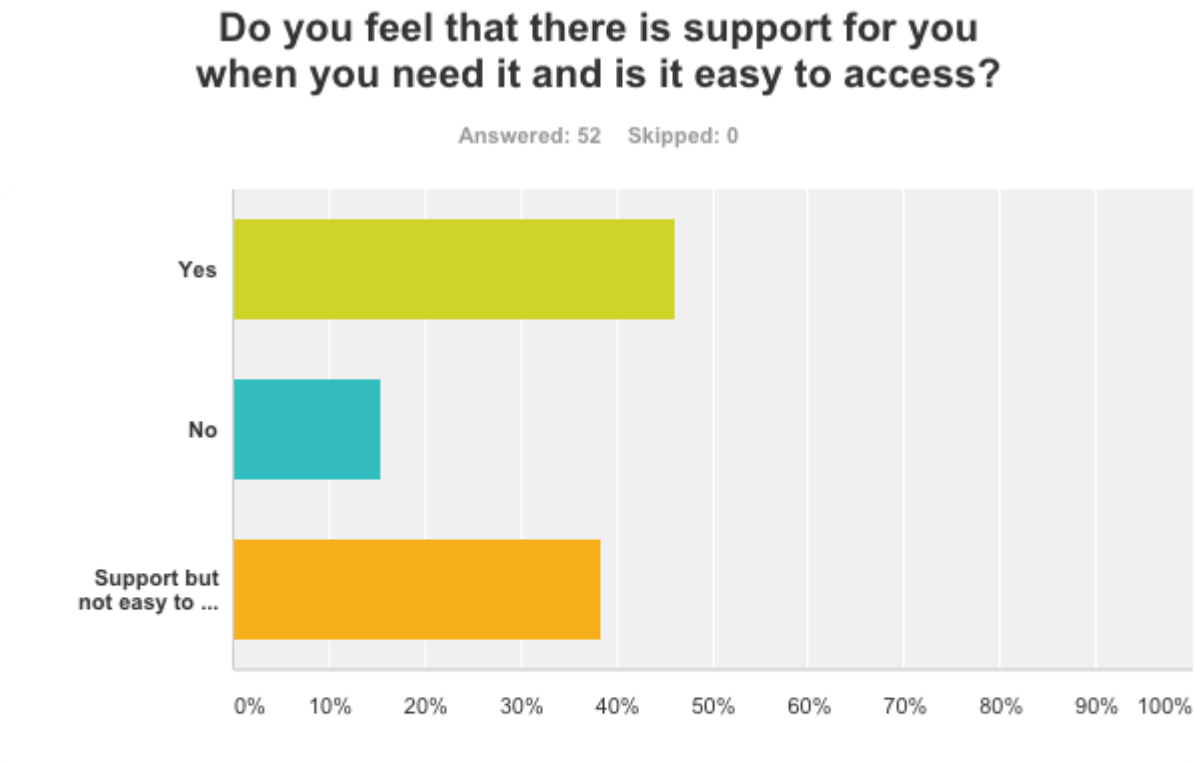


Answer Choices	Responses	
Yes	26.92%	14
No	73.08%	38
Total		52

Figure 14: Have you ever ended up in hospital due to Diabetic complications?

Diabetic complications cause a massive strain on the NHS and a lot of money is spent each year dealing with people who have had complications. When asking the forum if they had ever ended up in hospital due to complications with their diabetes, over 25% said that they had at some point. This shows that more needs to be done in the prevention of diabetic complications so that people do not end up in hospital and their diabetes is managed well.

Question 10



Answer Choices	Responses	
Yes	46.15%	24
No	15.38%	8
Support but not easy to get it	38.46%	20
Total		52

Figure 15: Do you feel that there is support for you when you need it and is it easy to access

Asking the forum whether they felt that there was enough support supplied to diabetics and whether or not it was easy to access. An alarming number of people said that support was available to them but that it was not easy to access. This could be due to factors such as waiting times. The quicker a person can get the support they need for their diabetes the less likely there will be complications with it.

CHAPTER 2

Insulin administration and Blood Glucose Monitors

3.0 Chapter 2

3.1 History of the insulin administration

When Dr. Frederick Banting successfully extracted insulin from a dog in 1922, it was described as a “Thick brown muck” (Gower, 2007). This was then injected into Leonard Thompson, a teenager with type 1 diabetes whose health was rapidly declining. Thompson developed abscesses but showed minor improvements in his blood glucose which led Banting to spend six weeks refining the formula and trying again. This then rapidly improved Thompson’s health and his blood sugars became manageable (Gower, 2007). Even though this was the first time a human had been treated with insulin it was not the first to become commercially available.

Insulin was successfully extracted from a Bovine pancreas on 22nd December 1922 by two men: Hans Christian Hagedorn (1888-1971) and August Krogh (1874-1949) (Novo Nordisk, 2011). Bovine means relating to an animal of the cattle group. A couple of months later in March 1923 the first patients were treated with insulin. Hagedorn described the treatment of a nine year old girl “... this child, who was previously very quiet, has become lively and alert, almost uncontrollable.” (Novo Nordisk, 2011, P. 5) Within the spring of 1923, Novodisk Insulinlaboratorium was created and the first insulin began to be marketed under the name ‘Insulin Leo’.

Figure 16: Insulin Leo

Two brothers, who worked with Hagedorn and Krogh for a short period, moved on and created their own company under the name of ‘Novo’. The brothers, Harold Pedersen (1878–1966) and Thorvald Pedersen (1887–1961) within a year of Insulin Leo becoming marketed as a tablet form of treatment for people with type 1 Diabetes, developed a stable liquid insulin called “Insulin Novo’. At the same time Harold Pedersen who was an inventor, designed a special syringe “The Novo Syringe” so patients could inject themselves with the correct insulin dose whilst injecting was as comfortable as possible. (Novo Nordisk, 2011, p.7). This is where the first syringe for administering insulin was develop and would eventually lead to the design of insulin devices of today.

Figure 17: The Novo Syringe

Even though the discovery and use of insulin was a breakthrough, it had a very short acting period and research needed to be done to develop and produce insulin that was long acting. In 1936, Hagedorn, with help from Norman Jensen, discovered that by adding the protein known as Protamine which was developed from milt of river trout. It was hailed as the biggest discovery since insulin itself and with that Nordisk could market it as a long acting insulin so people would not need in inject as many times in one day. (Novo Nordisk, 2011) This disadvantage of this was patients were required to add a neutralising fluid but within the year of this being release, two

Canadians D A Scott and A M Fisher developed Zinc-Protamine Insulin which didn't require a neutralising fluid and only required to be shaken before administration. (Novo Nordisk, 2011)

It wasn't until the 1970's that the first insulin pump was produced and not till 1985 until the first insulin pen became available. (Selam, 2010) Both of these devices greatly improve the accuracy of dosage for insulin when compared to the traditional syringe and vial used up until then. Insulin pumps in the 1970's were extremely bulky machines and traditionally had to be carried in a backpack for the user to be mobile, but over the past few decades technology has drastically improved and they have become smaller to the point where they can be clipped to a belt or put into a user's pocket. The discreet design of insulin pumps nowadays has made people more confident in using one. Improvements in insulin pumps have also allowed them to wirelessly connect to blood glucose monitors to help the user manage their diabetes better to make adjustments to insulin accordingly. (Selam, 2010)

Figure 18: Modern day Insulin pump

Insulin pens where a revolution when compared to the syringe and vial. Not only was the insulin pen extremely compact it also had a high dosage accuracy. (Spollett, 2012) Talks about how the adoption of Insulin pens is extremely low in the United States when compared to European adoption with less than 10% of insulin users in the United States owning a insulin pen with many still being on the syringe and vial. Factors for this is due to America's health service and that vials and syringes typically cost less than disposable insulin pens.

Disposable Insulin pens (14.6 cents)

Vial and syringe (11.9 cents)

That is 23% more expensive. (Spollett, 2012, P. 4) Spollett also mentions that due to the United Kingdom's National Health Service (NHS) Insulin pens have traditionally been chosen over syringe and vial to help people manage their diabetes better and have been widely available to people living with diabetes there since the mid 1980's when the first pen was introduced by Novo.

Figure 19: The NovoPen 1

3.2 - Blood Glucose Monitors

Anton Clemens developed the first blood glucose monitor over 40 years ago in 1970 and was seen as a landmark development, not only in diabetes but in general point of care (PoC) which greatly increased during the mid-1980's. Before the introduction of blood glucose monitors, the only way to traditionally test how much blood glucose was in a person's system was through their urine; done through factors such as appearance and even taste. This has been done since medieval times and it wasn't till 1850 that Jules Maumene developed simple method of detecting the presence of sugar in urine. (CLARKE and FOSTER, 2012)

Blood Glucose monitors still have their limitations. They have to be calibrated so they show correct reading and failure to do so could end up with a type 1 diabetic patient administering a dose of insulin which could lead to potentially fatal results. They will never be as accurate a laboratory tests but regular and constant calibration will make them as accurate as possible. (Coopey, 2014)

Figure 20: Blood Glucose test

Dr John Mastrototaro talks about a Blood Glucose device that is a Continuous glucose monitor (CGM) in which he talks about how it works and describes how the data from the small device which is inserted just under a patient's skin is wirelessly transmitted to either an insulin pump or a glucose monitor

every “5 minutes”. (Mastrototaro, 2011) This gives someone with diabetes as massive advantage over the control of their diabetes. As they system is designed to warn the user of upcoming hypoglycaemic episodes so that they can avoid them. A hypoglycaemic episode is where the blood sugar in a person’s body is low and the body then gives warning signs and signals to a person when they are having one. These can range from such symptoms as: Cold sweats, short temper, shaking and affecting ones vision. But if a diabetic has poor control over their diabetes some of these symptoms will not be as noticeable which can cause some life threatening complications. Having Continuous Glucose Monitors could be an excellent and effective way to help young people avoid complications later in life as their diabetes is controller much more effectively over a longer period of time.

Blood Glucose monitors have come a long way since their introduction since 1970. One of the biggest advancements is in their accuracy in measuring blood glucose, size and improvement in complexity of operation.

On 21st May 2013 a public meeting was put together by the Diabetes Technology Society with leading academic clinicians, medical device experts etc. To discuss the performance of some blood glucose monitors that are on the market are not currently meeting the accuracy standards (PR Newswire, 2013). This is a worrying concern for people with diabetes who may think that their diabetes is being well managed, when in fact it isn’t. This problem was commonly noticed among the cheaper blood glucose monitors. Strict restrictions and more testing on the accuracy of blood glucose monitors on the market have been put into place so the chance of diabetic complications can be lowered.

Leaps in the size of blood glucose monitors are being made. iHealth announced in 2014 an ultra-portable blood glucose monitor that could plug directly into the headset port of your phone. Then with the free companion app would recognise when the monitor had been plugged in and when a test strip inserted. It would then easily record all the results and show them on a graph including the ability of emailing your results to yourself or your doctor for viewing on a computer (iHealth, 2014). The advantage of seeing these results on a graph is a diabetic user can see trends in their blood sugar and adjust their dosage accordingly.

Figure 21: iHealth's phone compatible Blood Glucose Monitor

With the introduction of smartphones and smarter blood glucose monitors there is no longer a requirement for blood glucose coding strips which came with every new batch of test strips. This meant they only have a small amount of results that they could retain in memory but due to advancements it is no longer a problem.

3.3 Engineering Analysis of an Insulin Pen

Insulin pen devices have been around for around 30 years now and technology have come a long way. Insulin pens have a great deal of qualities as medical devices which puts them above the traditional syringe and vial in user satisfaction in administering insulin.

"Studies have shown that insulin pens are preferred by patients over vial and syringe, are more accurate than vial and syringe, and increase medication adherence. When asked to explain their preference, patients note the increased ease of administration, flexibility, convenience, discreetness, and decreased pain of injection."

(Breslin, Ignaut and Boyd, 2010)

3.3.1 Parts of the insulin pen

The advantages of Insulin pens are revolutionary for diabetes as well as the engineering that goes into producing them. They are made up of a number of parts and are made to resemble and be as discreet as an everyday pen. They are available as reusable or as disposable pens with the materials usually used in reusable ones being of a higher quality. The components that make up an insulin pen are:

- A Penfill cartridge holder
- Pen Cap
- Mechanical Part

The penfill cartridge holder holds a small cartridge of insulin which is usually contains around 3 ml of insulin solution. Most penfill cartridge holders are made out of injection moulded plastic and at one end have a coupling mechanism to lock into the mechanical part. They also have a window and a

residual scale for the user to see how much units of insulin is left in the cartridge.

The pen cap part is made out of either injection moulded plastic or in this case a NovoPen 4 is being used so it is made from high quality stainless steel. This part clips onto the penfill cartridge hold and sits flush with the mechanical part of the pen.

The mechanical part of the pen is the main part of the device. This part is key to delivering the correct dosage of insulin and it is crucial that this part is made from high quality materials to avoid this situation. NovoPen uses mostly metal parts for the mechanical part consisting of:

- Plunger
- Intermediate Cylinder
- Piston rod
- Jackscrew Driving Spindle
- Button
- Piston rod cap
- 3 rotary ratchets
- Pen Housing

Parts like the button and piston rod cap are traditionally made from plastic on nearly all insulin pen devices including NovoPen 4.

DuPont helped develop engineering thermoplastics for insulin pens so they could be manufactured more cheaply and sold to developing countries such India. One of the engineered thermoplastics used, Delrin acetal homopolymer can be used for the Jackscrew driving spindle and also the intermediate cylinder whereas Zytel was used for the piston rod, plunger, thumb pad and

piston rod cap. Delrin was chosen because of excellent dimensional stability and that it has a natural level of lubricity. Zytel was chosen due to its very high impact strength, elastic modulus and tensile strength (DuPont, 2008)

In a video on Novo Nordisk's website they talk about the whole design process of their latest iteration of insulin pen device "NovoPen 5". A device that can now remember a dosage for certain times of the day enabling diabetics to better their condition. Talking about its improvements over NovoPen 4 but also how they kept the design of the pen the same but now having to include electronics in the device to calculate half unit measurements. Jesper Klove who is the Senior Vice President of Device Research and Development at Novo Nordisk talks about the choice of stainless steel over plastic saying it provides a much high quality finish and feel as well as a much higher build quality. He also talks about the cost implications of manufacturing the pen out of this material but how it is still competitive in the market of insulin pens mentioning that the manufacturing costs of the pen have decreased 33% from the NovoPen 4 to NovoPen 5. (Novo Nordisk, 2014)

Figure 22: The NovoPen 5

3.3.2 How the mechanical part works

Kerr goes in depth about the mechanism that an insulin pen uses to deliver a dose of insulin to the user (Kerr, 2011). For this example a Novo Nordisk FlexPen was used. The FlexPen is very similar to the NovoPen 4 but in this case it is a disposable insulin pen rather than a reusable pen. The mechanism inside of the pen will be extremely similar to that of the NovoPen 4 but will be made mostly of plastic rather than stainless steel. But since it is designed by the same company the operation of the device will not change much if at all.

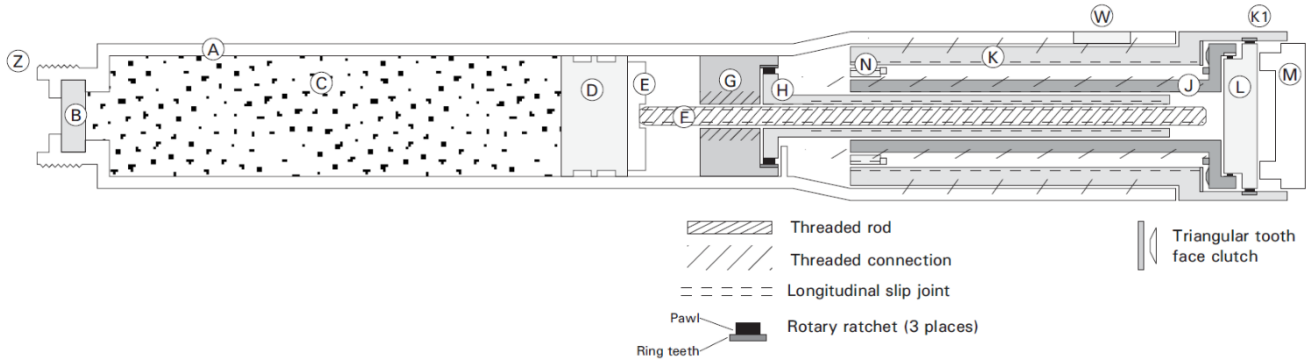


Figure 23: Cross Section of the Novo FlexPen

The plunger (K) and the pen housing (A) have a helical thread with a substantial pitch so as the plunger is rotated in a clockwise direction, it is effectively screwing out of the pen housing. This is how a dose is dialled on the pen. The FlexPen has maximum dial dose of 60 units of insulin (about 0.6ml). 60 units is reached in a total of 3 rotations of the plunger. The pen also has a viewing window to see the amount of units currently dialled, a fiducial indicates the current dialled amount.

Whilst the plunger is rotated it brings an intermediate cylinder (J) with it, but it is prevented from rotation due to a rotary ratchet which does not let it rotate and only enables it to turn counter clockwise such as when the plunger is pushed to deliver the dose. Another ratchet is used so the operating plunger

rests in a desired setting position it also clicks for each unit dialled on the pen. This provides a sound signal to the user that a unit has been dialled.

There is also a Jack Screw driving spindle (H) and a fix nut plate (G) which houses the piston rod, this all is housed with the Intermediate cylinder (J). The fixed nut plate (G) prevents the Jack Screw Driving Spindle (H) from rotating clockwise and out of the pen housing. If the user accidentally dials over the required units, they can rotate the plunger counter clockwise to reduce the amount of units. The two ratchets described effectively switch roles when the units of the FlexPen are decreased.

Within the plunger and just under the button (M) used to press in the plunger is a ratchet motor (L). When the button is pushed, the ratchet motor then meets with the face of the intermediate cylinder (J). Both the intermediate cylinder and plunger have a step with a number of teeth and when they make contact they effectively become locked to each other. With further pressure on the button both plunger and intermediate cylinder both spiral back into the pen housing due to the plunger being supported by a helical thread.

The jackscrew is (H) and the Intermediate cylinder (J) are coupled by a telescoping slip joint. A telescoping slip joint allows two parts to move in a lengthwise direction. The rotation of the intermediate cylinder causes the jackscrew driving spindle to rotate as well but due to the ratchet between the Jackscrew and fixed nut plate the jackscrew does not move in a lengthwise direction and only rotates.

The jackscrew and piston rod have a telescoping slip joint as well, so the movement of the plunger and intermediate cylinder which are locked together rotates the Jackscrew which in turn screws the piston rod through the fix nut

(G) and down into the insulin cartridge. At the end of the piston rod is the piston rod cap which then pushes the rubber syringe piston that is inside the insulin cartridge down thus ejecting the desired dose of insulin from the needle that is screwed onto the end of the insulin pen. If there was no needle screwed onto the end of the pen then whole mechanism would not work as there is no needle inserted through the membrane of the insulin cartridge for insulin to escape out of.

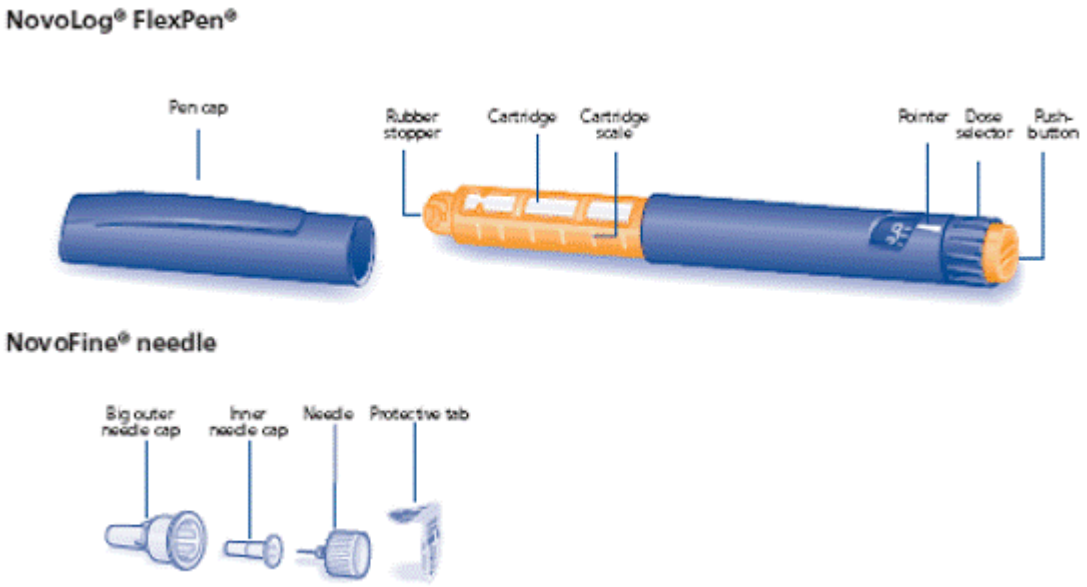


Figure 24: Novolog FlexPen

CHAPTER 3

New Technology and the Future of Diabetes

Chapter 3

3.1 Developments in technology and design that are helping managing diabetes better

There are lots advancements in technology and design around diabetes happening now and in the near future. One of the biggest developments was announced by Google. Based on the same idea as their Google glasses they have developed a smart contact lens, itself quite revolutionary. The idea is putting a extremely small circuit board in a contact lens and having a chip in the circuit board describe as no bigger than a ‘piece of glitter’ and a sensor no think than a ‘strand of hair’ (Android Authority, 2014) What the smart contact lens offers to diabetes is a way to monitor their blood glucose constantly without the pain and intrusion that traditional glucose monitors offer.

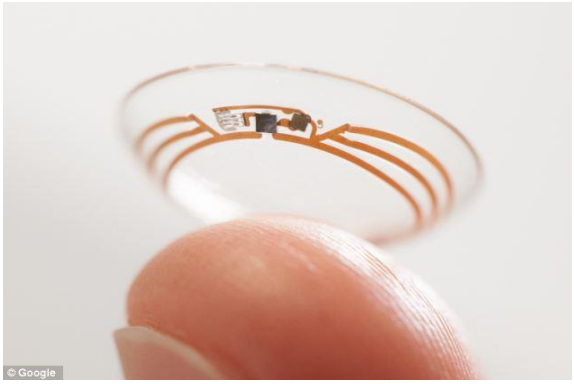


Figure 25: Google’s Smart Contact Lens

It has the ability to provide feedback on blood glucose once every second, a level of control which has never been achieved by any device before. This would eliminate the possibility of people with diabetes ever having a hypoglycaemic episode due to low blood glucose. The smart contact lens is able to charge wirelessly giving the user a lot of freedom. Google’s smart contact lens is still currently under development with hopes of reaching the

market within a couple of years. This could be the start of electronic companies branching out using their technology and research and development departments to expand into the health sector.

With the introduction and advancements of insulin pumps there have still been problems with managing the amount of insulin that's administered to the user. The problem is in the time it takes to recognise when blood glucose is too high and insulin needs to be administered and vice versa when blood glucose is low and the insulin needs to be stopped. Control algorithms have been created to reduce the time in recognition. It helps combat life's variables such as exercise and sickness (Atkinson, 2014). Three algorithms are currently under development and investigation with the hope of one being suitable and covering every possible base. This leads onto the development of faster acting insulin.

Main types of insulin preparations

Type	Onset	Peak	Duration	Comments
Rapid-acting insulin analogue	5-15 min	30-60 min	2-5 hr	Can be injected at the start of a meal
Short-acting (soluble/regular insulin)	30 min	1-3 hr	4-8 hr	Usually injected 15-30 minutes before a meal. Clear solution
Intermediate or long-acting insulin (isophane or zinc insulin)	1-2 hr (NPH, Lente) 2-3 hr (Ultralente)	4-8 hr 4-8 hr	8-12 hr (NPH) 8-24 hr (Ultralente)	Used to control glucose levels between meals. May be combined with short-acting insulin
Long-acting insulin analogue	30-60 min	No peak	16-24 hr	Usually taken once daily

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Figure 26: A range of insulin preparations

Insulin comes in many different variants from long acting insulin which lasts up to 24 hours and takes 90 minutes or so to begin working and fast acting insulin which lasts from 3-5 hours and traditionally begins to lower blood glucose in 15 minutes. Fast acting insulin is usually taken within 15 minutes before or after a main meal. Trails are currently on going to reduce the time it takes for the body to absorb fast acting insulin. Ongoing trials have proved successful in reducing the time of absorption. The reason for developing even faster acting insulin's is to try and match peak insulin levels with peak glucose levels. (DiaTribe, 2012)

In terms of type 2 diabetes, advancements are being made on that front as well. A new drug which was the first of its kind in the US called Invokana (Canagliflozin) (Vann, 2013) This pill is taken orally once a day as is designed to lower blood sugar by flushing excess glucose into the urine so it is taken out of the body. Furthermore it also helps lower blood pressure and helps reduce weight. As a warning, a user can experience some side effects from urinary tract infections to yeast infections as well as increased urination. This drug may not replace current type 2 diabetic medication but serve as an add-on treatment for people who aren't managing their diabetes well.

3.2 Diabetes in the next 20 years

Research into finding a cure and better ways to cope with diabetes is constantly on going. With technology progressing at such a rapid rate, the idea that a cure could be mere decades away is exciting. Many different trails are being tested on a small number of humans living with diabetes at the moment around the idea of having an artificial pancreas (The organ which produces insulin). Due to successful trials in other animals it has now moved onto human testing but is still in the very early stages, but if successful, the next step will be to further widespread testing in humans before it could be considered safe and a viable option. Islet cell transplants have been done by transplanting from dead donors to people with type 1 diabetes. The treatment itself is very effective but as with all transplants the cells only last for a certain period of time and it is also difficult to stop the body rejecting the cells causing more problems and complications. (Hobbs and Taylor with BBC Science, 2013).

Constant Glucose monitoring is growing rapidly by allowing people to get the "attainment of near normal blood glucose concentrations". (Burge MD *et al.*, 2008) But issues with this technology need to be overcome first with such factors as: The high cost of the devices, insurance coverage for the technology and limitations of its approved clinical uses of continuous blood glucose monitors.

Looking at the price of continuous blood glucose monitors isn't so much the price tag of around Receiver device but more the transmitter and the sensors for testing your blood glucose. The FreeStyle Navigator 2 price is in the UK is £450 for the receiver, £500 for the transmitter (which only lasts from 1-1.5

years) and then the sensors which have a typical 5 day use but with great care looking after them they can last longer but taking a 5 day average it costs about £10 per day.(Diabetes CGM Blog, 2013) This shows that the price is a major factor in the implementation of these devices as they are not affordable by most of the public who are suffering from diabetes.

Figure 27: A continuous Blood Glucose Monitor

With the growing population and likelihood of more people developing type 2 diabetes; if nothing is done to combat the issue, there will be a high strain on services as researchers have found that after diagnosis, people with type 2 diabetes “go on a journey of denial, anger, depression, acceptance and finally a sense of hope”. (The Herald - Glasgow, 2012) This is why the NHS is trying to offer more support to people who are newly diagnosed with the condition so that they can get the best help possible in managing the condition in the early stages, As it is said to “take up to 18 years for the users to feel in control of the condition if not supported properly” (The Herald - Glasgow, 2012) Shomali (Shomali, 2012) talks about what diabetes treatment might be like in the year 2025. He references science fiction in his conclusion saying that Type 2 Diabetes will only get more sedentary in the next 20 years unless

radical changes are made. Referring to science fiction of “controlling the world around us with only our thoughts” (Shomali, 2012) something he says no one couldn’t of even imagined 20 years ago, but with advancements in technology it seems that one day in the not too distant future, It may become a reality. This shows that there is a diabetes time bomb ticking away with numbers of Type 2 diabetes doubling in the past 10 years with that only expected to rise. In the journal of paediatric diabetes (Anastoot, 2009) The author talks about changing the future of diabetes explaining that more needs to be done to provide psychological support to children with diabetes. They talk about research carried out by company DAWN Youth and how “DAWN Youth is driving change” (Anastoot, 2009 pp. 58) showing the types of support provided in different countries for the well-being of children in today’s world. It is discussed that support is particularly more important among young people who are transitioning from childhood to adulthood. Teenagers with diabetes tend to find it more challenging living with diabetes when compared people in their adolescents, this could be due to the hormonal changes going on in the body during this time. Over the next 20 years support will gradually improve/increase for young people with diabetes.

There are also problems on two different levels in schools for children and young people with diabetes (Lange, Jackson and Deeb, 2009) One is that they are entitled to education as well as further education and are able to fully participate without being discriminated against because of their diabetes and not made to feel awkward because of it. The second problem is the practical means of taking part in school activities whilst at school or college. They spend most of their day at school so management of their diabetes is vital. In

some countries, some children with diabetes aren't allowed to take syringes or insulin whilst on school grounds which is a form of discrimination. This can then prove problematic for blood glucose management. This problem occurs mainly between the ages of 6-10 whereas teenagers are largely able to self-manage their diabetes effectively. Overtime schools are being educated on diabetes and the need insulin and syringes to be carried on a pupil with type 1 diabetes at all times. Places like the UK already have an understanding of these but there are still places out there still uneducated in diabetes and its requirements, something which will inevitably change over the coming two decades.

One of the major underlying problems that needs to be addressed with diabetes, in both type 1 and 2 cases is education. Even though education of diabetes is becoming more prominent, enough is still not being done to educate people on it and this seems to be based on geographical location as well with places like the United Kingdom having a good education on it and having the necessary support available.

3.3 Type 1 cure breakthrough (recent news)

"We're now just one pre-clinical step away from the finish line"

(Gallagher, 2014)

In October 2014 a significant breakthrough had been made in the search for a cure for type 1 diabetes. Researches at Harvard University have used stem cells to produce hundreds of millions of cells in a laboratory. With the use of mice who are genetically modified to have type 1 diabetes they were able to test this theory out. Because type 1 diabetes is caused when the immune system attacks the beta cells in the pancreas which produce insulin, the stem cells produced can be made so that they act as the same beta cells and produce and release insulin when high blood glucose is detected. Tests in mice have proved successful in achieving something doctors always thought was possible.

Figure 28: Doug Melton who made the breakthrough

If further trials are successful *"the impact on the treatment of diabetes will be a medical game changer on a par with antibiotics and bacterial infections"*

(Knapton, 2014) It would change the lives of 400,000 people in Britain who are currently living with type 1 diabetes with an end to daily injections and minimising the damage from the complications of having type 1 diabetes. The next big hurdle is to stop the immune system from attacking the new stem cell produced beta cells as originally the immune system attacked the beta cells. To do this, the Harvard researchers are already collaborating with colleagues at MIT (Massachusetts Institute of Technology) to produce an implant that will protect the new beta cells implanted in the pancreas from attack from the immune system. Professor Melton described the implant as currently going under rigorous testing in mice and currently the implant has protected the cells from immune system attack for many months but further lengthy testing and development is need until the next trial phase can begin (Paddock, 2014).

CONCLUSION

Summary of Findings

4.0 Conclusion

There is no running away from the facts. Diabetes is an epidemic which is almost out of control. This applies to type 2 diabetes as type 1 is an autoimmune caused and there is no avoiding it. Type 2 needs to be addressed more urgently. There are already initiatives in place attempting to combat it but not enough is being done by governments to reduce the amount of people being diagnosed with type 2 diabetes. With the 90%/10% split between type 2 and type 1. Type 2 is a massive drain on services and costs the NHS a staggering amount each year. This doesn't just apply to the UK in general but other geographical places which equally have the same problem. Due to the United States of America not having a national health service they are still quite behind in technology, such as insulin pens which are freely available on the NHS in the United Kingdom but due to the US people having to have health insurance, they are not really supported by those companies so many people are still using the traditional vial and syringe.

Research in the form of a questionnaire showed some interesting results. It was clear that more support and the ease to access it is required for diabetics. Having the support there for diabetics is vital as not having it can leave diabetics feeling alone and cause other problems such as depression. It also showed that people do not do enough exercise. With the obesity epidemic contributing to the sharp rise in type 2 diabetes more needs to be done to get people more active. Small steps like this would go a long way to reducing the strain on the NHS. The questionnaire also shows that most of the correspondents were between the ages of 40 - 60. This shows there is a generation of diabetics out there who don't know the kind of support they can

get from other diabetics out there who are in the same position as they are and who are willing to give advice and help.

Design and technology are helping people manage their diabetes a lot better with the introduction of insulin pens. Smart insulin pumps which administer doses of insulin when needed as well as continuous blood glucose monitors that monitor blood sugar. All of these helping people with both type 1 and 2 diabetes. There are still improvements to be made to these devices but there are also so exciting developments around new technology such as Google's smart contact lens. Having the ability to monitor blood glucose once every second would give huge control and would pretty much eliminate someone from suffering a hypoglycaemic and/or hyperglycaemic attacks.

The news in late 2014 of a breakthrough in the development of a cure for type 1 diabetes excited everyone in the diabetic community as the hope of one day being rid of the daily injections may soon become a reality in the coming years. This would have a knock-on effect on reducing the amount of strain on the NHS and reducing the amount a year spent on treating diabetes. The would still be people with type 2 diabetes but the amount of people developing it could be reduced if certain actions were taken such as increased exercise and healthy eating.

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