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MOBILE HEALTH APPLICATIONS IN DIABETES CARE

The user experience and the impact on HbA1c levels and self-management; a narrative literature review

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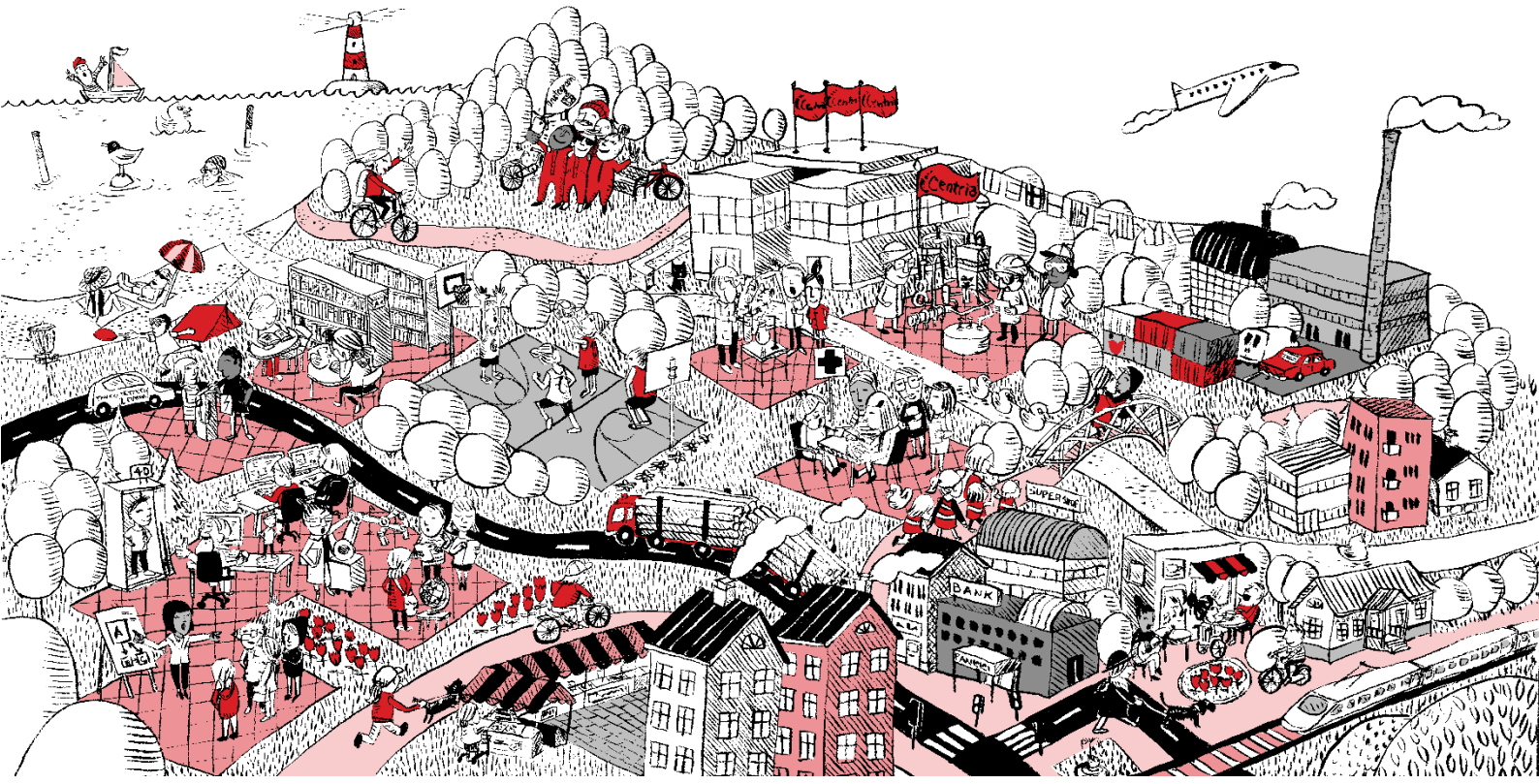

ABSTRACT

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This thesis was conducted for Centria HealthLab, a development and education platform for Central Ostrobothnia's companies and social and health care operators.

The topic of this thesis was mobile health applications in diabetes care. The aim was to collect knowledge about the user experiences of the applications and their impact on self-management of diabetes and HbA1c levels.

The theoretical framework of the thesis consisted of different diabetes types, diabetes care and welfare technology and mobile application developed for diabetes care. Sources for the theoretical background were drawn from diabetes-related current care guidelines and literature and research articles.

This thesis was carried out as a narrative literature review. The literature chosen for the study was analysed using thematic analysis. The literature search was conducted in Academic Search Elite, PubMed and ScienceDirect databases.

The results from the studies had similarities and differences. The majority of the studies did not find significant differences on HbA1c levels and self-management between mobile application intervention groups and control groups. Some differences could be found with specific participant groups as well as with changes in measured levels at the beginning and at the end of the studies. Both positive and negative user experiences could be found. Applications could be helpful with self-management, but they can also be challenging to use because of technical issues.

Key words
diabetes, HbA1c, mobile application, self-management, user experiences

ABSTRACT
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1 INTRODUCTION

This thesis is written as a narrative literature review and it aims to find and present the current knowledge about mobile health applications used in diabetes self-management. The purpose was to establish what kind of experiences people have concerning mobile diabetes applications, and whether these applications have an impact on the self-management of diabetes, or their use affects the long-term blood glucose level HbA1c.

The topic of the thesis was chosen based on personal interest towards diabetes and mobile applications. As the thesis plan was being written, it was suggested to present this literature review as a possible commission to be done for Centria's HealthLab. After presenting the topic the thesis was commissioned by Centria HealthLab, which is an education, innovation and development platform for the social and health care operators and companies in Central Ostrobothnia. A literature review on the subject gave background knowledge about the impact of mobile application use in health-management setting.

This topic of the thesis is important because it will produce information about what people think of mobile health applications and how these applications can be improved. It will also give an overview on the impact of using mobile health applications. This subject is important to diabetes patients as it will gather information about the other users' experiences and the possible positive effects of using such applications. To the health care personnel, this subject is important as it shows the patients' opinions towards mobile health application use and its efficacy. Developers of these applications will find this topic important as it demonstrates people's views about using mobile health applications and it will bring up some of the different improvement ideas the users have.

The importance and prevalence of mobile health applications in managing chronic diseases such as diabetes is likely on the rise. This is likely to be due to the growing amount of the smartphone owners and the fast-growing development of new health care innovations. These applications are not yet commonly used but they can be seen as one way to ease the management of diabetes. (Shan, Sarkar & Martin 2019.) The number of mobile applications in diabetes care is increasing at a fast pace. A review of the current knowledge on the subject can be beneficial for the developers, users, and health professionals.

In the theoretical background of the thesis, diabetes as a disease and its different types are analyzed first. Next, the management and care of diabetes are discussed and the final part of the theoretical background

consists of information on welfare technology, eHealth and mobile applications used in diabetes care. Afterwards, the purpose, objectives and research questions of the thesis are presented, and this is followed by the implementation process of the thesis and the data retrieval and analyzing are gone through. The next chapter discusses the results found in the chosen literature. Finally, the discussion concerning the results, reliability and ethics and thesis process and professional growth are presented.

2 THEORY AND BACKGROUND

This chapter discusses theory and background behind the thesis topic, first focusing on what is diabetes and what self-management of diabetes contains. After that the medical treatment of diabetes is presented with the diabetes associated health issues. Next the thesis will describe what are eHealth and welfare technology, as well as what mobile health applications are available for supporting the self-management of diabetes.

2.1 Diabetes

Diabetes is a malfunction which prevents the body from metabolising glucose to energy. It is caused either by the absence of insulin secretion from the pancreas, the decreasing amount of insulin production or the weakened effect of insulin. All of the forementioned reasons can have an impact on the onset of diabetes. The symptoms of diabetes begin to arise when the excessive level of glucose in the plasma causes the amount of glucose to rise also in the urine, which in turn leads to increased need to urinate, thirst and dehydration. Other symptoms include lack of energy, losing weight, tiredness and proneness to infections. Maintaining good blood glucose levels is the key for treating diabetes. Self-care and self-monitoring of the glucose levels are essential for diabetes care. (Ilanne-Parikka, Niskanen, Rönnemaa & Saha 2019, 9-39.)

The amount of people suffering from diabetes is rising worldwide. In Finland, there are approximately 400 000 people diagnosed with the disease. Most of them, 80-90 percent are suffering from diabetes type 2. The other common form of diabetes is diabetes type 1. (Ilanne-Parikka et al. 2019, 9-39.)

2.1.1 Diabetes type 1

In type 1 diabetes, the autoimmune reaction damages the beta-cells of the pancreas. The damage, which prevents the cells from working adequately, leads to decreased insulin production. Production lessens over a period of time until there is no insulin being produced in the pancreas anymore. This causes the symptoms of diabetes to appear and eventually the person is relying on the insulin administered from

outside of the body. The reason why type 1 diabetes develops is partly hereditary and partly dependant on environmental reasons, such as viral infections. (Ilanne-Parikka et al. 2019, 9-39.)

Often people being diagnosed with diabetes type 1 are suffering from ketoacidosis at the time of the diagnosis. Ketoacidosis is a state where the body is lacking insulin and it is unable to use the glucose for energy even though the glucose level in the body is usually elevated. Instead, the body turns to adipose tissue for energy. Using adipose tissue for energy causes the ketoacids to build up in the body, causing acidosis when the pH-level in the blood falls under 7,35. Symptoms of ketoacidosis start with pain in the abdomen and nausea. Urine production also increases causing a feeling of thirst. If the state continues without treatment, the next symptoms are dehydration, decreased blood pressure, elevated heart rate, smell of acetone on the breath and abnormal breathing. Without treatment ketoacidosis can lead to death. (Ilanne-Parikka et al. 2019, 9-39.)

Treatment of diabetes type 1 aims to normalize the glucose level in the blood. This then leads to less long-term complications, longer life-expectancy and improved quality of life. Insulin treatment is required for the management of the disease. It can be administered through multiple injections per day or through an insulin pump. Blood glucose level has to also be monitored throughout the day. This can be done by measuring the glucose level from the fingertip or through the continuous glucose monitoring device. The aim is to find the suitable solution for every individual suffering from diabetes type 1. (Insulin Deficiency Diabetes: Current Care Guideline 2020.)

2.1.2 Diabetes type 2

Often, hereditary reasons are partly behind the diagnosis of diabetes type 2. The condition usually develops over a longer period of time. People suffering from diabetes type 2 can be asymptomatic. When the symptoms start to show, these might include thirst, an increased need to urinate, tiredness, slowly healing wounds and recurrent infections. In this condition, the production of insulin in pancreas eventually diminishes to the point where the amount of insulin secreted is not sufficient to keep the blood glucose levels in the desirable state. Insulin resistance, the state of the body not being capable of using insulin effectively, is another aspect of diabetes type 2. The amount of adipose tissue in the body is strongly related to the development of the insulin resistance. The human body is able to maintain the correct glucose levels for a while by increasing insulin secretion but over the course of the disease the

production often slows down, and hyperglycemia develops. This will start the symptoms that the person might be experiencing. (Ilanne-Parikka et al. 2019, 9-39.)

Treatment consists of lifestyle changes such as good nutrition, weight loss and exercise. The aim is to maintain a steady, acceptable level of blood glucose. This improves the quality of life and helps to maintain the life-expectancy similar with the age group in question. The long term HbA1c levels should be under 53 mmol/l. Oral diabetes medications, such as Metformin, which affect the glucose production of the liver, can be used to help to maintain the correct blood glucose level. If the combination of Metformin and lifestyle changes is not enough to maintain good blood glucose levels, other oral diabetes medications can be used alongside with Metformin. If the effect is still not adequate, insulin treatment can be also brought to the medication list. (Diabetes Type 2: Current Care Guideline 2020.)

2.1.3 Gestational diabetes

Gestational diabetes refers to hyperglycemia occurring during pregnancy, which is diagnosed using a glucose tolerance test. In Finland all the expecting mothers are screened for gestational diabetes at 24-28 weeks of pregnancy. If the mother is under greater risk for developing gestational diabetes, such as being overweight or having diabetes type 2 in the family, the glucose tolerance test is already performed during pregnancy weeks 12-16 and repeated again during 24 to 28 weeks. The glucose tolerance test is performed after 12 hours of fasting, and it starts with measuring the fasting level of blood glucose, after which a drink containing 75 grams of glucose is consumed. Following the drink, blood glucose is measured after hour and 2 hours. If any of the measurements exceed the set goals, gestational diabetes is diagnosed. All the blood glucose measurements are taken as a blood sample from the vein instead of the fingertip measurement. (Gestational Diabetes. Current Care Guideline 2013.)

During pregnancy, added weight and hormonal changes caused by the placenta can increase the insulin resistance. This can elevate the amount of insulin needed to keep the blood glucose levels acceptable. The treatment consists of nutritional therapy, possible oral medications and insulin treatment, if necessary. The type of treatment needed is evaluated case by case. After childbirth, the glucose levels usually return to the normal levels. Gestational diabetes reoccurs in one third of the mothers that become pregnant again. Gestational diabetes also increases the risk of being diagnosed with diabetes type 2. Early prevention and patient education are important. Glucose tolerance test is also repeated after the childbirth. If the expectant mother had to rely on insulin during the pregnancy, the glucose tolerance test

is done sooner. If lifestyle management was enough, the test is performed one year after birth. (Gestational Diabetes. Current Care Guideline 2013.)

2.1.4 LADA and MODY

Latent Autoimmune Diabetes in Adults (LADA) is considered to be a form of diabetes between the two main types, type 1 and type 2. It is described to start with slow decreasing of the body's own insulin production through an autoimmune reaction. The process is usually slower than with the type 1 diabetes, and people suffering from LADA can at times be without insulin treatment in the beginning of the disease. It is most often diagnosed among adults and women are more commonly diagnosed with the disease. (Ilanne-Parikka et al. 2019, 9-39.)

Maturity Onset Diabetes in the Young (MODY) means adult-type diabetes beginning in an early age. It can be already diagnosed in 10-year-olds. It is caused by the insufficient insulin production; insulin resistance does not play a part in this condition. There are several types of MODY diabetes, the most common being MODY type 2. It is characterized by only slightly elevated fasting glucose levels. The rise in the blood glucose after meal is on the same level as in people without the condition. The difference is that with MODY type 2, the pancreas starts to produce insulin after meals with higher blood glucose levels compared to a person without diabetes. In other words, it takes longer for the body to start to react to elevated blood glucose levels. Otherwise, the body is capable to react adequately to the rise of blood glucose. Nutritional therapy is usually enough to keep the disease in a good treatment level. MODY 3 is the last common type, characterized by having fewer insulin productive cells in the pancreas since the fetal development. It worsens over time and fasting glucose levels and glucose levels after meals are both elevated. Oral medications are used for managing the disease and it is common to have to transfer to using insulin treatment as the condition continues. (Ilanne-Parikka et al. 2019, 9-39.)

2.2 Diabetes care

Diabetes care consists of lifestyle management, glucose monitoring and medication treatment. The care plan is done individually together with the patient, doctor, diabetes nurse and the patient's family members. The Finnish Current Care Guideline offers common goals for the diabetes care, such as acceptable fasting blood glucose levels and long term HbA1c levels. (Ilanne-Parikka et al. 2019, 9-39.)

The goal for fasting blood glucose levels is under 7 mmol/l, and two hours after meal the goal is under 10 mmol/l. The long term HbA1c level should be under 53 mmol/mol, unless the patient is suffering from severe hypoglycaemias, in which case the blood glucose drops dangerously low, and then the individual goal for HbA1c can be set to be higher. LDL cholesterol level should remain under 2,5 mmol/l. If the patient is suffering from atherosclerosis or has other risks for arterial diseases, the goal for LDL is set for lower, at 1,8 mmol/l. The aim is also to keep the blood pressure measurements at an acceptable level at under 140/80 (mm/hg). (Insulin Deficiency Diabetes: Current Care Guideline 2020.)

Self-management of diabetes is supported by regular appointments and laboratory exams. These appointments used to be arranged with steady intervals and always at a health care facility, but recently the direction has been that appointments are arranged on a schedule based on the patient's needs. If necessary, they are arranged more often and when the treatment is in a good balance, the time between appointments can be longer. The amount of remotely arranged appointments via for example phone have gotten more common. The goal of the appointments is to evaluate the current situation and offer support for the patient for managing the disease. (Ilanne-Parikka et al. 2019, 9-39.)

2.2.1 Self-management of diabetes

When diagnosed with diabetes, lifestyle changes play an essential part in the care of the disease. The same nutrition recommendations apply to the people diagnosed with diabetes as to the rest of the population, and these consist of eating plenty of vegetables and whole-grain products, limiting the intake of sugars and white grains, limiting the intake of saturated and trans fats and instead using for example oils. Reducing the daily salt intake is also important. If the patient is struggling with the dietary plan it is recommended to direct the patient to visit a nutritional therapist. (Insulin Deficiency Diabetes: Current Care Guideline 2020.)

A steady meal rhythm eases the self-management of diabetes. It reduces the highs and lows in blood glucose between meals and eases controlling the blood glucose and calculating the correct insulin dose. It also assists with regulating the weight. For type 1 diabetes patients, it is important to have a regular meal rhythm. Insulin intake is based partly on the carbohydrates eaten within a meal. Learning to calculate the amount of carbohydrates and adjusting insulin accordingly is part of the basis of care.

Carbohydrates are calculated within the accuracy of 5-10 grams. In the beginning of the insulin treatment, the patient's individual carbohydrate-insulin ratio is determined, meaning how big amount of carbohydrates is one unit of fast-acting insulin able to cover for. For adults, this is usually 0,5-2 units of fast-acting insulin per 10 grams of carbohydrates. Based on this number, the amount of insulin per meal is calculated. Doing this requires practice, it has been proven that people who have been living with the disease for a longer period of time, make more errors when calculating the necessary amount of insulin. That is why it would be beneficial to offer practising this skill during the follow-up appointments. If the blood glucose level is elevated already before a meal, it is also taken into consideration with the calculation for the insulin needed. This amount is called correction insulin. (Insulin Deficiency Diabetes: Current Care Guideline 2020; Insulin treatment and insulin deficiency diabetes: Current Care Guideline 2018.)

Weight management is also a part of diabetes self-care. The patients being overweight is common especially in the case of type 2 diabetes. Reducing the excess weight helps with maintaining the glucose levels at correct state and helps to eliminate other metabolic disturbances such as elevated LDL-levels. It can also help to reduce the need of oral diabetic medications. When a patient suffering from type 1 diabetes has excess weight, it is possible that they also suffer from aspects of diabetes typically being connected to type 2 diabetes, such as insulin resistance and metabolic syndrome. Losing weight can also help to reduce the chance of developing other conditions, such as fatty liver disease, osteoarthritis and sleep apnoea. (Ilanne-Parikka et al. 2019, 141-163; Obesity (children, youth and adults): Current Care Guideline 2020.)

Regular physical activity is recommended for the people suffering from diabetes, as for the rest of the population. For diabetes care, especially in the case of diabetes type 2, physical activity has been shown to have a positive impact on the person's health, by decreasing insulin resistance, thus making the insulin more effective and also increasing the intake of glucose to the muscle tissue. Other positive impacts include maintaining a healthier blood pressure levels, normalizing cholesterol levels and helping with weight management. Regular activity is also beneficial to the overall wellness and feeling energetic. (Ilanne-Parikka et al. 2019, 163-179; Diabetes Type 2: Current Care Guideline 2020.)

At the same time that physical activity has benefits to the patient's health, physical inactivity has a harmful impact. Inactivity increases the risks for cardiovascular diseases and affects negatively on glucose metabolism. If the person has been inactive in the past, increasing physical activity is recommended to be done gradually. There is also a risk with hypoglycaemias during physical activity

when using insulin or certain oral diabetes medications. In these cases, the individual can adjust the insulin and medication doses and carbohydrate intake when they learn how their bodies react to physical activity. It requires practise at first, and having quick carbohydrate snacks available during the activity is recommended as well as monitoring the blood glucose. (Ilanne-Parikka et al. 2019, 163-179; Diabetes Type 2: Current Care Guideline 2020.)

Part of the lifestyle changes for diabetes management is the cessation of tobacco use and limiting alcohol intake. Especially when using insulin or certain oral diabetes medications, there is an elevated risk for developing hypoglycemia while using alcohol. Alcohol hinders the glucose production in the liver, which means that in the case of developing hypoglycemia, the body's own methods elevating glucose level are not functioning fully. Under the influence of alcohol, the signs of developing hypoglycemia are also more easily missed. To prevent this, individual should drink responsibly and help the body to maintain correct glucose levels by eating while drinking, not injecting insulin to cover the carbohydrates in alcoholic beverages and eat properly after. (Mustajoki 2019.)

Cessation of smoking is recommended for everybody. Carcinogens in tobacco can cause cancer and cause damage to the lung function. Tobacco usage increases the risk for developing diabetes type 2. A person who suffers from diabetes and also uses tobacco, is under a heightened risk for developing cardiovascular diseases. Mortality from these diseases also increases. The nicotine in tobacco causes elevation in heart rate and blood pressure, constricts blood vessels and increases the chances of developing additional diseases commonly seen in people suffering from diabetes, such as changes in the eyes, kidneys and nervous system. (Diabetestalo 2021a.)

2.2.2 Monitoring glucose levels

A major part of self-management of diabetes is monitoring glucose levels. Most of the blood glucose monitors show the glucose levels as the glucose in plasma. The patient can adjust the treatment, to reach the goals of the care put together by the patient and the doctor by monitoring blood glucose levels. Monitoring glucose levels is functional when the patient is aware of the goals of care and has the means to adjust the treatment to reach the goals. The need and intervals of measuring the glucose levels differ from the type of diabetes the person is suffering from and the goals of the treatment. For type 1 diabetes, monitoring glucose levels several times a day is required for performing appropriate insulin treatment and avoiding the risks with for example hypoglycemia. For the people suffering from type 2 diabetes,

glucose can be monitored a few times a week. The need for glucose monitoring should be discussed at the doctor appointments with the patient, as the need differs from patient to patient. (Ilanne-Parikka et al. 2019, 83-123.)

A common way for monitoring blood glucose is taking a small blood sample from the fingertip, called capillary glucose measurement. Tools for monitoring blood glucose can be received from the municipality's treatment equipment distribution center. The tools consist of a glucose monitor and blood glucose slips, sampling device and lancets. Sampling devices can be set to prick the skin on different depths which can ease the associated pain. At times the individual can also use single use lancets without the sampling device, these tools are personal. Lancets are meant for a single-use, but if kept clean, it is possible to use one for a full day. To ensure that the glucose monitor works correctly, it is important to calibrate the monitor periodically using a control solution. This confirms that the monitor reads the glucose level in the plasma correctly. This can also be done during the visits to the diabetes nurse. (Insulin Deficiency Diabetes: Current Care Guideline 2020; Ilanne-Parikka et al. 2019, 83-123.)

One of the benefits of measuring the blood glucose from the fingertip is the active blood flow. It is recommended to use the sides of the finger, as the blood flow is the most active there. It is also beneficial to avoid the forefinger and thumb as well as the top of the fingertips, as these areas are more commonly used during the daily activities and there is some pain associated with taking a blood sample from one's finger frequently. If the blood flow in the fingers is poor, it is recommended to warm up the hands and do pumping motions with the fingers prior to taking the blood sample to activate the blood flow. (Ilanne-Parikka et al. 2019, 83-123.)

The new generation of blood glucose monitors have many features that make the managing of the disease easier. They often have a built-in memory for the results, as well as designated mobile apps that can be used alongside the monitor. Mobile applications offer the chance to for example, record the used insulin doses and note physical activity and diet. Some monitors also offer an insulin dose calculator, which can be used to support calculating the correct dosages. This requires entering additional information to the monitor, such as the individual carbohydrate-insulin ratio. It is possible to also use the traditional method of marking down the glucose levels on a designated glucose-level booklet. (Ilanne-Parikka et al. 2019, 83-123.)

Continuous glucose sensoring is another way of monitoring blood glucose, and it is most typically used for children and teenagers. It can be also used with adult patients having difficulties with maintaining

the correct glucose levels, and who are often in danger of developing hypoglycemia. The price of the devices has been one of the limitations for their use, but since the development of so-called flash sensors, which are commonly lower in price, the user group has expanded to people who are suffering from insulin deficiency diabetes. Continuous glucose monitoring can be helpful with maintaining the correct blood glucose levels, decreasing the amounts of hypoglycemia and lowering the Hba1c levels. (Ilanne-Parikka et al. 2019, 83-123.)

All the available sensors work through a device that is attached on the skin. The device consists of the sensor end, which is underneath the skin and is measuring the glucose level from the subcutaneous tissue, and the transmitter, which is located on the skin. One device is attached on the skin for 1-2 weeks. The transmitter can send the glucose measurements wirelessly to the connected devices continuously every 1-5 minutes, or in the case of flash sensors, the measurements are recorded by the device when the connected device is brought close to the transmitter. Flash sensors cannot send the measurements independently, and they do not warn about possible hypoglycemia. They cannot be used with people who are suffering from hypoglycemia and cannot recognize hypoglycemia on their own. The device that is wirelessly connected to the sensoring device can be a designated scanner, smart phone, insulin pump or a smart watch. Some of the sensoring devices can also send the measurements to more than one device at the same time, with a help of a designated mobile application. The scanning device shows the glucose measurement, as well as a graphic display of the latest measurements and the direction of the change with an arrow. (Diabetestalo 2021b; Insulin Deficiency Diabetes: Current Care Guideline 2020; Ilanne-Parikka et al. 2019, 83-123.)

In addition to the glucose monitoring at home, the HbA1c level, which shows the glycated portion of the hemoglobin, can be measured from the blood. It can be taken at the laboratory, or as more common nowadays, it is taken during the appointments with the diabetes nurse, where it is done as a quick test. The HbA1c level shows the average glucose level within the last 6-8 weeks, and the goal level for HbA1c is under 53mmol/mol. Depending of the patient, it is measured every 3-6 months. An increased HbA1c level suggests that the person might be in a danger of developing additional health complications associated with diabetes. (Ilanne-Parikka et al. 2019, 83-123.)

When using continuous glucose monitoring, in addition to HbA1c measurements, the Time In Range (TIR) can also be taken into consideration. Although HbA1c shows the average blood glucose level from the last 6-8 weeks, but it does not take into account the amounts and levels of hypo- and hyperglycemias. This means that the HbA1c level can be the same in two patients, one of whom is remaining more stably

at the goal level between 3.9-10 mmol/l, whereas as the other has severe hypo- and hyperglycemias and is unable to stay at the preferred level. The goal for TIR is suggested to be at 70 %, which translates as the patient staying at goal level 70 % of the time when the sensor is used. (Koistinen & Cederberg-Tamminen 2019.)

2.2.3 Diabetes medications apart from insulin

People suffering from type 1 diabetes cannot be treated with oral diabetes medications. Whereas people with diabetes type 2 can benefit from oral medications for diabetes care together with the lifestyle management of the disease. The goal is to be able to lower the glucose level in the blood. There are multiple different medications with different active substances and mechanisms of action. The medication or the combination of them is chosen individually for every patient. While choosing, it should be considered is the goal of the treatment to affect the decreased insulin resistance or the decreased production of the insulin. Other issues to be taken into account are, for example the individual glucose level goals, sensitiveness to hypoglycemia and the patient's age. (Ilanne-Parikka et al. 2019, 233-249.)

The first oral medication recommended for the treatment of diabetes type 2 is Metformin. It lowers the glucose production in the liver, which in turn lowers the glucose level in the blood. It does not cause hypoglycemia, and it has a low number of interactions with other medications making it relatively safe to use. It also helps with weight management. Common adverse effects with starting Metformin are gastrointestinal symptoms such as stomach pain, loss of appetite, diarrhoea, nausea and vomiting. These symptoms are usually only seen in the beginning of the treatment, and they subside after a while. They can also be prevented with taking the medication at the same time with the meals and starting the treatment gradually, with increasing doses weekly. (Metformin in diabetes care: Current Care Guideline 2016; Pharmaca Fennica 2020.)

Other oral medications that can be used individually, or as combination with other oral diabetes medications are, for example glinides and sulfonylureas, which affect to the pancreas and increase the body's own insulin production. Glinides act on the short term, whereas sulfonylureas have a longer effect. Medications that affect the insulin production by increasing the number of intestinal hormones, are gliptins and GLP-analogs. They support the glucose dependent insulin production and are fit to be used for treatment of post-meal hyperglycemias. They do not cause hypoglycemia. Other types of medication that can be used are glucose removers. They increase the secretion of glucose to the urine,

thus lowering the glucose level in the blood. Glitazones are the only medication affecting the improvement of the insulin resistance. They sensitize the adipose and muscle tissue to the insulin, thus making the insulin in the body more effective. Their effect is accomplished slowly and a follow-up appointment for their efficiency should be booked 3-6 months after starting the treatment. (Diabetes Type 2: Current Care Guideline 2020.)

2.2.4 Insulin treatment

Without diabetes, the pancreas is producing insulin. Insulin, consisting of two amino acid chains, is produced by the pancreatic beta-cells in the islets of Langerhans. The amount of insulin produced is controlled by the glucose levels in the plasma. When the level is higher, more insulin is produced and the glucose level decreases. In a non-diabetic person, the highest level of glucose in the blood is reached within one hour after eating, and the level also normalises within the same hour. When the person is suffering from diabetes, the level reaches its peak in 1-2 hours and still remains elevated after 3-4 hours. (Leppäluoto, Kettunen, Rintamäki, Vakkuri, Vierimaa & Lätti 2012, 349-351.)

Originally insulins were extracted from bovine and porcine pancreases in the 20th century. First short acting insulin was developed and it was later followed by the long-acting insulins. There are still some animal derived insulin products available with special authorization in Finland, but their use in the Western countries has nearly ended, as their use and production are difficult. Their structure with amino-acids is not fully similar to human insulin. The insulin gene was discovered in 1970, and from the beginning of 1980, human insulin could be produced with gene-technology. In 1990 the structure and features of human insulin could be modified. The goal of the modification was to affect insulin absorption and secretion. These modified insulins are called insulin analogs. The first insulin analog was a fast-acting insulin, which simulates the body's own insulin production better than the short-acting insulins. There are also long-acting insulin analogs available that provide a steadier insulin absorption compared to traditional long-acting insulins. (Ilanne-Parikka et al. 2019, 179-211.)

Insulins can be separated into different categories based on the timeline of their effect. Short-acting insulin starts its absorption at 30 minutes after injection, and the peak effect is at 1,5-3 hours after administering. Even though the name is short-acting insulin, the effect can last up to 5-8 hours. This can cause hypoglycemia between meals. Fast-acting insulins are insulin analogs. Their amino acid structure has been modified to allow for the absorption of the insulin to start quicker. The effecting time of fast-

acting insulin is 3-5 hours with its peak at 2-3 hours. The absorption starts immediately after administering and it starts effecting at 10-20 minutes after injection. (Ilanne-Parikka et al. 2019, 179-211.)

There are different types of long-acting insulin available. NPH-insulin is a human insulin, which is not an insulin analog. Its effect depends on the individual it is administered to. The effect period on an adult varies between 12-18 hours. It is also highly dependent on how well the insulin ampule has been mixed prior injection. There are multiple long-acting insulin analogs available with different effect profiles and times, such as degludec-, detemir-, or glargine-insulins. From these, the choice of the insulin product is made by the doctor to suit the individual suffering from diabetes. Their effect times differ from 20-42 hours and they can be injected once a day or twice a day, depending on the product. (Ilanne-Parikka et al. 2019, 179-211.)

Another way to categorize insulins is based on their use, so there are long-acting insulins, so called basal-insulins and short- and fast-acting insulins called meal insulins. The first treatment for insulin deficiency diabetes is commonly insulin treatment with multiple injection therapy. This means that the basic need of insulin in the body is covered with basal-insulin such as detemir- or glargine-insulin. This maintains the glucose level between meals and at night. When the dosage is correct, the glucose level does not fluctuate drastically. The dosage of basal-insulin must be always taken, even if the person cannot eat at the time. The basal insulin is administered either once or twice a day. Meal insulin is used to correct the glucose levels throughout the day with meals. Their dosage is based on the carbohydrates in a meal and the glucose level before meal. Short-acting insulin is recommended to be injected 30 minutes before the meal. Fast-acting insulins can be administered at 15 to a few minutes before meal. (Ilanne-Parikka et al. 2019, 179-211.)

Insulin is administered through a subcutaneous injection. For the injection, it is possible to use single use unit syringes with ampullae that the insulin is drawn from. There are also pre-filled insulin pens and pens with changeable insulin ampullae inside, with pens a designated needle is used. The choice what is used is based on personal preference. Pre-filled insulin pens are considered simple to use. The needle length varies between 4-12 millimeters, with 4-8 millimeters being the recommended size based on the thickness of the adipose tissue. It is recommended to change the needle after each injection, as using a needle multiple times increases the chances of developing swelling and hardened spots under the skin. This then would impact on how well the insulin absorbs. The correct injection technique is important while administering insulin. The target tissue is the adipose tissue underneath the skin. Common

injection sites are the stomach area and thighs. For the injection, the skin is pressed between fingers to raise the adipose tissue from the muscle. The needle is injected to the tissue at a 45-degree angle, or in case of a short enough needle, at a 90-degree angle. Insulin is slowly injected into the tissue while maintaining the skin fold. After injection, the needle is hold in place while counting to ten. Next, the needle is taken out of the skin and the site of the injection is pressed with fingers for a moment to make sure that the insulin stays in the tissue. (Ilanne-Parikka et al. 2019, 179-211.)

Insulin can also be administered through an insulin pump. Insulin pump, which consists of the pump itself, a cannula which is attached to the subcutaneous tissue and a tube which connects these two. In the pump, there is also a storage container for the insulin and the pump transfers the insulin through the tube to the subcutaneous tissue with a help of a small motor. The cannula and the tube should be changed every 2-3 days and the insulin container should be changed when it is empty or nearly empty. Fast-acting insulin is the only type used in insulin pumps. The dose is given continuously throughout the day at a preset speed and intervals, thus acting as a basal insulin. Insulin for meals and correcting elevated glucose level is administered separately as an additional bolus in conjunction with meals. Self-monitoring of glucose levels is needed for the pump use. (Ilanne-Parikka et al. 2019, 211-233; Diabetestalo 2021b.)

Artificial pancreas, insulin treatment which is partially or completely automated, works through an insulin pump, which is able to use the glucose measurements from a continuous glucose sensor to maintain the correct glucose level. It uses computer algorithms to make decisions based on the measurement, glucose trend, previous measurements and the amount of active insulin in the system and other aspects. Meal insulin still needs to be administered manually. (Ilanne-Parikka et al. 2019, 211-233.)

Hypoglycemia is a complication associated with insulin treatment, meaning the glucose level falling below 4 mmol/ml. It may be caused by insulin working too effectively in comparison to food intake and exercise. Also, sulfonylureas and glinides increase the risk for hypoglycemia. Common symptoms are tremors, palpations, sweating and hunger. If the state continues, other possible symptoms are pins and needles in the lips and hands, headache, mood changes, irritability and drowsiness. The last symptoms are unconsciousness and possible convulsions. Hypoglycemia is divided into mild, significant and severe. In the mild hypoglycemia glucose level is from 3 to 3.9 mmol/ml. In significant hypoglycemia the level is under 3mmol/ml. Mild and significant hypoglycemia can be treated at home by consuming 10-20 grams of fast-absorbing carbohydrates to increase the glucose level. Hypoglycemia is considered

severe, not depending on the measured glucose level, when the level of consciousness is lowered, the ability to function is impaired and the person is suffering from insulin shock. In this state the patients cannot treat the condition by themselves. If they are unconscious or resisting help, a glucagon injection can be used. Patients with an increased risk for developing hypoglycemia might carry glucagon injection with them for these kinds of situations. (Ilanne-Parikka et al. 2019, 379-397; Insulin Deficiency Diabetes: Current Care Guideline 2020.)

2.2.5 Conditions associated with diabetes

Being diagnosed with diabetes increases the risk for developing associated diseases. These are for example, cardiovascular conditions and dyslipidaemia. Other commonly seen conditions are issues with eyes, nervous system, kidneys and feet. Moreover, the risk for developing coronary artery disease increases. The risk is three times higher than in the rest of the population. This is connected to the increased tendency for developing atherosclerosis. Atherosclerosis, which translates as the collection of plaque in the arteries making them constricted. The greatest risk factor for developing atherosclerosis is elevated cholesterol levels, and their effect is heightened in people diagnosed with diabetes. The common goal for LDL-cholesterol levels for diabetics is under 2,5mmol/l. If the person with diabetes is also diagnosed with coronary artery disease, cerebral artery disease or peripheral artery disease, the goal is set for 1,8 mmol/l. Cholesterol levels can be controlled with the help of lifestyle management and statin medications. Insulin resistance also causes inflammation and changes in the arteries making them more prone for atherosclerosis. If the blood pressure is elevated, it also needs to be treated. The goal pressure level for diabetics is 140/80 mmHg. To reach the goal, lifestyle changes and medications might be necessary. (Ilanne-Parikka et al. 2019, 397-425; Insulin Deficiency Diabetes: Current Care Guideline 2020.)

Diabetic retinopathy is a condition affecting the eyes, causing changes in the structure of the eye and causing weakening of the eyesight and blindness. Elevated blood glucose levels and increased blood pressure amplify the risk for developing retinopathy. All the individuals diagnosed with diabetes should be screened periodically for retinopathic changes. Already developed retinopathy can be treated with laser treatments, surgery and medication. The amount of people registered blind from retinopathic causes has decreased significantly sincr 1990, but it is still one of the leading causes of visual impairment in the working age population. (Diabetic retinopathy: Current Care Guideline 2014.)

People suffering from diabetes can also develop diabetic kidney disease, a condition where elevated blood glucose and blood pressure levels have affected the kidney function, causing reduced glomerulus filtration rate and albumin in the urea, which translates to the weakening of the kidney function. Patients diagnosed with diabetes are screened for these changes at regular intervals. If changes are noticed, taking better control over glucose and blood pressure levels in addition to smoking cessation can improve the situation. Treatment with medication is also possible. (Diabetic kidney disease: Current Care Guideline 2020.)

Diabetic neuropathy is a condition where the elevated blood glucose levels affect the nervous system, causing changes. It is more common among people diagnosed with diabetes type 2. The changes can be found in single peripheral nerves or in all the peripheral nerves causing pins and needles in the limbs, numbness, pain, weakened muscle function in the legs and the trunk as well as double vision and pain in the abdominal area. Changes in autonomic nervous system cause changes in the bowel function, heart function, urine bladder dysfunction and erectile dysfunction. (Insulin Deficiency Diabetes: Current Care Guideline 2020.)

2.3 Welfare technology, eHealth and mobile applications

Digital health services are becoming more common and accessible in the future. Digital health services consist of wearable health accessories, mobile health applications, telehealthcare and tailored health care. As technology and new methods for implementing health care are developed at a fast pace, they are seen as a solution for providing health services to a growing population of people diagnosed with chronic diseases. Available digital health services can be, for example platforms where the patient can book a time for a health care service, view previous laboratory results and physicians' comments, renew prescriptions, fill out forms and interact with a health care professional. This can allow the patient to seek treatment in a more effortless way, in addition to motivating and supporting the self-management of the diseases. (Meskó, Drobni, Bényei, Gergely & Győrffy 2017; FDA 2021; Terveyskylä 2020.)

eHealth services can benefit the health care system in multiple ways. From the patient's perspective, they can make the self-management easier, increase independency, make patients feel like they are more in control of their own health and improve the follow through with the treatment plan. From the professional perspective, they can improve coordination and communication between professionals. This can lead to the improvement of the continuity of the care, as well as the elevation of patient safety

and quality of care. Challenges with implementing a change towards more widespread use of eHealth services can include resistance by the patients and the medical personnel from a cultural point of view, lack of applicable ICT infrastructure, lack of funding and training opportunities. (Cuesta, German Millberg, Karlsson & Arvidsson 2020; Melchiorre, Papa, Quattrini, Lamura & Barbabella 2020.)

An example of eHealth services in Finland is the Kanta system, which has been gradually taken into use since 2010 in Finland. It provides the citizens with an opportunity to view their medical records and request the renewal of prescriptions. Through Kanta, physicians can make electronic prescriptions and medical statements, such as medical statement b, can be sent to Kela, the Social Insurance Institution, electronically. Kanta also works as an archive for medical records. Continuity of care and public accountability can be improved by using Kanta. (Kanta 2021; Kanta 2020.)

Another platform used in Finland is Omaolo, which is currently being taken in use across Finland. At the moment, it reaches approximately 4 million Finns. It provides the clients with an opportunity to contact health care professionals through a chat system, perform symptom assessments of certain conditions and the program offers a suggestion on what to do. These suggestions can be for example to follow the situation at home or to contact a health care facility. Welfare programs are also available, such as decreasing alcohol use or weight management. It is also possible to fill out a questionnaire about personal health and well-being and to get a report on how client's lifestyle and mental well-being could impact their estimated length of life and risk for being diagnosed with certain diseases. (DigiFinland 2021.)

The omahoito platform is also used in Soite, which is a joint municipal authority for social and health services in central Ostrobothnia. Omahoito allows the patient to contact health care professionals in health care centers as well in maternity, children and family planning clinics through electronic contact request. (Soite 2021.)

2.3.1 Mobile health applications in diabetes care

Mobile health applications are part of the welfare technology. They are applications that the patient can download on their preferred device or they can be built-in programs as well. They consist of apps designed to work together with medical devices, and general well-being and lifestyle applications. They are anticipated to improve patient-centred care, increase the availability of health services and put added

focus on bettering the self-management and patient participation for personal health care. A growing amount of mobile health applications are available to the consumer. There are different kinds of applications aimed at for example for health promotion and taking care of long-term diseases. They have a possibility to enhance management and care of these diseases, even to the point of possibly changing the health outcome. There is a challenge with how to get the patients to use applications. Designing the applications from a user-friendly point of view is an important aspect of this issue. Simplicity, accessibility, personalization and making the applications easy to use are important. So far only a small fraction of the applications have been reviewed and approved by government administrations such as the Food & Drug Administration (FDA) in the USA. (Shan, Sarkar & Martin 2019; Sheppard 2020; Holopainen 2015.)

Developing mobile applications for health management has been rapid over the past years. Contributing to that is the increased usage and ownership of mobile smartphones over the world. There were over 300 000 applications available to the consumer in 2017. The number of health-associated applications are also on the rise. Applications for diabetes management were the second most common disease-specific applications in the market. The development of mobile applications has happened simultaneously with the increasing prevalence of diabetes worldwide in the last of couple decades. (Shan et al. 2019; Veazie, Winchell, Gilbert, Paynter, Ivlev, Eden, Nussbaum, Weiskopf, Guise & Helfand 2018; Fleming, Petrie, Bergenstal, Holl, Peters & Heinemann 2020.)

Using mobile health applications and SMS-message based solutions in diabetes care are well suited for its purpose. Diabetes is a chronic disease that requires regular monitoring and keeping in touch with the health care professional. Using these applications is seen as a convenient option. They can allow the patient record aspects of their health in a possibly simpler way and get feedback on their results. This can support and increase the self-management and motivation to regulate their condition. A growing amount of people using a smartphone daily also makes it possible to reach a larger number of patients. It is likely that the use of mobile health applications will rise in the future. (Shan et al. 2019.)

Different types of applications for managing diabetes are, for example applications used for calculating insulin dosages. These applications take into account the current blood glucose level and other numeric values. These values include the pre-determined insulin carbohydrate ratio, consumed carbohydrates in a meal, dosage of the basal insulin as well as physical exercise. With some of the applications, there is a chance to be in contact with health care professional, either through a phone call or text messages. (Shan et al. 2019.)

Another type of available applications can be used together with devices meant for measuring blood glucose levels. These can be wirelessly connected to the application on a mobile phone or a reader device, and the data from the measuring device can be transferred to a computer automatically. The applications can also be used together with real-time continuous glucose monitoring devices. With some of the applications, the health care professional can keep track of the blood glucose measurements remotely, whereas other the results from the device can be transferred to the computer at the health care facility via a reader. Examples of these application include Accu-Check Connect and LibreLink. (Shan et al. 2019.)

Another field of applications designed for diabetes care are applications that provide the patient with diabetes education and information about lifestyle changes. These applications are not limited only to calculating insulin dosages and keeping track of glucose measurements, but they also offer a wider picture of self-management of the disease focusing on the general well-being of the person. (Shan et al. 2019.)

2.3.2 User experiences and impact of the applications

User experiences of using diabetes self-management applications have been researched before. Most application users find them easy to use. Marking glucose levels into a phone is seen as convenient. Graphs showing data from measurements are one of the features why people want to use these applications. Being able to see trends in glucose levels easily from a longer period of time is seen as important and motivating. (Jeffrey, Bagala, Creighton, Leavey, Nicholls, Wood, Longman, Barker & Pit. 2019.)

Negative experiences about the applications are usually connected to the technological issues with the apps. Having to start the use of the application from the beginning after the application ceases to work is considered problematic. One of the biggest issues among application users is the cost of some of the applications. As they are healthcare related, the customers would like them to be freely available for everyone. Another issue with the applications is also the fact that a big part of them are developed and targeted for a certain country. This can be seen when the measurements or units cannot necessarily be changed. (Jeffrey at al. 2019.)

The impact of diabetes self-management applications has also been studied. Studies on occasion have shown a slight improvement of the patient's HbA1c levels over the study period while using a self-management application. (Cui, Wu, Mao, Wang & Nie 2016.)

3 PURPOSE, OBJECTIVES AND RESEARCH QUESTIONS

The purpose of this thesis is to describe the possible impact of mobile health application use on diabetes self-management. The efficacy of the applications is measured by the impact they have on HbA1c levels. Another purpose for this thesis is to explore on what the people using these applications think of them and whether does using them improve patients' diabetes self-management skills.

The research questions are as follows:

1. Is there a change in HbA1c levels when using mobile health applications?
2. How do patients using mobile health applications experience their usability and does using them change patients' self-management skills?

4 IMPLEMENTATION OF THE THESIS

This thesis is conducted as a narrative literature review. Narrative literature reviews, also called traditional, descriptive and standard literature reviews, gear towards acknowledging the previous research, enabling verification, summarizing information, building on research done before and recognizing possible gaps or exclusions in current research of the topic. They review the latest or current research done on the topic chosen. They can commonly review a greater amount of research compared to systematic literature reviews, but at the same time their focus and method can be less specific. (Coughlan & Cronin 2017, 6-31; Grant & Booth 2009.)

The process of writing narrative literature review starts with selecting the topic. The topic can be specific or, depending of the review, also more comprehensive. After selecting the topic, the background research for the review is conducted. The next stages of the process include forming the research questions, creating limitations for the source material and conducting the data retrieval process. This is followed by analysing the collected data and presenting and reflect on the results. (Coughlan & Cronin 2017, 51-68.)

4.1 Outlining source material

When conducting a literature review, outlining the source material is important. Having clear research questions that guide what studies to include in the review simplifies the process. Researchers create their own research key words with a goal to find answers to their research questions. Using valid and relevant databases and sources also eases the research effort. The process of conducting data retrieval can be daunting, as depending on the topic, relevant literature can be difficult to find, or the quantity of research can be overwhelming. (Coughlan & Cronin 2017, 51-68.)

Creating clear limitations on what sources to include in the review is important, as plain searches in databases commonly yield a large quantity of material. The currentness of the article is a limitation commonly used. To create a relevant literature review, it is suggested to use studies conducted recently that have also been peer-reviewed. Setting a language limitation also outlines the material. Evaluating the efficacy of the literature search during the process is important. Oftentimes the initial search for

material has to be modified later on to find more of the relevant literature. (Coughlan & Cronin 2017, 51-68.)

Outlining the source material for this thesis was done according to the forementioned recommendations by Coughlan & Cronin (2017, 51-68). The time period for the studies chosen was set to studies published between 2016 to 2021, as to include the most recent studies done on the topic. The language limit was set to studies published in English or Finnish. Only scientific articles that are available as a whole text and contain an abstract were included. The selected studies should contain relevant information either on user experiences of mobile health applications used in diabetes care or data about HbA1c levels at the beginning and at the end of the study. Studies focusing on type 2 diabetes care are included. The criteria for the inclusion and exclusion can be seen in TABLE 1.

TABLE 1. Criteria of inclusion and exclusion.

Inclusion criteria	**Exclusion criteria**
Study is published between 2016 to 2021.	Study is published before 2016.
Language of the study is English or Finnish.	Language is other than English or Finnish.
Article is available as a whole text.	Only an abstract is available.
Abstract is included.	Study does not include an abstract.
The study is a scientific research article.	The study is not peer-reviewed or is a thesis or non-scientific article.
The study contains relevant information on diabetes mobile health application's user experiences or efficacy.	The study focuses on another disease or does not contain information relevant to the thesis topic.
The study is focused on diabetes type 2.	The study is focused on other diabetes types.

4.2 Data retrieval process

Data collection is a key part of the thesis writing process. For the data retrieval process some key words and phrases need to be created for the search. Using multiple databases for the data retrieval increases the chance of finding more of the relevant literature. (Coughlan & Cronin 2017, 51-68.)

The data retrieval process for this thesis was performed in multiple databases during October, 2021. The databases used were Academic Search Elite, Cinahl, Sage Journals, Medline, PubMed, Medic, Finna and ScienceDirect. The search terms used were *diabetes and mobile application*, *diabetes and mobile health* and *self-management of diabetes*. The forementioned search limitations such as publication date of the article were used in the search.

The inclusion process is presented in TABLE 2. The search terms mentioned above were used in all of databases. In Finna and Medic, the search was conducted in Finnish using the search terms *diabetes* and *mobiili* and *sovellus*. In the rest of the databases, the search terms were used in English. In all of the databases the initial search with just the chosen search terms gave hundreds of results, thus coarse exclusion had to be conducted to lower the amount of relevant literature, and it was based on the publication date of the article, language, availability as a whole text, inclusion of an abstract and whether the article was a scientific article. In the majority of the databases used in the search, these terms could be chosen to limit the number of results, and they were used if applicable. The fine exclusion phase was conducted in two parts. Firstly, an initial selection was done based on the headings of the articles. During the second stage, the abstracts of chosen articles were read through carefully. During both parts of the phase articles were excluded if they did not contain relevant information towards the thesis topic. During the last phase, the remaining 33 articles were read and eight articles were chosen to be part of this narrative literature review.

TABLE 2. The inclusion process.

Database	**Initial results**	**Coarse exclusion**	**Fine exclusion**	**Included studies**
Academic Search Elite	206	67	9	2
Cinahl	626	82	0	0
Sage Journals	5231	393	0	0
Medline	1002	114	1	0
PubMed	355	178	7	5
Medic	3073	465	7	0
Finna	200	57	3	0
ScienceDirect	1400	681	6	1
All together	12093	2866	33	8

Two of the articles were found from Academic Search Elite, five from PubMed and the remaining one from the ScienceDirect database. The efficacy of the applications and the changes in HbA1c levels were examined in six of the eight studies. User experiences of the applications were the focus of the remaining two studies. Studies focusing on the efficacy of the applications through changes in HbA1c level were quantitative in nature and focused on the numerical data collected for the study. Studies concentrating on user experiences were qualitative and conducted mainly as interviews with the participants. Study participants for all of the studies were people diagnosed with diabetes type 2. Studies were conducted around the world. Four of the studies were conducted in Asia, one in North America, one in Europe and two in Australia.

4.3 Thematic analysis

While conducting narrative literature review, the first part of the analysing the results is to create a summary of the main information and findings drawn from the studies chosen. The summary can be presented as a text or as a table. Readability is increased when using a table form for presentation. Details such as reference, origin of study, methodology, aims and objectives, participants and study setting and main findings are part of the details that can be presented in the summary. (Coughlan & Cronin 2017, 93-115.) The main details for the eight studies chosen for this narrative literature review can be seen below in TABLE 3.

TABLE 3. Summary table

Reference and country of study	**Research design and methods**	**Study aims and objectives**	**Participants and settings**	**Main findings relevant to the review**
Agarwal, Mukerji, Desveaux, Ivers, Bhattacharyya, Hensel, Shaw, Bouck, Jamieson, Onabajo, Cooper, Marani, Jeffs & Bhatia.	Randomized controlled trial.	To determine whether using BlueStar mobile app would improve the HbA1c levels with T2DM patients with poorly	223 participants with T2DM and HbA1c level in the beginning same or greater than 8% were chosen for the study. 120 participants	No statistically significant difference to HbA1c levels was found during the study between the mobile app intervention group

(2019) Canada		controlled blood glucose levels.	completed the process.	and the control group.
Gong, Baptista, Russel, Scuffham, Riddel, Speight Bird, Williams, Lotfaliany & Oldenburg. (2020) Australia	Randomized controlled trial.	To determine effectiveness and usability of My Diabetes Coach app-based program.	187 participants were recruited for the study and divided for intervention and control groups.	Significant difference in HbA1c levels between intervention and control group was not detected at the end of the study.
Jeffrey, Bagala, Creighton, Leavey, Nicholls, Wood, Longman, Barker, & Pit. (2019) Australia	Qualitative study. Semi-structured interviews. Data analysed with deductive content analysis.	Evaluate user experiences and challenges with app usage between app users and non app users.	16 app users and 14 non app users were chosen for the study.	Visible visual trends, convenience and user friendliness were considered useful. Multiple barriers toward app usage exist. Health care professional's involvement and recommendation are seen as important.
Lee, Yoo, Min, & Park. (2020) Korea	Randomized controlled open-label trial.	To evaluate the efficacy of mobile health-based app Healthynote and individualized messages from health care professionals towards impact self-management and HbA1c levels.	72 participants were chosen for the study. They were split in control group (n=27) and intervention group (n=39) which was further divided in the self-referred group and physician-referred group.	No significant difference in HbA1c level was found between the control and intervention group at 6 months.

Sunil Kumar, Prakash, Subhash Chandra, Shrinivas Kadkol, Arun, Jom Thomas, Kulkarni, Gopi, & Narayana Murthy. (2021) India	Randomized controlled trial.	To assess whether using mobile health app Diaguru aimed at lifestyle modification and medication management have a change in HbA1c levels.	300 participants were chosen for the study. Participants were divided to control and intervention groups.	Difference in HbA1c levels between control and intervention group was detected after 6 months. According to the study HbA1c level in intervention group lowered and increased in control group.
Torbjørnsen, Ribu, Rønnevig, Grøttland, & Helseth. (2019) Norway	Qualitative descriptive study. Semi-structured interviews.	Evaluate user's acceptability towards diabetes self-management mobile application.	26 participants 1 year history with mobile diabetes diary app use were interviewed for the study.	Acceptability differs between individuals. If used regularly the app can be useful but it can also take up too much time.
Yu, Yan, Li, Li, Wang, Wang, Zhang, Xu, Tang, Yan, Chen, He, Chen, & Feng. (2019) China	Randomized trial.	Evaluate the effectiveness of Diabetes-Carer mobile app for diabetes management with or without regular self-monitoring of blood glucose.	200 participants with diabetes type 2 were chosen for the study and divided to four groups. 160 participants completed the study process.	During study HbA1c lowered in all study groups but the change was evaluated to be significantly more in latter groups with mobile phone app intervention and self-monitoring of blood glucose.
Zhai & Yu. (2020) China	Randomized controlled trial.	Evaluate the efficacy of mobile phone diabetes app Yutangyihu on the HbA1c levels.	120 participants were chosen for the study and divided to intervention and control group.	There was no change between groups in HbA1c level at baseline or in 3-month measurements but

				at 6 months HbA1c level in intervention group has decreased more than in the control group.

Content analysis, also called synthesis, is the main method for drawing results from the chosen studies towards the literature review. Multiple different types of content analysis methods exist and they can be used for different types of research literature. Some are focused to be used with quantitative studies, some with qualitative studies and some work also towards mixed literature. One of the methods used for mixed literature is thematic analysis and it is the most often seen system for analysing results in narrative literature reviews. The main aim of the thematic analysis is to present the summary of the current knowledge of the review topic. (Coughlan & Cronin 2017, 93-115.)

Conducting thematic analysis translates to first coding the literature chosen for the study. Coding means searching for the results in the studies and giving them a label such as a set of words to identify them. The main interest for coding should be in the result and discussion parts of the literature. After coding, themes are created by selecting the codes similar and supportive to each other's and grouping them together. After that, these groups are collected in bigger categories and in the end, to main categories. (Coughlan & Cronin 2017, 93-115.)

Literature chosen for this thesis was synthetized using thematic analysis. All the literature was read and the main results answering the research questions were collected in a separate file. Results from a single study were coded with a chosen color and each study got an assigned color. The results were recorded in the file as they were written in the literature. The next step was to simplify the written results and create short phrases to describe them. Color coding the phrases according to the study continued in this phase. The phrases were printed out and cut to separate pieces and grouped together based on similarities they shared. These groups were named based on the common topic phrases in the group shared. These names created the subcategories, which were further grouped together to upper categories and main categories and written down in a table form.

5 RESULTS

The results of this narrative literature review are presented through the research questions. First. The included studies and their perspectives are presented in text, after which the results are presented according to the thematic analysis of the literature conducted earlier. The aim is to provide overview on the current knowledge of the thesis topic.

5.1 Studies focusing on the impact of mobile diabetes applications and user experiences

Eight studies were chosen for this narrative literature review. Six studies focused on the impact of mobile application use to HbA1c levels (Agarwal et al. 2019; Gong et al. 2020; Lee et al. 2020; Sunil Kumar et al. 2021; Yu et al. 2019; Zhai et al. 2020) and two focused on user experiences of diabetes mobile health applications (Jeffrey et al. 2019; Torbjørnsen et al. 2019). Seven studies focused on one application, though the application was different for each of the studies, one study (Jeffrey et al. 2019), did not limit which application was used by the study participants, all the mobile diabetes applications used by the participants before the study were applicable. All of the studies were published after 2016, though interviews for study by Torbjørnsen et al. 2019 were conducted before 2016. Two of the studies (Gong et al. 2020; Sunil Kumar et al 2021) focused on studying an application the researchers had designed for the trial, on the remaining studies the mobile diabetes application was designed separately or it had already been available beforehand. Application in the study Gong et al. 2020 differed from the other applications studied, as it was built around embodied conversational agent conducting diabetes coaching in separate modules over the time of the study.

In all of the studies, the data was collected from the participants diagnosed with diabetes type 2. For the quantitative studies, the main information gathered was the measurement of HbA1c levels. In addition to that, other measurements such as fasting blood glucose and lipid levels were collected in the majority of the studies. Additionally, different questionnaires evaluating self-management skills, self-efficacy and user experiences were collected during the study period. The two qualitative studies were carried out as semi-structured interviews. Data about the app usage was also collected through the applications. The number of study participants varied between 26 to 300. Larger number of study participants were found in the quantitative studies. Studies were conducted in Asia, Australia, Europe and North America.

The perspectives and aims of the chosen studies had some differences. Six of the studies had in common the assessment of the impact of mobile application use on self-management of diabetes. Of these, one also focused on the impact of self-referred participation with the application use and one included the comparison of mobile application intervention and self-monitoring blood glucose. One of the studies assessed how the applications are used in self-management of diabetes among the application users, whereas another evaluated the user's acceptability towards mobile diabetes applications.

5.2 Results describing the impact of mobile diabetes applications and the user experiences

Using thematic analysis, three main categories were created. These categories represent the main themes the studies focused on. The main categories are as follows: *impact in HbA1c, impact on self-management* and *user experiences and application engagement*. Upper categories correlating with *impact on HbA1c* are *differences between groups* and *effect on baseline HbA1c*. Upper categories for *impact on self-management* are *self-management* and *aiding self-management*. Upper categories for the *user experiences and application engagement* are *engagement*, *negative experiences* and *positive experiences*. Subcategories, upper categories and main categories described are shown in a table form below (TABLE 4).

TABLE 4. Categories based on thematic analysis

Subcategory	**Upper category**	**Main category**
Changes in HbA1c	Differences between groups in HbA1c	Impact on HbA1c
Promoting difference		
Change towards baseline	Effect on baseline HbA1c	
Effect of mobile phone application		
Self-efficacy	Self-management	Impact on self-management
Used functions		
Creating routines	Aiding self-management	
Giving overview		

Impact of interaction with professionals	Engagement	User experiences and application engagement
Engagement on applications		
Application engagement over time		
Positive outcomes with engagement		
Barriers for use	Experiences	
Cost		
Usability		
Ratings		
Effort		

5.2.1 Differences between groups in HbA1c

Category *differences between groups* includes *changes in HbA1c* and *promoting difference*. Changes in HbA1c levels during the studies were found in the majority of the studies. According to Gong et al. (2020), HbA1c measurement decreased in both trial and control arm at a similar rate during the 12-month-long trial. Similar results were found by Yu et al. (2019), HbA1c level lowered similarly all across the 4 study groups. According to Agarwal et al. (2019), no significant differences in HbA1c levels were found between the intervention and control group at three-month mark. Statistical, not significant difference in HbA1c levels was found between the trial group and the control group at the end of the trial at 6 months. (Lee et al. 2020). At 3-month mark there was no significant difference between the study groups in a study conducted by Zhai et al. (2020). Difference between the groups in HbA1c levels was visible after six-month intervention with the application. (Zhai et al. 2021). Sunil Kumar et al. (2021) suggests that glucose control was improved with application intervention, HbA1c level was lowered in the application intervention group and increased in the control group. According to Torbjørnsen et al. (2019), the median HbA1c level among the study participants increased during the 12-month study compared to the baseline measurement.

Aspects affecting the degree of change in HbA1c levels between groups and promoting the difference in HbA1c levels are for example, what was the baseline HbA1c level at the beginning of the study. Higher baseline HbA1c level at the beginning of the study provided a statistically significant difference in HbA1c level during the study compared to those whose baseline level was closer to the recommended level. (Gong et al. 2020). Another aspect that was noted to make a difference was whether the participants were self-referred or referred by a health care professional. Lee et al. (2020) suggests that in the self-referred group the changes in HbA1c level were greater compared to the group referred by health care professionals. (Lee et al. 2020).

5.2.2 Effect on baseline HbA1c

Effect on baseline category includes the *change towards baseline* and *effect of mobile phone application*. Differences in HbA1c levels in the studies were not found between the trial and the control groups. Rather the change in HbA1c level happened within the same group compared to the starting level of the HbA1c. According to Yu et al. (2019), the proportion of those patients whose HbA1c level lowered under 7%, was higher in the trial groups utilizing the mobile application. When the study used factorial analysis to establish whether the self-monitoring glucose levels or the mobile diabetes application use was responsible for the lowering of HbA1c, they came to the conclusion that mobile application had the larger impact. (Yu et al. 2019.)

5.2.3 Self-management

The self-management category describes the patient-reported impact on self-management and the typically used application features. Self-efficacy and self-management skills were evaluated through questionnaires in the majority of the studies. Level of self-management, quality of life and the utilization of health care services were screened through questionnaires during the study, and no significant differences were found in these categories between the intervention and control group at the end of the study (Agarwal et al. 2019). When measuring self-efficacy score at the beginning and at the end of the study, it was noted that the self-efficacy level increased in both trial and control group during the study. The level was more elevated in the mobile application trial group. (Zhai et al. 2021.) Self-management skills, especially with self-referred participants, increased during the intervention with a mobile diabetes management application (Lee et al. 2020). During a twelve-month long study, health-related quality of

life questionnaire showed significant improvement with the mobile diabetes application intervention group compared to the participants in the control group (Gong et al. 2020). 10 out of 17 participants interviewed about diabetes application use told that they felt using the application improved their self-management. Some of those who did not see the application improving their self-management, told that bettering self-management was more in their own hands with the help of health care professional. The application was seen as a tool to aid with the self-management. (Jeffrey et al. 2019.)

Mobile diabetes applications commonly include multiple different functions. The most used feature was blood glucose recording and meal and carbohydrate recordings (Zhai et al. 2021). Blood glucose recording was the most often used function recording physical activity feature was the least used function (Agarwal et al. 2019). In a study with multiple different mobile applications, the most commonly used feature was blood glucose recording. Some of the applications were also connected to the glucose measurement device, thus making the recording more effortless. Another commonly used feature was the ability to view current blood glucose trends through graphs created by the application. (Jeffrey et al. 2019.)

5.2.4 Aiding self-management

The aiding self-management category includes *creating routines* and *giving overview*. Routines, such as measuring blood glucose levels and exercising regularly can improve the self-management of diabetes. Utilizing diabetes mobile applications can help to create and maintain routines to better self-management of the disease (Torbjørnsen et al. 2019).

Multiple diabetes mobile applications have a possibility to offer an overview of the management and the process of achieving the goals of the treatment. Application can offer an overview of the individuals progress, and aid in learning to control their disease. Having the measurements and visual graphs to aid with controlling their glucose levels and helping with making decisions can make the individual feel more like in control and it can help in learning causality. (Torbjørnsen et al. 2019.) Visual representation of the measurements, convenience and portability are features aiding in the self-management of diabetes and application use might increase the motivation for bettering the self-management (Jeffrey et al. 2019).

5.2.5 Engagement

The engagement category was comprised of *impact of interaction with professionals*, *engagement on applications*, *application engagement over time* and *positive outcomes with engagement*. Meaningful interactions with health care professionals perceived important and a part of improving the self-management of diabetes (Torbjørnsen et al. 2019). When interviewing patients diagnosed with diabetes type 2 who were not utilizing diabetes mobile applications in their diabetes self-management, it was noted that they were not necessarily aware of the existence of these applications. They were not against the idea of such applications, many of the interviewees explained that they would be willing to try and possibly use diabetes mobile applications, especially if they were recommended by health care professionals responsible for their care. (Jeffrey et al. 2019.)

Data about application engagement was collected in multiple studies. It was noted, that application engagement measured with the number recordings made by the participant per week was higher in the self-referred group compared to the control group (Lee et al. 2020). Application use during the study by Agarwal et al. (2019) was relatively low. 46% of the participants used the application for 10 days or less during the 6-month trial. The study was conducted in 3 demographically different sites around Ontario, Canada. It was noted that the site had an impact on the application usage with participants using the application significantly less in some locations. Newly diagnosed participants were more engaged with the application use measured in log-in days and there was a small group of participants that were using the application more actively. (Agarwal et al. 2019.) During the 12-month long study, the participants had 1942 interactions using chat with the conversational agent Laura, totaling in 243 minutes of using the chat per person. (Gong et al. 2020).

App engagement over time is the next category included in engagement. What was common in many of the studies, was that the application usage lowered over time. Out of 26 participants, 12 kept using the application over the year, six used it occasionally and six stopped utilizing the application quickly after the study started (Torbjørnsen et al. 2019). When the study assessed how many chats participants had with the conversational agent, it was noted that the number of participants who had at least one chat per month with the program dropped from 81 in the first month to 14 in the final test month at the end of the year. Recording blood glucose in the application also dropped from 73 participants to 21 participants over the same period of time. It was noted that the total application use decreased over time. (Gong et al. 2020.) Application utilization was also seen decreasing significantly over the 26-week long study

period. Improving long-term engagement with application utilization was perceived as important. (Agarwal et al. 2019).

Positive outcomes with application engagement are the final part of the engagement category according to the analysis. Among the studies it was noted that ongoing application engagement over time had a possibility to create positive outcomes for the participants' self-management. When comparing health-related quality of life questionnaire results between participants who used the application more often, to the ones that used the application rarely, it was noted that higher user engagement increased the results of the questionnaire significantly (Gong et al. 2020). The participants whose group engagement on the application was high, had a significant change in their HbA1c values when compared to the levels in the beginning of the study. Engaged application usage suggest a 0,4% decrease in HbA1c level per 25 days of application use. (Agarwal et al. 2019). The impact of the application use to self-management skills also takes time (Zhai et al. 2021).

5.2.6 Experiences

The *experiences* category includes the *barriers of use*, *cost*, *usability*, *ratings* and *effort*. Barriers of use were described in two of the studies, and these were cost, technological skills and lack of awareness towards diabetes mobile applications. Problems with internet access and technological issues with the application were also common. These were for example when application ceased to work and Bluetooth connectivity issues. Some participants of the study found the applications difficult to use as they required multiple steps to finish a task and were complicated in their structure. For some, the application was difficult to use because of the unfamiliar units for blood glucose and insulin used within the application. Some struggled with the fonts of the applications being too small. (Jeffrey et al. 2019.) More barriers for use were described to be technological and related to time and motivation. It was noted that the application did not always function as it was supposed to. Usability with a small smartphone with small buttons was lacking for some of the participants. Constantly using the application was also seen burdensome, it was difficult to find the time to manually input the different recordings throughout the day. It was also noted that some of the participants reported feeling stressed when trying to use the application constantly to improve their self-management of glucose levels. Deciphering the trends of blood glucose from the data provided from the application was seen to be difficult and stressful, if the application did not provide obvious patterns in glucose levels. (Torbjørnsen et al. 2019.)

The next category is cost which was discussed in two of the studies. Many of the participants of the study brought up the affordability of the applications. As the cost of the applications can prevent some individuals from utilizing them, it was seen as a matter of health care equality. (Jeffrey et al. 2019.) If given continued access to application, around 40% of the participants stated they would continue using it. When questioned about whether the participants would be willing to purchase the application to use it, just over half of the participants stated they would not pay for the usage of the application. (Agarwal et al. 2019.)

The usability of the applications is the next category under experiences. Usability was evaluated in three of the studies. The majority of the participants answered that the applications were generally easy to use (Jeffrey et al. 2019). Navigating the application was simple according to most of the participants of the study (Zhai et al. 2021). When interviewed, the majority of the participants stated that the application provided them with easy readability of the trends, accessibility and simple organization of the measurements. Automatic transfer of the measurements to the application was also seen as a positive feature. (Torbjørnsen et al. 2019.)

Next the experiences category includes the ratings and recommendations about the applications. These were evaluated in four of the studies. 66 of the participants answered when asked about their experiences with conversational agent Laura. 80% of them stated the conversational agent was efficient and helped with their self-management. Just over 70% of the participants considered that they were able to trust Laura. (Gong et al. 2020.) When participants were asked about their recommendations and experiences of the application use, 105 answered. Nearly half of them would recommend the application to people struggling with the same condition. 56 of them rated the application 4/5 and 41 rated it 3/5. (Agarwal et al. 2019.) The majority of the application users would recommend the application they were using to others. 3 out of 17 described that the application did not meet their needs. (Jeffrey et al. 2019.) During the interviews for the study, multiple participants raised the question why the application was not introduced to them at an earlier stage after getting the diagnosis (Torbjørnsen et al. 2019).

The last category described in the experiences was the effort required for the application use. It was noted that the application can help with the self-management and help with creating meaningful routines. It was stated that all of the forementioned requires work and effort by the application user. It was also noted, that if the individuals using the application wants it to become beneficial for their self-management, they also need to be prepared to make changes. (Torbjørnsen et al. 2019.)

6 DISCUSSION

The aim of this narrative literature review was to describe the current knowledge about the impact of mobile diabetes applications on the HbA1c levels and on the patients' self-management skills. Another aim was to explore the user experiences of these applications. In this chapter the results and conclusions drawn from this review are discussed. Additionally, the reliability and ethicality of this thesis is examined. The last part of the chapter focuses on the thesis process and professional growth.

6.1 Review of results and further review topics

Results on HbA1c levels, impact on self-management skills and user experiences had similarities and differences between the studies. The common theme in multiple studies was the improvement of HbA1c levels and self-management skills in the participant groups, both the intervention group and the control group.

The majority of the studies suggested that there was no significant difference in HbA1c levels between the intervention and control groups after the trial. One study found that the difference between groups was visible after 6 months of application use and another stated mobile application intervention had a significant impact on HbA1c levels as the HbA1c level lowered in the intervention group and increased in the control group (Zhai et al. 2021; Sunil Kumar et al. 2021).

Even though differences in HbA1c level decreasing between the study groups were not found in the majority of the studies, reduction in HbA1c level compared to the starting level at the beginning of the study was found in multiple studies. Furthermore, slightly greater differences could be found after further analysis was done with added comparison of participants with higher usage rate of the application, self-referred participation or higher baseline HbA1c level.

The improvement of the self-management skills and self-valuated quality of life and self-efficacy increased according to many of the studies. In some, the improvement happened in both trial and control groups, and in others, the increase was greater in diabetes mobile application intervention group. Greater improvements were commonly seen in the studies that measured the abovementioned matters over longer trial periods.

The common theme around application engagement was the decrease of the engagement over time. Many of the studies showed a vast decrease over the study period in the time spent on the application and the times participants logged in. As shown in a number of the studies, continuing engagement with application use can help to support reaching positive outcomes with self-management of diabetes. Finding out how to improve the engagement levels staying sufficient over time is an important aspect with mobile diabetes applications.

The usability of the applications was commonly found easy. Nevertheless, participants also at times struggled with technical and connectivity issues, the complicity of the applications and lack of internet access. Another theme also brought up was the affordability of the applications. When asked to rate the applications, the ratings were commonly positive.

All in all, mobile diabetes applications can have a possibility to aid with the self-management of diabetes, the application itself does not make the difference. Effort and engagement of the individual with diabetes seems to have a greater impact on the outcome of application use. Further research could be focused towards the effect of the application engagement.

6.2 Reliability and ethics of the thesis

This thesis was conducted as a literature review meaning that the possible ethical issues come from the responsible conduct of the research. Following the responsible conduct of research is the responsibility of the individual conducting the thesis project. When conducting research, important aspects are avoiding plagiarism, openness and methodical approach to the process as well as being throughout. (Arene 2020; Tutkimuseettinen neuvottelukunta 2012.)

Quality of the data retrieval is a main aspect of the reliability of narrative literature review. The chosen literature has to be evaluated critically and quality of the literature search and analysis has to be assessed throughout the process. (Coughlan & Cronin 2017, 51-68.) For this narrative review, the databases used for the literature search were found from the Centria University of Applied Sciences library guide and their use was approved for earlier assignments as a reliable source of information. The current nature of the literature reviewed for this thesis was ensured by limiting the literature to have been published between 2016 and 2021.

The literature search, search phrases and limitations used for this thesis were presented in a text and table form and can be repeated by another researcher. The analysis of the literature was also presented in a table and a text form as to express how the analysis was done and how the results were drawn. Reliability of the thesis was increased by the ability to seek help with the process from the instructing teacher.

6.3 Thesis process and professional growth

The thesis writing process was carried out during the years of 2020 and 2021. The thesis plan was submitted and evaluated in the spring of 2020. Originally, it was planned to do majority of the writing during 2020, but the actual writing process started in the summer of 2021 with the theoretical background. The background was finished during September and in the beginning of October the literature search for the thesis was conducted. Analysing the literature and writing out the results took place during the end of October and beginning of November. The final parts of the thesis were completed during November 2021.

During the writing process I have had a chance to deepen my knowledge about diabetes and its self-management. While researching the literature, I was able to learn about the current knowledge of mobile application use in diabetes care. I found the topic to be important and interesting as the use of self-management applications might be on the rise. Also, even when researching an interesting topic, managing the timing for the project occasionally poses a challenge. With this thesis I was able to practise managing my time more efficiently.

REFERENCES

Arene. 2020. *Ammattikorkeakoulujen opinnäytetöiden eettiset suositukset*. Available at: https://www.arene.fi/julkaisut/raportit/opinnaytetoiden-eettiset-suositukset/. Accessed 12 November 2021.

Coughlan, M. & Cronin, P. 2017. *Doing a Literature Review in Nursing, Health and Social Care*. 2nd edition. Los Angeles. Sage Publications.

Cuesta, C., German Millberg, L., Karlsson, S. & Arvidsson, S. 2020. *Welfare technology, ethics and well-being a qualitative study about the implementation of welfare technology within areas of social services in a Swedish municipality*. International Journal of Qualitative Studies on Health and Well-Being. Vol 15. Available at: https://doi.org/10.1080/17482631.2020.1835138. Accessed 22 September 2021.

Cui, M., Wu, X., Mao, J., Wang X. & Nie, M. 2016. *T2DM Self-Management via Smartphone Applications: A Systematic Review and MetaAnalysis*. PLoS ONE. Available at: https://doi.org/10.1371/journal.pone.0166718. Accessed 19 October 2021.

DigiFinland. 2021. *Omaolon palvelut*. Available at: https://digifinland.fi/toimintamme/omaolo-palvelu/omaolokasikirja/omaolon-palvelut/. Accessed 23 September 2021.

FDA. 2021. *What is Digital Health*. Available at: https://www.fda.gov/medical-devices/digital-health-center-excellence/what-digital-health. Accessed 22 September 2021.

Fleming, A.G., Petrie, J.R., Bergenstal, R.M., Holl, R.W., Peters, A.L. & Heinemann, L. 2020. *Diabetes Digital App Technology: Benefits, Challenges, and Recommendations. A Consensus Report by the European Association for the Study of Diabetes (EASD) and the American Diabetes Association (ADA) Diabetes Technology Working Group*. Diabetes Care. American Diabetes Association. Available at: https://care.diabetesjournals.org/content/43/1/250. Accessed 15 November 2021.

Diabetestalo. 2021a. *Tupakointi ja diabetes*. Terveyskylä. Available at: https://www.terveyskyla.fi/diabetestalo/diabetes/diabetes-ja-p%C3%A4ihteet/tupakointi-ja-diabetes. Accessed 6 September 2021.

Diabetestalo. 2021b. *Glukoosisensorin toimintaperiaate*. Terveyskylä. Available at: https://www.terveyskyla.fi/diabetestalo/diabetes/diabeteksen-seuranta/glukoosisensorointi/glukoosisensorin-toimintaperiaate. Accessed 8 September 2021.

Diabetic kidney disease. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim and Finnish Society of Nephrology. Helsinki: The Finnish Medical Society Duodecim, 2020. Available at: https://www.kaypahoito.fi/hoi50060. Accessed 20 September 2021.

Diabetes Type 2. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish Internal Medicine Society and Finnish diabetes association. Helsinki: The Finnish Medical Society Duodecim , 2020. Available at: https://www.kaypahoito.fi/hoi50056. Accessed 31 August 2021.

Diabetic retinopathy. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish Ophthalmologist association and Finnish diabetes association. Helsinki: The Finnish Medical Society Duodecim, 2014. Available at: https://www.kaypahoito.fi/hoi50043. Accessed 14 September 2021.

Gestational Diabetes. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish diabetes association and The Finnish Society of Obstetrics and Gynaecology. Helsinki: The Finnish Medical Society Duodecim, 2013. Available at: https://www.kaypahoito.fi/hoi50068. Accessed 31 August 2021.

Grant, M. & Booth, A. 2009. *A typology of reviews: an analysis of 14 review types and associated methodologies*. Health Information and Libraries Journal. Available: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1471-1842.2009.00848.x. Accessed 21 October 2021.

Holopainen, A. 2015. *Mobiiliteknologia ja Terveyssovellukset. Mitä Ne Ovat?* Lääketieteellinen aikakauskirja Duodecim. 131(13). Available at: https://www.duodecimlehti.fi/duo12334. Accessed 22 November 2021.

Ilanne-Parikka, P., Niskanen, L., Rönnemaa, T. & Saha, M-T. 2019. *Diabetes*. Helsinki. Kustannus Oy Duodecim.

Insulin Deficiency Diabetes. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish Internal Medicine Society and Finnish diabetes association. Helsinki: The Finnish Medical Society Duodecim, 2020. Available at: https://www.kaypahoito.fi/hoi50116. Accessed 11 August 2021.

Insulin treatment and insulin deficiency diabetes. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish Internal Medicine Society and Finnish diabetes association. Helsinki: The Finnish Medical Society Duodecim, 2018. Available at: https://www.kaypahoito.fi/nix02506. Accessed 1 September 2021.

Jeffrey, B., Bagala, M., Creighton, A., Leavey, T., Nicholls, S., Wood, C., Longman, J., Barker, J. & Pit, S. 2019. *Mobile phone applications and their use in the self-management of Type 2 Diabetes Mellitus: a qualitative study among app users and non-app users*. Diabetology & Metabolic syndrome. Volume 11. Available: https://doi.org/10.1186/s13098-019-0480-4. Accessed 19 October 2021.

Kanta. 2021. *Mitä Kanta-palvelut ovat?* Available at: https://www.kanta.fi/mita-kanta-palvelut-ovat. Accessed 23 September 2021.

Kanta. 2020. *Omakanta syntyi 10 vuotta sitten – Kanta-palvelujen juhlavuosi käynnistyy*. Available at: https://www.kanta.fi/tiedote/-/asset_publisher/cf6QCnduV1x6/content/omakanta-syntyi-10-vuotta-sitten-kanta-palvelujen-juhlavuosi-kaynnistyy. Accessed 23 September 2021.

Koistinen, H. & Cederberg-Tamminen, H. 2019. *HbA:n tuonne puolen – aika glukoositavoitteessa ja insuliininpuutosdiabeteksen hoidon optimointi*. Lääketieteellinen aikakauskirja Duodecim. Available: https://www.duodecimlehti.fi/duo15131. Accessed 8 September 2021.

Leppäluoto, L., Kettunen, R., Rintamäki, H., Vakkuri, O., Vierimaa, H. & Lätti, L. 2012. *Anatomia + Fysiologia. Rakeenteesta toimintaan*. Helsinki. Sanoma Pro oy.

Melchiorre, M. G., Papa, R., Quattrini, S., Lamura, G & Barbabella, F. 2020. *Integrated Programs for People with Multimorbidity in European Countries. eHealth Adoption in Health Systems*. BioMed Research International. Volume 2020. Available at: https://doi.org/10.1155/2020/9025326. Accessed 22 September 2021.

Meskó, M., Drobni, Z., Bényei, É. & Györffy, Z. 2017. *Digital health is a cultural transformation of traditional healthcare*. mHealth 3:38. Available: https://mhealth.amegroups.com/article/view/16494/16601. Accessed 22 September 2021.

Metformin in diabetes care. Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, Finnish Internal Medicine Society and Finnish diabetes association. Helsinki: The Finnish Medical Society Duodecim, 2016. Available: https://www.kaypahoito.fi/nix00780. Accessed 10 September 2021.

Mustajoki, P. 2019. *Diabetes ja alkoholi*. Terveyskirjasto Duodecim. Available at: https://www.terveyskirjasto.fi/dlk00887. Accessed 6 September 2021.

Obesity (children, youth and adults). Current Care Guidelines. Working group set by the Finnish Medical Society Duodecim, the Finnish Association for the Study of Obesity and Finnish Paediatric Society. Helsinki: The Finnish Medical Society Duodecim, 2020. Available at: https://www.kaypahoito.fi/hoi50124. Accessed 1 September 2021.

Pharmaca Fennica. 2020. *Metformin Vitabalans*. Lääketietokeskus. Available: https://pharmacafennica.fi/spc/2179028. Accessed 10 September 2021.

Shan, R., Sarkar, S. & Martin, S.S. 2019. *Digital health technology and mobile devices for the management of diabetes mellitus: state of the art*. Diabetologia 62, 877-887. Available: https://doi.org/10.1007/s00125-019-4864-7. Accessed 24 September 2021.

Sheppard, M. K. 2020. *mHealth apps: Disruptive Innovation, Regulation, and Trust- A Need for a Balance*. Medical Law Review. Vol 28. No 3. Available at: https://doi.org/10.1093/medlaw/fwaa019. Accessed 22 September 2021.

Soite. 2021. *Omahoito*. Available: https://www.soite.fi/omahoito. Accessed 8 November 2021.

Terveyskylä. 2020. *Mitä e-terveyspalvelut ovat*. Available at: https://www.terveyskyla.fi/terveyskyl%C3%A4n-palvelut/e-terveyspalveluiden-opas/mit%C3%A4-e-terveyspalvelut-ovat. Accessed 22 September 2021.

Tutkimuseettinen neuvottelukunta. 2012. *Hyvä tieteellinen käytäntö ja sen loukkausepäilyjen käsitteleminen Suomessa*. Available at: https://tenk.fi/sites/tenk.fi/files/HTK_ohje_2012.pdf. Accessed 12 November 2021.

Veazie, S., Winchell, K., Gilbert, J., Paynter, R., Ivlev, I., Eden, K., Nussbaum, K., Weiskopf, N., Guise, J-M. & Helfand, M. 2018. *Mobile Applications for Self-Management of Diabetes. Agency for Healthcare Research and Quality*. Technical Brief 31. Available at: https://www.ncbi.nlm.nih.gov/books/NBK518944/pdf/Bookshelf_NBK518944.pdf. Accessed 15 November 2021.

Review Articles

Agarwal, P., Mukerji, G., Desveaux, L., Ivers, N.M., Bhattacharyya, O., Hensel, J.M., Shaw, J., Bouck, Z., Jamieson, T., Onabajo, N., Cooper, M., Marani, H., Jeffs, L. & Bhatia, R.S. 2019. *Mobile App for Improved Self-Management of Type 2 Diabetes: Multicenter Pragmatic Randomized Controlled Trial*. JMIR Mhealth and Uhealth 2019;7(1). Available at: https://doi.org/10.2196/10321. Accessed 27 October 2021.

Gong, E., Baptista, S., Russel, A., Scuffham, P., Riddel, M., Speight, J., Bird, D., Williams, E., Lotfaliany, M. & Oldenburg, B. 2020. *My Diabetes Coach, a Mobile App–Based Interactive Conversational Agent to Support Type 2 Diabetes Self-Management: Randomized Effectiveness-Implementation Trial*. J Med Internet Res 2020;22(11). Available at: https://dx.doi.org/10.2196%2F20322. Accessed 27 October 2021.

Jeffrey, B., Bagala, M., Creighton, A., Leavey, T., Nicholls, S., Wood, C., Longman, J., Barker, J. & Pit, S. 2019. *Mobile phone applications and their use in the self-management of Type 2 Diabetes Mellitus: a qualitative study among app users and non-app users*. Diabetology & Metabolic syndrome vol 11. Available at: https://doi.org/10.1186/s13098-019-0480-4. Accessed 27 October 2021.

Lee, D.Y., Yoo, S., Min, K.P. & Park, C. 2020. *Effect of Voluntary Participation on Mobile Health Care in Diabetes Management: Randomized Controlled Open-Label Trial*. JMIR Mhealth Uhealth 2020;8(9). Available at: https://dx.doi.org/10.2196%2F19153. Accessed 27 October 2021.

Sunil Kumar, D., Prakash, B., Subhash Chandra, B.J., Shrinivas Kadkol, P., Arun, V., Jom Thomas, J., Kulkarni, P., Gopi, A. & Narayana Murthy, M.R. 2021. *Technological innovations to improve the health outcome in type 2 diabetes mellitus: A randomized controlled study*. Clinical Epidemiology and Global Health 9. Available at: https://doi.org/10.1016/j.cegh.2020.06.011. Accessed 27 October 2021.

Torbjørnsen, A., Ribu, L., Rønnevig, M., Grøttland, A. & Helseth, S. 2019. *Users' acceptability of a mobile application for persons with type 2 diabetes: a qualitative study*. BMC Health Serv Res 19. Available at: https://doi.org/10.1186/s12913-019-4486-2. Accessed 27 October 2021.

Yu, Y., Yan, Q., Li, H., Li, H,. Wang, L., Wang, H., Zhang, Y., Xu, L., Tang, Z., Yan, X., Chen, Y., He, H., Chen, J. & Feng, B. 2019. *Effect of mobile phone application combined with or without self-monitoring of blood glucose on glycemic control in patients with diabetes: A randomized controlled trial*. Journal of Diabetes Investigation 10;5. Available at: https://doi.org/10.1111/jdi.13031. Accessed 27 October 2021.

Zhai, Y. & Yu, W. 2020. *A Mobile App for Diabetes Management: Impact on Self-Efficacy Among Patients with Type 2 Diabetes at a Community Hospital*. Medical Science Monitor 26. Available at: https://dx.doi.org/10.12659%2FMSM.926719. Accessed 27 October 2021.