A Work Project, presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

Technology in Diabetes Care:

Factors that impact accessibility

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Abstract

This work project explores four factors that impact the adoption of technology in diabetes care around the world. The factors addressed hereby are (i) education on diabetes and technology, (ii) regulatory agencies, (iii) socioeconomic reality and (iv) healthcare system and insurance coverage. The analysis was developed using a qualitative approach in order to understand the topic according to existent data, and finally, reach the author's own conclusion about the topic.

Keywords: Diabetes, treatment, technology, devices, adoption, accessibility

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Contents

1. Introduction

Diabetes is a health condition characterized by a high level of blood glucose caused by a lack of insulin in the patient's body. It is estimated that 1 in 11 adults in the world have diabetes and this number will increase rapidly over the next years, passing 600 million people in 2040, (Diabetes Community UK, 2019). The condition can be treated in different forms, and this factor has suffered a major change since the discovery of the disease, from patients doing starvation dieting in 20th century to the launch of an artificial pancreas in 2016, (American Diabetes Association, 2020.b).

Diabetes is considered one of the most expensive health conditions of the world, the International Diabetes Federation (2019) estimates that around 10% of the global health expenditure is used by governments only in diabetes care, not considering the private investment that patients need to make to acquire necessary supplies. Along with that, 80% of patients come from middle and low income countries, where the socioeconomic, educational and healthcare contexts are less developed in comparison with higher income regions. Therefore, because the disease requires such high financial spending, there is a major problem of treatment accessibility and inequality around the world.

When considering innovative options as a part of the treatment, the inequality gap is even bigger, as they are more expensive than traditional means, (Lansdown, 2017). Fortunately, it is known that technology plays a major role in developing diabetes treatment and giving patients much more freedom nowadays, providing good results and even compensating the financial investment in the long term, thus, there is a great effort to improve accessibility in different contexts, (International Diabetes Federation, 2019).

Accordingly, to have a better understanding of the diabetes and technology topic, this work project explores four factors that limit the percentage of patients with access to diabetes

technology worldwide. The objective is to explore the factors and understand how they restrict the adoption of such advanced treatments. In order to develop this research, it was used a qualitative approach to analyze documents already available from governmental institutions, healthcare experts, diabetes associations from different countries, pharmaceutical companies and papers developed on diverse diabetes topics.

The work project sections are divided as follows: (1) introduction, (2) background and definitions about diabetes and technology, (3) methodology used in the development of the research, (4) analysis of the factors that create a barrier to technology adoption, and finally (5) conclusion with the author's discussion about the topic, followed by limitations and further work recommendations.

2. Background and definitions

2.1. Diabetes mellitus

According to the World Health Organization (2016.b), diabetes mellitus occurs either when the pancreas do not produce enough insulin or the body do not make the right use of it, therefore, blood glucose cannot be controlled. The medical condition can be divided mainly by four different types, (i) gestational diabetes, when the woman develops the disease during the pregnancy only, (ii) Moody, when the patient secrets insulin until its pancreas stops working, and the most common ones (iii) type 1 and (iv) type 2. For the purpose of this research, the paper will be focused on the last two.

The World Health Organization (2016.b) explains that patients with diabetes type 1 (T1) have a deficiency of insulin production in their body, leading to a dependence on the hormone to survive as part of their treatment. T1 counts for almost 10% of the cases, the disease is not preventable and the cause is not well established. On the other side, diabetes type 2 (T2) is characterized by the body's inefficient use of insulin, most of the patients do not depend on it

to survive, needing a combination of different treatments to deal with the disease. T2 is responsible for almost 90% of the cases, being caused mainly by a long term unhealthy life style and genetic conditions.

Regarding the total number of patients, there are approximately 470 million adults and more than 1.1 million kids and teenagers with diabetes around the world. The number of diabetics have tripled during the last 20 years and will exponentially grow over the next decades, especially in T2 cases, (International Diabetes Federation, 2019). The exhibit 1 pictures the prevalence of adult patients nowadays.

Moreover, the condition is responsible for a big slice of health expenses in most of the countries. It is estimated that governments spend USD 760.3 billions and that this number increases in USD 90 billions over the next 10 years. China, India and the United States are the countries with the biggest number of patients (exhibit 2) and also higher total expenses in diabetes, around 18% of the total annual health budget each, being 43% of the world diabetes expenses spent only in the North American and Caribbean region (International Diabetes Federation, 2019).

Regarding the prevalence in specific regions, the fact that middle and low income countries have a higher incidence in comparison with high income countries can be explained by number of the population and lack of measurements to prevent diabetes T2 cases. It is also estimated that over the next years poorer countries suffer a steady increase in the number of patients as the economy will develop and socioeconomic changes happen, leading to a rise in bad eating habits, (World Health Organization, 2016.b).

2.2. Traditional Treatment and Timeline

Wu (2019) states that the first dated discoveries about diabetes were in the 20th century, when patients would die in weeks or months after the first symptoms. Fortunately, in the current context there are many treatment options available. The table below depicts the timeline from the main discoveries to current days.

1915	1922	1955
"Starvation dieting", lack of calories and carbohydrates was used to treat diabetes at that time until the commercialization of insulin	Leonard Tompson, first patient to be treated with insulin from pigs	First oral pills commercialized for diabetes type 2 patients
1961	1964	1968
Commercialization of Glucagon, hormone to treat hypoglycemia	Introduction of test strips to check blood glucose	Use of the HbA1c test to monitor the efficiency of treatments
1976	1982	1999
Development of the first wearable insulin pump to a limited number of patients	Creation of the human insulin	First continuous glucose monitoring (CGM) and insulin pump approved to limited number of patients
2000	2014	2016
Introduction of the long-acting insulin, Lantus	Approval of the flash-glucose and CGM sensors for commercial use in Europe	The first artificial pancreas was approved for commercial use

Table 1 – Diabetes treatment timeline

Source: Own elaboration based on American Diabetes Association (2020.b), Wu (2019) and Gebel (2012)

2.3. Innovation and Technology

As shown in table 1, there are many changes in diabetes treatment over the years and technology is responsible for a major part of it. Technologies started to be developed in 1976, but only in recent years patients were actually able to buy it, (American Diabetes Association, 2020.b). Nowadays, there are several options of devices and monitors that can be used to treat the disease, from flash glucose monitoring, insulin pumps, artificial pancreas to smartphone

applications. For further analysis purposes, the table below depicts the main technologies available in the market and their definitions.

Technology	Definition
Self-monitoring of blood glucose (SMBG) or blood glucose test strips	Strips that collect patient's blood from a finger test giving the glucose level. The newest models come with smartphone applications connection
Smart insulin pens	Insulin pens that have a variable options of doses, being able to adapt to patient's treatment. Some of them come with a smartphone application to support the calculation of necessary units
Flash Glucose Monitoring (FGM)	Sensor attached to the patient's body that when scanned shows the blood glucose level
Continuous Glucose Monitoring (CGM)	Sensor that regularly checks patient’s glucose and sends to a monitor by WIFI or Bluetooth
Insulin pumps or Continuous subcutaneous insulin infusion (CSII)	Device that automatically injects insulin in the patient's body with commands
Artificial pancreas	A CGM sensor to check glucose levels and a pump to inject insulin according to the data from the sensor. It is the most advanced technology in the market, called closed loop system

Table 2 – Diabetes technologies and definition

Source: Own elaboration based on Roche (2020), Ahn (2019), Abbott (2020), Medtronic (2019), Sora (2019) and Wetsman (2019)

2.3.1. Impact

Although technology official use is new in the market, it has already started to show impacts in different areas, especially in financial aspects and treatment results. According to an article from Abbott, the FreeStyle Libre FGM sensor has diminished the number of times a patient needs to visit doctors and hospitals, consequently lowering overall costs, (Abbott, 2019.b). As for smartphone applications, Whaley et al. (2019) states that patients using traditional blood glucose measurement combined with smartphone applications reduced their medical costs in 21,9%.

Regarding treatment results, as stated by Beck et al. (2017) the American Diabetes Association conducted a trial to measure the impact of FGM and CGM in patients' treatments in the United States. It was observed that patients lowered the number of extreme events in around 31% and increased in 44% good blood glucose levels.

2.4. Accessibility

Having described the traditional and advanced treatments existents, it is important to know that many patients are not able to access these supplies. The International Diabetes Federation (2019) estimates that approximately one in two people with diabetes T2 have access to the right treatment prescribed by the doctor. This number changes depending on the region, in African countries for example, it is known that only 24% of the patients have access to insulin in contrast with 90% in high income countries. As stated by the World Health Organization (2016.b), the contrast between regions is preoccupying as the majority of patients live in middle to low income regions and it is known that these are the countries with the highest estimated growth for the next years.

Furthermore, not only the economic reality of the country affects accessibility of the treatment. Novo Nordisk (2020), the biggest insulin producer in the world, states that there are other factors, such as the healthcare system of each country, education on diabetes and supply chain

that impact on the adoption of basic treatment worldwide. When it comes to technology treatment, Naranjo et al. (2016) says that the most relevant barriers are psychological, structural and demographic, composed by financial and economic context, education on diabetes and technology, insurance systems, regulatory guidelines and the possible errors from technology functioning. As an example to understand more about the adoption curve of technologies, the figure below depicts the percentage of patients using devices in the United States in 2014.

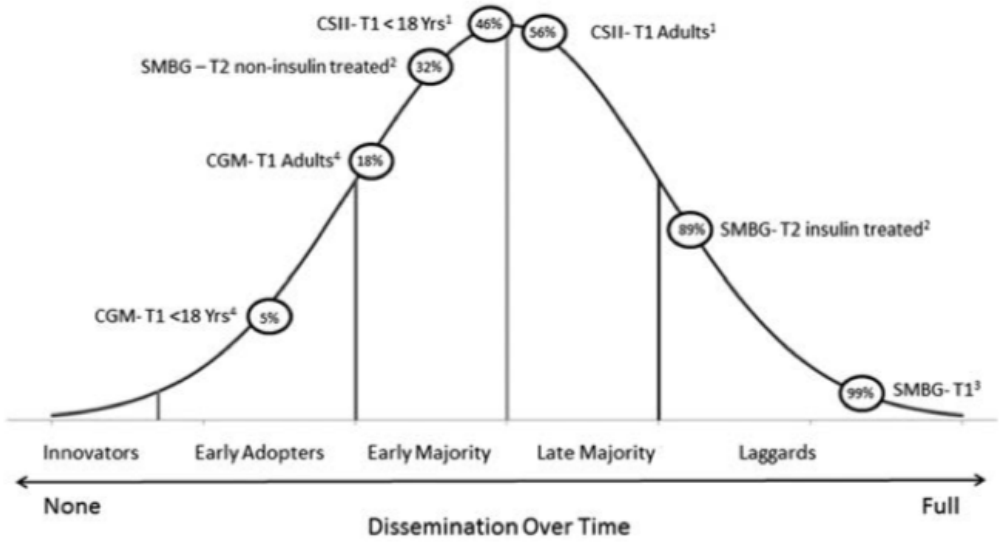

Figure 1 – Dissemination of technologies in the United States per percentage of patients

Source: Retrieved from Frederick et al. (2016)

Basic technologies such self-monitoring blood glucose (SMBG) is widely available in the United States, as 99% of T1 and 89% of T2 patients make use of it in their treatment. However, advanced technologies such as continuous glucose monitoring (CGM) and insulin pumps (CSII) still need improvement in accessibility, (Frederick et al., 2016). In 2017 it was estimated that only 15% of total T1 diabetic patients in the United States make use of a CGM device (Close, 2017), a slight increase in comparison with the information from figure 1.

Moreover, the FGM system was not available during the period described in the picture, but it is known that there are between 1.5 million to 2 million users of the FreeStyle Libre sensor since its beginning in 2014. It is important to highlight that there are more than 460 million

patients around the world, meaning that there is a small slice of them using FGM sensors, (Abbott 2019.a).

According to the information presented above, this work project aims to address and explore four factors that impact technology accessibility around the world. The next sections will be dedicated to understand this topic in dept.

3. Methodology

Based on the objective of this paper, a qualitative research was the methodology chosen to develop it. The work project is composed by a contextualization of the scenario and further analysis of already existing documents, based on findings and exploration rather than testing hypothesis.

The elements of the paper were categorized and interpreted according to data from healthcare and political institutions, companies reports, previous papers and websites. All the documents used were chosen according to its reliability and quality of the information provided, institutions such as the United Nations and World Health Organization to papers from specialists on the diabetes and technology topics, were used as sources.

The information found on the sources were analyzed and put in the context of this research, so they could be interpreted by the author. The learnings retrieved from the sources were combined with other findings, therefore, the author was able to create her own opinion about the topic.

A quantitative method was not suitable for this research as the objective was not to measure or create patterns based on data. Additionally, as previously described, because the use of developed technology in diabetes care is relatively new, there are not enough quantitative data that could support the question to be analyzed. Accordingly, because of the limitations in the quantitative approach for this context and the objective of the research, the author chose to use a qualitative methodology.

4. Analysis

4.1.Measuring the future impact

Considering the positive outcomes from technology development described in this paper, it is possible to see that innovation is already making a great advance in different areas of diabetes care. However, these results are part of a small slice of patients that have access to technologies, as described previously.

What specialists know is that diabetes technologies are indeed seeing a rise in its adoption worldwide – considering the market size (exhibit 3) – and there is an effort in the community to evaluate the real impact of technology in diabetes care in the future. However, it is necessary a much larger amount of data to estimate concrete results, especially considering that the majority of patients adopting technologies come from high-income countries – as it will be shown in the topics below – leading to a lack of results from a different socioeconomic reality. Accordingly, now it is important to understand the factors that influence the adoption of technological devices around the world, thus, it is possible to better estimate concrete results and take actions in the future when the necessary quantitative information become available.

This being said, the factors analyzed were chosen according to the literature studied to conduct this research and the author's understanding of relevance, knowing that they are not the only ones impacting technology adoption.

4.1.1. Education on diabetes and technology

Many people around the world are not aware of their diabetes diagnosis, along with that, it is estimated that only 50% of T2 patients have the right treatment, meaning that a small percentage of diabetics are actually educated about their condition. According to the Brazilian Diabetes Association (Sociedade Brasileira de Diabetes, 2019), diabetes education is one of the main pillars of self-management, especially for patients using new technologies. The Juvenile Diabetes Research Foundation (2020), also states that having the right information about the

disease is a decisive factor for technology adoption and positive treatment results in the United Kingdom.

Additionally, both reports state that patients rely on information from doctors and nurses, thus, if these professionals do not have enough time and are not educated to provide information about new technologies, it is unlikely that patients will adopt the use of devices by themselves. In the United Kingdom, users of such devices also state that the reason that affect the most their choice to look for a different treatment was their doctors' opinion, in 42% of the cases, confirming again that patients rely on health experts to take a big part of the decision, even though there is easy information about technological treatments online.

Furthermore, according to Heerden et al. (2017), devices require a middle and high level of education on technology and how to handle possible outcomes from the adoption. Along with that, the American Diabetes Association (2020.a) states that the constant changes and development in diabetes technology might create a complex context if the patient has a low level of technology acquaintance. Schneider (2019) also says that regardless of the socioeconomic situation and the possible coverage by the public healthcare system or private insurance, the patient needs to be eligible to wear the technology, meaning that it is necessary a basic technical training on how to handle it before the adoption.

As approximately half of the world have access to internet connection, it is unlikely that the other offline 50% have enough technology access and knowledge to deal with advanced devices and applications, (Roser et al., 2020).

Moreover, considering that 90% of diabetes cases in the world are T2, composed by adults or older patients, it is harder for them to adopt in their daily lives such advanced technology and especially keep up with different devices and smartphone applications rapid changes. Also, because devices give patients so much more freedom, it is easier to make a mistake without doctors advices, thus, not every patient can use it, (Herden et al., 2017).

Diabetes and technology education are influenced by many factors, prepared professionals to teach about the advanced treatment, active learning from patients, understanding of their own personal limitations, access to internet and acquaintance with basic technologies such as smartphones. All of these elements indirectly impact the adoption of technology treatment in the educational context, (Sociedade Brasileira de Diabetes, 2019).

All in all, taking in consideration that there is a high percentage of patients who are not aware of their condition or do not properly have access to care, summed with the context of lack in technological knowledge, there is a long way to provide the necessary education to a higher adoption of devices and smartphones applications.

4.1.2. Regulatory agencies

Diabetes technologies are being developed for many years, taking in consideration the table 1 of this paper, it is noticeable that the advanced supplies currently commercialized had its first versions years ago, such as the insulin pump in 1976, limited to clinical trials and patients tests. Regulatory agencies have an important role in this process, institutions such as the Food and Drug Administration (FDA) from the United States, are responsible for the approval of all new treatments, and that can take from three to seven years in average when considering devices that require high human interaction, (Norman, 2016). As every country has its own regulatory agency, the time needed to put medical technologies in the market can vary from region to region. Take FreeStyle Libre from Abbott as an example, the FDA approved in 2016 its use for clinical trials, it took one year after that to approve it for patients use, but in Europe the device was already available since 2014, (Blum, 2018).

Not only countries have a different timeline in terms of development to approval, but also the type of product has variations and different regulations needed. According to Fleming et al. (2019), smartphone applications created to support diabetic patients in the United States and in European countries are unregulated in your majority, mostly because of a lack of evidence on

security and data. There is a concern from the authorities to regulate such applications without concrete data and conclusive tests because of such important decisions taken with the information provided by them.

Furthermore, the considerable recent rise of the cybersecurity topic, has put authorities in a dead-lock between keeping patient's data safe and not interfere in its collection from the healthcare institutions for development purposes. Regulatory agencies have based diabetes technology security in other medical devices, and it has been a barrier for faster advances and adoption because of many threats from the past, such as groups trying to hack cardiac pacemakers, (Ginsberg; Klonoff; Crabtree, 2017).

CGM, FGM and CSII have shown to be susceptible to invasion years ago, there are several cases of patients hacking into the devices to develop new functions or to collect private data. Even before an official commercialization of CGM or artificial pancreas systems, there were already patients using non regulated smartphone applications to hack basic technologies and turn them into what became available in the market years after, (Ginsberg; Klonoff; Crabtree, 2017).

Therefore, regulatory agencies tend to create guidelines that limit users of such technologies. As previously discussed, patients must have a high level of diabetes and technical education to become an user, not only the device itself requires this knowledge during daily life, but also federal agencies recommend healthcare institutions, governments and insurance agencies to limit users because of this fact, (Ginsberg; Klonoff; Crabtree, 2017).

Considering this, regulatory agencies have an important role in technology adoption as at the same time they need to be aware of possible negative outcomes in terms of security, an extreme limitation of these technologies may hold development and commercialization to patients.

4.2.3. Socioeconomic reality

The cost of purchasing technological devices is one of the most common barriers for patient's adoption around the world, mainly those with higher income compose the majority of people able to afford these options, as the ones coming from a lower income reality need to rely on the healthcare system or donations, (International Diabetes Federation, 2019).

High income countries are the ones with the highest expenditure in diabetes care adjusted per patient, meaning that governments and healthcare institutions have a larger budget to spend in the particular disease. The figures below depict the ranking of the ten countries with the lowest and highest expenditure per adult patient in 2019.

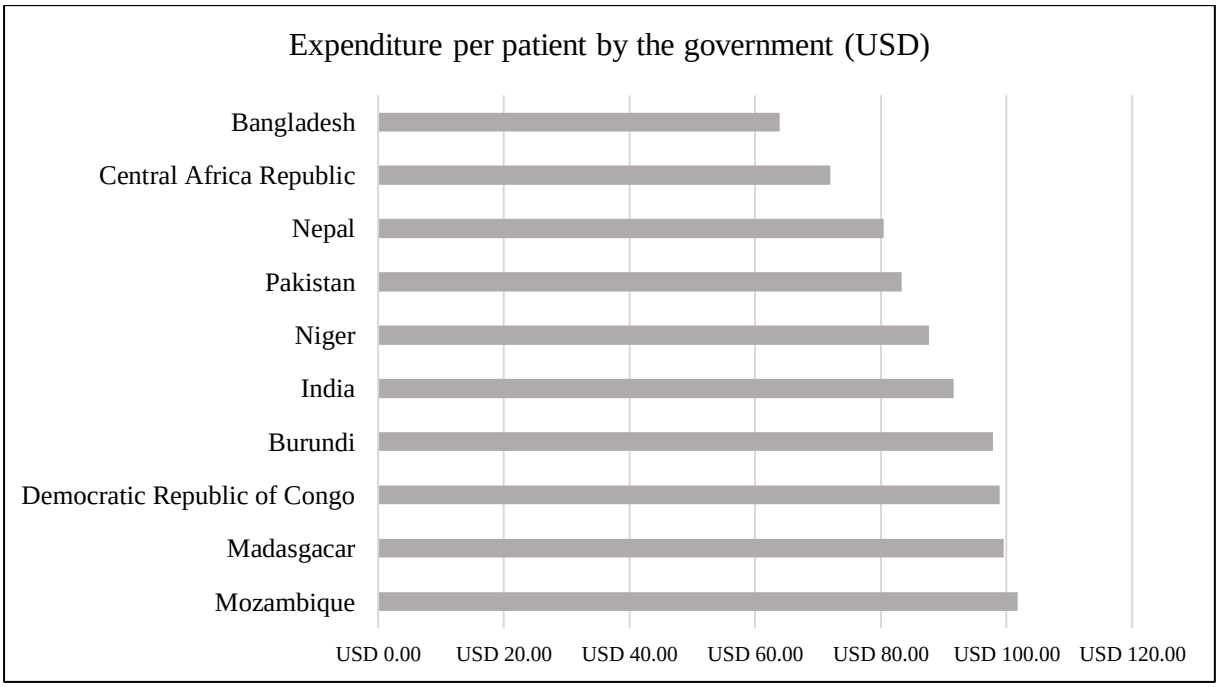

Figure 2 – Countries with the lowest expenditure per patient in 2019

Source: Own elaboration based on the World Health Organization (2016.a)

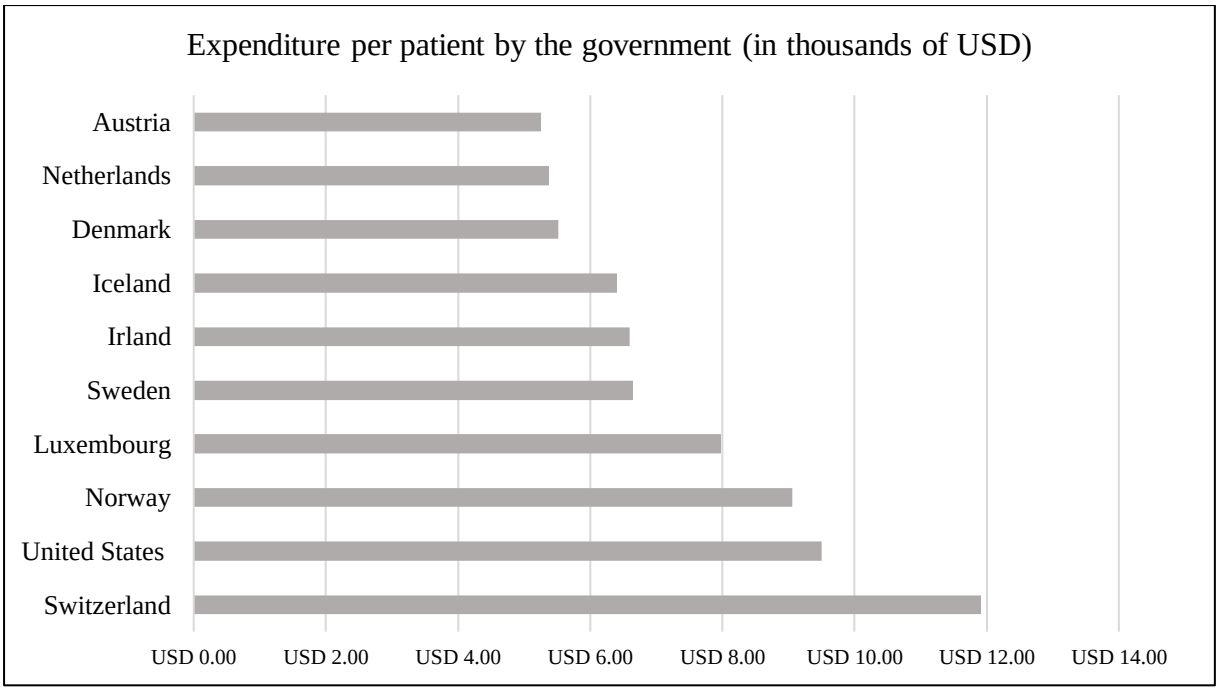

Figure 3 – Countries with the highest expenditure per patient in 2019

Source: Own elaboration based on the World Health Organization (2016.a)

Using the information from figure 3, Switzerland is the country with the highest expenditure per diabetic patient. Also, according to the World Health Organization (2016.a), the country has 5.6% of the population with diabetes, most of the basic technologies are available in the public health system and advanced technologies can be acquired by a private insurance or can be reimbursed by the government depending on the context – this last factor will be addressed in the next topic.

However, Bangladesh has 8% of its population with diabetes, provides only two out of seven basic technologies to patients in the primary care and according to figure 2, is the country that spends the least in patient's treatment. Going further, India, which is the second country in number of patients, also lacks in governmental investment in patient's care and has only two out of seven basic technologies available, (World Health Organization, 2016.a).

What it is interesting to notice is that the percentage of diabetic patients in the country is not a determinant factor for a higher adoption of devices, the socioeconomic reality indeed has a

stronger impact in this context. As showed, developed countries with a lower percentage of patients – with the exception of the United states – have a higher adoption of technologies.

Furthermore, according to data from Abbott's FGM sensor, FreeStyle Libre, 59% of the total devices around the world come from five high income countries: United States, Italy, Germany, Japan and France, (Calliari et al. 2019).

Having in mind the five countries with the highest incidence of diabetes – China, India, United States, Pakistan and Brazil – it would be proportionally logical if the highest adoption of technologies included these countries. However, we have seen that it is not the case, with the exception of the United States.

Additionally, according to the World Health Organization (2016.b) report, low-income countries usually charge more from patients when it comes to buying more advanced tools, such as smart insulins pens. Governments from such countries, choose the "wrong" suppliers and as a consequence, it leads to a higher mark-up in the final price. For a better understanding of the world picture on smart insulin prices, see exhibit 4.

The International Diabetes Federation report (2019) on accessibility around the world, described that only 10% of patients in low-income countries make use of smart insulin pens in comparison with 75% in high-income regions. Although poorer countries do have different recommendations to provide access of basic and technological treatments to the population, it does not seem to work as expected, many governments report difficulty to reach an affordable supplier or even to be able to negotiate with companies that develop devices for a cheaper price.

Moreover, the economic factor is not only impacted by the country's income category, but also on the patient's financial reality. Bennett and Hazelton (2019) conducted a study in the United Kingdom with the objective to address important information about accessibility of devices in the region. They affirm in the Juvenile Diabetes Research Foundation report that approximately

12% of the high-income respondents in the United Kingdom were unaware of the flash-glucose devices, but the percentage doubles to 24% when analyzed patients with a lower income.

Regarding South African patients, according to Petersen (2018), the context is worse in poorer countries as smartphone applications and many devices require internet connection or phone data and many patients cannot afford to pay for it.

To conclude this topic, it was showed that the socioeconomic factor has a high impact in accessibility. It is also essential to understand that patients from a high income country do not always live in this condition, thus, his personal financial context also affects weather he is able to acquire technologies or not.

4.1.4. Public healthcare and insurance coverage

When healthcare systems or private insurances cover part of a diabetic patient treatment, most of the times it includes only traditional supplies, making the financial cost of the disease go up as diabetes requires a high investment and many patients cannot afford paying for the treatment privately, (World Health Organization report 2016.b).

Messer and Weinzimer (2020) state that the traditional glucose level tests (SMBG) are in major covered by health insurances in most European countries and, as described in figure 1, it is widely available in the United States, being the opposite reality in other continents. As regarding CGM and CSII, these devices are not covered in many cases and in the United States it is estimated that three quarters of all patients already using an insulin pump cannot renew the reimbursement.

According to Graham (2017), a decisive factor that impacts the coverage of CGM is the health state of the patient. Similarly, the majority of cases in which CSII are covered belong to patients that need to use the device for treatment purposes, meaning that those who want to use but maintain a good control of the disease with traditional supplies, will have a harder time to get a coverage for a technological option.

On the other hand, FGM devices are already included in some insurances policies in high-income countries. Technology development seem to be pushing insurance agencies and countries to change their policies, as many health specialists advise the use of a more technological option, there are already countries preferring to reimburse FGM devices instead of traditional glucose strips (SMBG), encouraging patients to adhere to the first one. It is also important to state that FGM systems are cheaper and easier to manipulate than CSII and CGM devices, thus it is expected that it is more accessible, (Graham, 2017).

For a better overview of diabetes technology coverage, table 3 depicts the number of basic technologies available for free in the public care system in low to middle income countries. It is followed by table 4 that describes the guideline for reimbursement or coverage of CSII and CGM devices in the public care in high income countries.

Country	Availability in public care (out of seven)
Bangladesh	Two
Pakistan	None
Nepal	One
India	Two
Brazil	Four
Mozambique	None

Table 3 – Basic technologies available in public care

Source: Own elaboration based on World Health Organization (2016.a)

Country	Coverage or reimbursement
United States	Coverage for CGM and pumps in T1 patients only
United Kingdom	Coverage for pumps and CGM on cases that the patient has an unstable control of the condition
Switzerland	Coverage for CGM and pumps on cases that the patient has an unstable control of the condition
Austria	Coverage of pumps and CGM on cases that the patient has an unstable control and pregnant women
Norway	Coverage for CGM and pumps depending on local budget

Table 4 – Advanced technologies coverage

Source: Own elaboration based on Graham (2017) and Iotova et. al (2017)

It is noticeable that countries in table 3 are not able to provide basic technologies to patients, such as insulin pens, blood tests and SMBG. Pakistan, the fourth country in number of patients worldwide, does not provide any technology in public care. Also, crossing with the information provided in the figure 2, there is a correlation between countries that have the lowest investment per patient and those that cannot provide basic or advanced technologies – as we have seen these are the regions with highest percentage of diabetics.

On the other hand, looking at table 4, the countries described there not only provide basic technologies but also cover or reimburse the advanced ones such as CSII and CGM. Important to mention that even high income countries do have limits in terms of coverage, as mentioned before in this topic, usually patients in a specific condition of the treatment will be reimbursed.

5. Conclusion

5.1. Discussion

It was indeed concluded that the four factors explored impact technology adoption by diabetic patients around the world. Education on diabetes and technology showed to be very important as a basic step to accessibility, it was learned that a misinformation on the treatment leads to unawareness of devices existence and its functions, relying on healthcare experts to receive information. As for lack of technology handiness, because guidelines require this as basic knowledge, it limits patients on eligibility to be an user of such innovations.

Additionally, the socioeconomic context creates a barrier on the adoption financially speaking, knowing that 80% of the patients live in middle to low income regions and technologies require high financial investment, many of them cannot afford to acquire devices or even basic supplies as internet connection – necessary to the usage – thus, the majority of adopters come from high income countries. Moreover, the public healthcare system, that could be a partial solution for the socioeconomic issue, either do not cover basic technologies in public care in poor countries or limit patients per health condition in developed ones, which leads to again rely on personal financial condition in many cases.

As for an external factor, it was learned that regulatory agencies play an important role in approving technologies to be commercialized. It was discussed that countries have a different guideline for devices and smartphone applications approval, delaying the adoption in some regions in comparison with others.

In the author's opinion, all the factors analyzed should work together to promote technologies accessibility, logically the factors are also connected, the socioeconomic context is a barrier itself to education on diabetes and technology. Similarly happens to public healthcare system, if the country does not have enough financial funding, hardly it will invest in technologies before basic care.

The work project obtained its objective to analyze and explore the four factors and present how they impact accessibility among patients. The information provided is important to understand the diabetes challenge and which points are necessary to be addressed to increase adoption around the world, providing better life quality and economic relief to patients and governmental institutions.

5.2. Limitations

Concerning the limitations found during the development of this research, the author found it challenging to reach documents about technology adoption in some regions of the world, such as Central America and South East Asia. The information found in institutions such as United Nations, International Diabetes Federation or World Health Organization give an overview about technology adoption in non-developed countries, however, there are no conclusive numbers.

Regarding the types of technologies discussed in the research, depending on the level of development, some devices or applications have more available information than others, leading to a paper focused mainly on five technologies – smart insulin, flash glucose sensors, continuous glucose monitoring systems, insulin pumps and smartphone applications – it is important to say that there are many technologies in the market besides the ones addressed in the research, such as inhaled insulin, artificial pancreas and other systems.

Finally, the factors analyzed as barriers for technology adoption around the world were chosen according to the author's understanding of importance and value for the analysis based on previous research of the bibliography. There are other factors that could have been analyzed, but because of space and information relevance the author had to restrict to the ones addressed.

5.3. Further work

As a next step, it would be interesting to conduct a quantitative work project based on the qualitative information provided here. The focus would be on creating a model to understand

what is the proportion of the impact from the four factors in technology adoption. The next research would provide a deeper understanding of where governments and healthcare institutions could focus to improve accessibility around the world and also which factor is more important depending on the region addressed.

To conclude, in the next years the diabetes community will have a larger amount of data available from technologies, also better categorized from country to country, being a start to develop this research in a quantitative approach now that the qualitative research was already developed.

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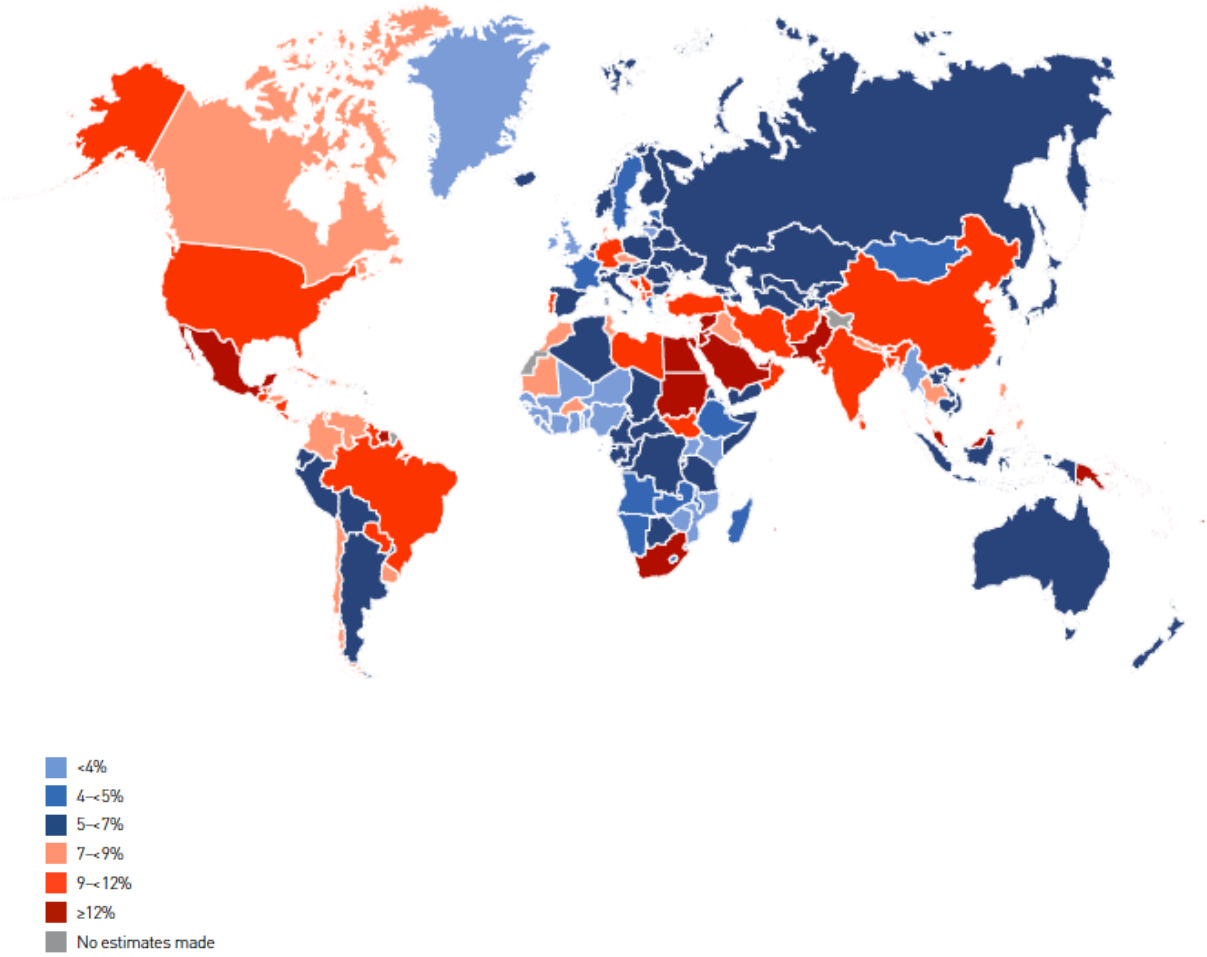
Appendix

Exhibit 1 – Diabetes prevalence around the world in percentage of the population



Source: International Diabetes Federation (2019)

Exhibit 2 – Number of diabetic patients in 2019

Country	Number of patients in 2019 (in millions)
China	116,4
India	77
United States	31
Pakistan	19,4
Brazil	16,8
Mexico	12,8
Indonesia	10,7
Germany	9,5
Egypt	8,9
Bangladesh	8,4

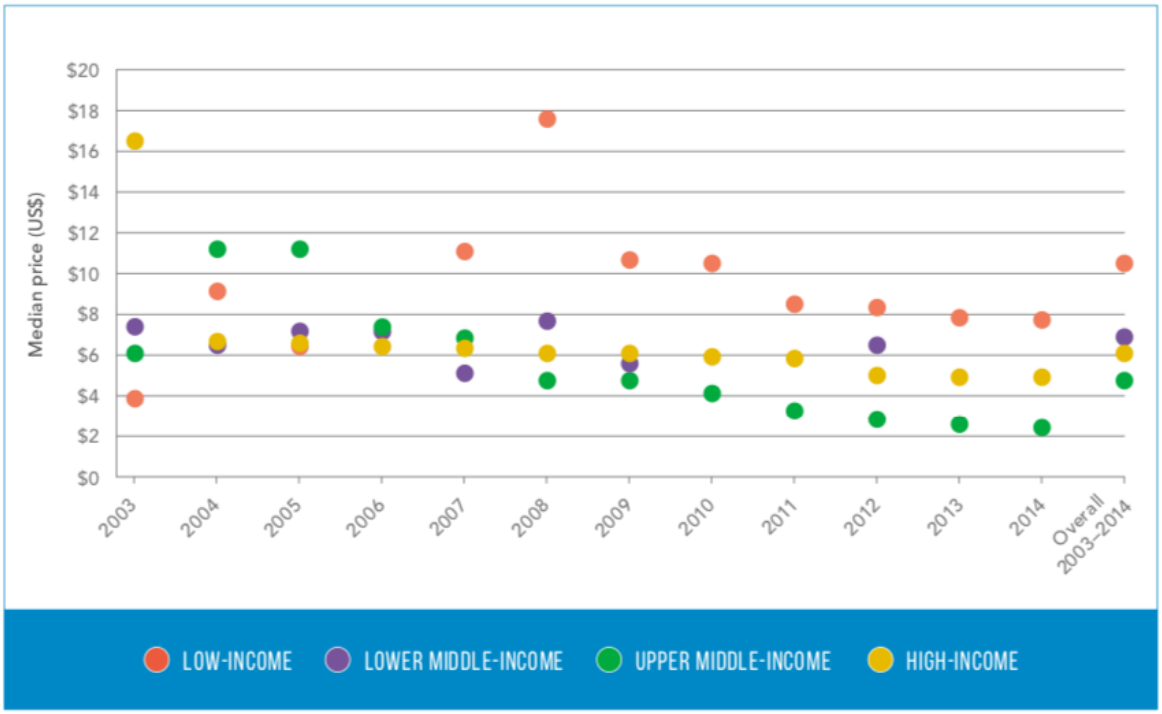
Source: Own elaboration based on World Health Organization (2016.a)

Exhibit 3 – Size of the CGM market in the world

Year	Size of the market (billions of USD)
2017	USD 11,98
2018	USD 12,63
2019	USD 13,33
2020	USD 14,09
2021	USD 14,92
2022	USD 15,83
2023	USD 16,83
2024	USD 17,91
2025	USD 19,11
2026	USD 20,42
2027	USD 21,85

Source: Own elaboration based on The Insight Partners (2019)

Exhibit 4 – Price of smart insulin pens according to income (USD)



Source: Retrieved from World Health Organization (2016.b)