Design of a Mobile App to Monitor and Control in Real Time Type 2 Diabetes Mellitus in Peru

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Abstract—Diabetes is a big problem in the world. Also, in Peru there is a high rate of type 2 diabetes mellitus; this happens due to insulin resistance, which causes damage to the muscles and liver. In addition, fat cells do not generate insulin properly because the body needs to generate more insulin, so glucose can enter the cells. Due to this problem, we sought a solution that aims to develop the design of a mobile app that monitors and control, in real-time, diabetes in patients. This will help patients to have an effective follow-up plan. The methodology used in this research is Design Thinking because it fits perfectly with the solution of social problems, which was developed successfully using five phases: empathize, define, ideate, prototype, and finally test. As a result, the design of the mobile app to monitor and control in real-time type 2 diabetes mellitus in patients in Peru was developed. In addition, we obtained the diabetes data verified by the Peruvian Ministry of Health.

Keywords—design thinking, mobile app, monitors and control, prototype, type 2 diabetes mellitus

1 Introduction

The prevalence of chronic kidney disease (CKD) has increased worldwide. Diabetes is now considered the leading cause of the end-stage renal disease (ESRD), accounting for up to 89.7% of cases of dialysis disease. Diabetic nephropathy is one of the most costly complications for the healthcare system because patients with this condition often end up on dialysis, which proves to be an expensive treatment [1]. US data showed that ESRD expenditures exceeded 120 billion in 2017. As an aggravating factor, cardiovascular mortality grows in proportion to the decline in glomerular function, and among diabetics who initiate dialysis treatment, less than 20% survive after 5 years [2].

Glycemic control of chronic renal patients on dialysis presents additional difficulties because both uremia and dialysis can affect insulin secretion and tissue sensitivity to insulin. In these patients, increased insulin resistance and hepatic gluconeogenesis are observed. In addition, intracellular glucose metabolism is altered, insulin clearance is decreased, and insulin secretion is diminished and enhanced by metabolic acidosis [3]. Such factors contribute to the wide fluctuations in blood glucose levels and exogenous insulin requirements, which are further affected by altered pharmacokinetics of exogenous insulin and hypoglycemic agents and predisposition to asymptomatic hypoglycemia [4].

Hemoglobin is a standard indicator for assessing long-term glucose control in diabetes. Patients undergoing dialysis treatment have erythrocytes with a reduced lifespan and often use erythropoiesis-stimulating agents to treat anemia. These agents, by increasing erythropoiesis, increase the proportion of young, non-glycosylated erythrocytes, underestimating the estimated average glycemia. It also contributes to underestimating the reduction in erythrocyte lifespan [5]. The latest guidelines for improving global outcomes in renal disease highlight the inaccuracy of HbA1c and suggest the use of continuous monitoring devices as an alternative [6].

Type 2 diabetes mellitus (T2DM) is one of the most common metabolic disorders. It is caused by a combination of two main factors: defective insulin secretion by pancreatic cells and the inability of sensitive tissues to respond adequately to insulin. As insulin release and activity are essential processes for glucose homeostasis, the molecular mechanisms involved in insulin synthesis and release, as well as its detection, are tightly regulated. Defects in any of the mechanisms involved in these processes can result in a metabolic imbalance responsible for the development of disease. This review analyzes the key aspects of DM2, as well as the molecular mechanisms and pathways involved in insulin metabolism that led to DM2 and insulin resistance. To do so, we summarize the data collected so far, focusing especially on insulin synthesis, release, and sense; as well as downstream effects on insulin-sensitive organs. The review also covers pathological conditions that perpetuate DM2, such as nutritional factors, physical activity, intestinal dysbiosis, and metabolic memory. In addition, since DM2 is associated with the accelerated development of atherosclerosis, some of the molecular mechanisms linking DM2 and insulin resistance (IR), as well as cardiovascular risk as one of the most common complications of DM2, are reviewed [7].

This project aims to help people suffering from type 2 diabetes, who could not receive medical attention during the pandemic, as the healthcare system collapsed due to Covid-19. Therefore, patients with diabetes in Peru did not receive adequate medical care. Because of this problem, an idea was proposed based on detailed research about diabetes; managing to implement a mobile app that helps patients to keep constant monitoring and control in real-time. This is controlled by the app based on the needs of the user; managing to help many people and contribute to society with the development of a medical app.

Diabetes is the result of the inability of the organism to produce an adequate amount of insulin and is a very common disease that affects more than 9% of people around the world. In Peru, type 2 diabetes mellitus affects mainly people over 30 years old, complicating the health of patients at a risky level. The methodology used is Scrum because each of the phases helps to perform a detailed structure, starting with initiation, planning and estimation, implementation, reviewing and retrospect, and finally the releasing phase. Thanks to the help of each of the phases, this study successfully achieved its purpose, which is the implementation of a mobile app that monitors and controls, in real-time, type 2 diabetes mellitus in people. The research objective is to design a mobile app to monitor and control in real-time type 2 diabetes mellitus in patients.

The paper is structured as follows: Section 2 describes in detail the literature review. Section 3 shows the methodology, Section 4 shows the case study, Section 5 shows the results and discussion and finally, Section 6 presents the conclusion and future work.

2 Literature review

The author [8] makes emphasis on mobile apps and their use for self-management for type 2 diabetes mellitus patients. Also, most of the users found that the applications improved their self-management skills and health and that the recommendations sent through the app by health experts had positive results with the same improving level of satisfaction. However, only a minority of patients had a doctor assigned on the mobile app. Therefore, the barriers the author faced were the lack of understanding and awareness of the app as a healthcare tool. In addition to, perceptions of pathology severity, technological and health literacy, or practical constraints, such as rural connectivity. Also, the author did not use medication reminders; but thought that sending weekly messages involved with their self-management might be appropriate. Concluding that the use of mobile devices can be very helpful for patients with diabetes.

For the control and monitoring of people suffering from diabetes, one option would be the use of apps. If these mobile applications are well-designed, they contribute to the science of health. In addition, they serve for the control and monitoring of diseases that people may have. In this sense, the author Samer [9], states in his research that mobile apps are necessary for communities because it facilitates interaction through apps. According to the author, today's apps are used frequently, contributing to the people who need them; that is why it would be important that the districts should have an agreement with the municipalities for the use of Information and Communication Technologies (ICT) to have greater progress.

Additionally, the author [10], the use of mobile applications raises the efficacy of self-care interventions to obtain favorable outcomes in patients with diabetes. His study aimed to conduct a systematic review with controlled trials to examine in detail the self-care assistance by mobile applications used for type 2 diabetes mellitus patients. As a result, primary study results were obtained, which showed numerous components of self-management participation, such as the inclusion of blood glucose, blood pressure, and medication management. Also, communication with health care providers consequently automated feedback, personalized goal setting, reminders, and data visualization. Thus, the author concluded that mobile application-assisted monitoring and care interventions can be very efficient tools for controlling glucose as well as blood pressure.

In addition, the author [11], investigated and made emphasis on the users' acceptance of mobile apps, where the users are patients with type 2 diabetes. The objective was to obtain a deeper insight into the users' acceptability of the mobile application for diabetes management. The study method used was a descriptive qualitative design in which the research investigators conducted in-depth interviews with people with type 1 and type 2 diabetes for about 1 year. As a result, they obtained the acceptability of the patients, being of routine use that could offer an overview of diabetes registration and provide new insights into self-management; so, the help of healthcare personnel with diabetes-based knowledge was explained as paramount. Also, to confirm the choices made in the functionality of the use of the application or to obtain additional support for self-management; therefore, the author concluded that it had high acceptance classified in different levels.

On the other hand, the author [12], studied glucose control in children and adults with diabetes, through the use of mobile applications via smartphones. The objective was to study the literature that evaluates the apps, and review which ones were related to diabetes. The method applied was the systematic database search, and as result, we obtained a study that demonstrated a reduction in hypoglycemia. Also, a reduction in hypoglycemic events was observed and compared to another study, thus demonstrating a reduction in the average hemoglobin levels. Regarding the app, the author can collect the user's feedback by asking the user to review the mobile app. Most of the mobile apps were well-rated; thus, recording highly relevant parameters for diabetes management. In conclusion, the study emphasizes that other research investigators should continue to explore the efficacy of disease-based apps; thus, gaining a better perspective. In addition, it was shown that the population would benefit from the use of technological tools.

3 Methodology

Design Thinking is very popular in the corporate environment because it generates better ideas through the process of questioning. In addition, it makes it possible to solve problems with high-level innovative solutions for the benefit of users or a company; thus, we used the methodology design thinking because it concentrates specifically on consumer needs. As shown in Figure 1, this methodology has 5 phases consisting of empathize, define, ideate, prototype, and test, which we will detail below [13].

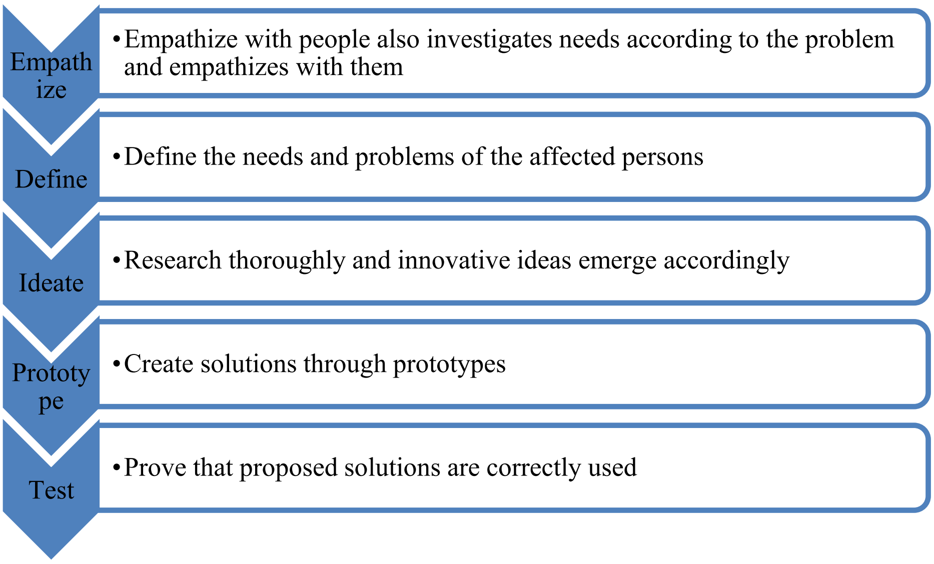

Fig. 1. Phases of the methodology

3.1 Empathize

In this phase, we research about the problem, regarding the people or patients who have diabetes disease that is classified as type 1 and type, 2 affecting children and adults. In this study the focus of attention is the type 2 diabetic people, and research their need to give solutions to the problem, meaning to provide a tool. As shown in Figure 2 the symptoms of diabetes such as increased fatigue or blurred vision, loss of appetite, numbness in the hands, and increased thirst, among others [14].

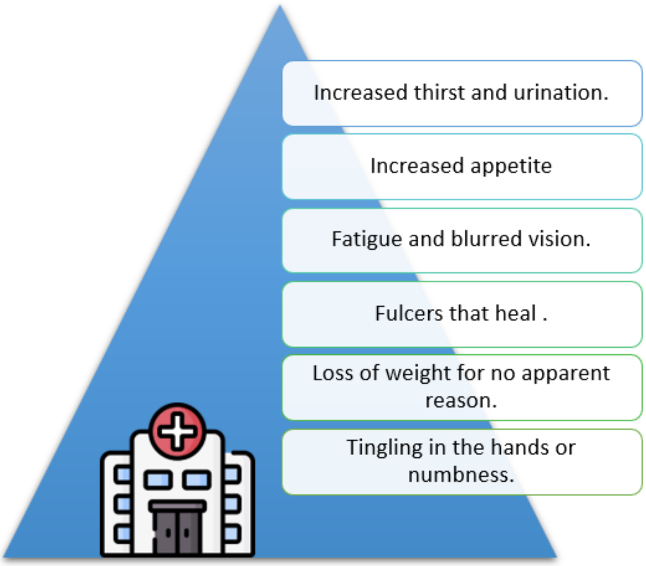

Fig. 2. Empathize with the problem

3.2 Define

In this phase, the needs of the user and the problems they come across are defined. In this case, the problem is that some hospitals in Peru are often collapsed by a large number of patients. Therefore, the mobile app helps both the hospital and the patient, since the patients do not necessarily have to go every day for a follow-up but should always be communicating with their respective doctor in case they have any symptoms, no matter how minimal it may be. Thus, in this phase, the requirements of the patients are defined to have a better perspective. As shown in Figure 3, type 2 diabetes mellitus is defined as a metabolic disease characterized by elevated blood glucose levels due to cellular insulin resistance related to insulin secretion located in the pancreas and if not treated in time there are high risks, including death [15]. It is a metabolic disease characterized by elevated blood glucose levels due to cellular resistance to insulin, with localized insulin secretion in the pancreas causing weight loss for no apparent reason.

Fig. 3. Definition of diabetes-glucose

3.3 Ideate

Once the phases of empathizing and correctly defining the problem are clear, we move on to the ideation phase in which we have a clear perspective of both the problem and the innovative solution that will help the users [16]. Therefore, the idea to be developed is first discussed among all the research investigators. That is why, in this phase, different ideas are obtained based on research of type 2 diabetes and the best idea that fits the solution is chosen, thus obtaining favorable results.

3.4 Prototype

In this phase, the design of an implemented idea is prototyped, which is the design of the mobile application to monitor and control in real-time type 2 diabetes mellitus in patients in Peru [17]. This is of great benefit for those patients who can better manage their follow-up plans. And as shown in Figure 4 the flow chart details the process of the mobile app from the beginning. It starts with the registration, then login to determine if the registration was done correctly, and once the data enters the system, the database will store all the valuable information. After that, the user will go to the main interface of the app where they will have a daily evaluation that consists of questions. In addition, if the patient presents symptoms, it will automatically contact the doctor in charge. Finally, the system adds this information to the patient's medical history.

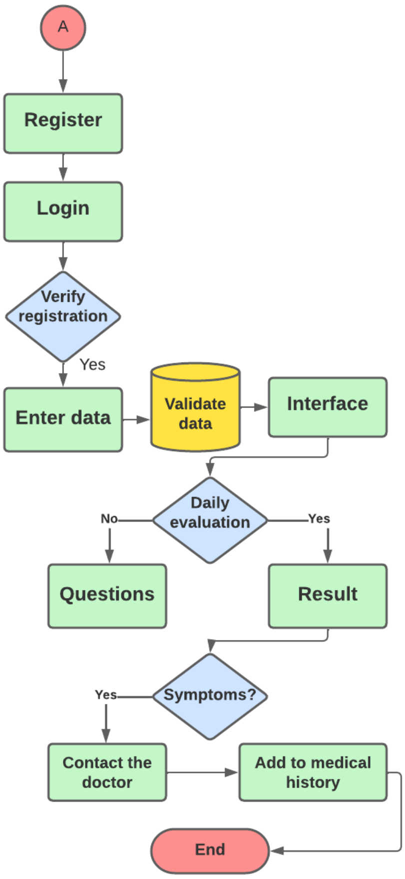

Fig. 4. Flow Diagram

3.5 Evaluate

In this phase, the previous phases are observed to make sure that they have been used correctly and, if any correction is missing, it is done immediately, which does not affect the process. Also, the design of the application is evaluated in detail which will be helpful for the patient having the interface of registration [18]. Once you log in, the main screen menu is where users can access daily reminders as part of a follow-up plan for a detailed evaluation related to Type 2 Diabetes Mellitus.

4 Results

4.1 Diabetes

Table 1 shows the characteristics of the cases of diabetes registered in 2022 in the first quarter, classified by gender: males and females. The population was divided into age groups such as 0 to 19, 20 to 34, 35 to 49, 50 to 69, and 65 to more. Also, it was identified that males were a total of 2019 and females 3004 with a total of 5023 [19]. Likewise, the body mass index was identified in detail for both men and women. These data were obtained from the National Center for Epidemiology, Prevention and Disease Control (CDC-PERU).

Table 1. Cases of Diabetes registered in Peru-2022

Cases of Diabetes	Men		Woman		Total	
Variables	N	%	N	%	N	%
Age(average)	58,16	13,99	56,84	13,48	-	-
0 a 19	18	0.9	25	0.8	43	0.9
20 a 34	97	4.8	136	4.5	233	4.6
35 a 49	415	20.6	644	21.4	1059	21.1
50 a 69	791	39.2	1308	43.5	2099	41.8
65 a mas	698	34.6	891	29.7	1589	31.6
Total	2019	100.0	3004	100.0	5023	100.0
IMC (kg/m2)	N	%	N	%	N	%
(kg/m2)	32	1.7	45	1.6	77	1.6
18,5 a 24,9	637	33.3	738	25.5	1375	28.6
25,0 a 29,9	819	42.8	1118	38.4	1937	40.3
30,0 a mas	426	22.3	992	34.3	1418	29.5

Table 2 shows the type of diabetes classified as type 1 having 99/ 44.9% in males and females 185/ 6.2%, type 2 in males 1908/ 94.5% and in females 2751/ 91.6%, gestational in males 0% and in females 53/1.8%, unclassified in males 10/0.5% and in females 14/0.5% [20].

Table 2. Types of Diabetes

Type of Diabetes	Male	Female	Total
DM Type 1	99/ 4.9%	185/ 6.2%	284/5.7%
DM Type 2	1908/ 94.5%	2751/ 91.6%	4659/92.8%
D Gestational	0/0.0%	53/1.8%	53/1.1%
Not Classified	10/0.5%	14/0.5%	24/0.5%
Other	2/0.1%	1/0.0%	3/0.1%
Total	2019	3004	5023

Table 3 shows the types of diabetes in men and women in Peru in the year 2022 based on the first trimester, obtaining data on the types of complications such as microvascular, retinopathy, nephropathy, polyneuropathy, diabetic foot, and macrovascular. In addition, the frequency of complications according to type in registered cases of diabetes in Peru 2022 is observed, showing that 37% of the cases found at least 1 complication; showing microvascular and polyneuropathy as the most common complications. Thus, the table specifies the exact number of cases; likewise, the data were obtained from the National Center for Epidemiology, Prevention, and Disease Control CDC-PERU [21].

Table 3. Types of Diabetes in Men and Women

Type of Complication	N	%	IC 95%
Cases Complication	889	36.8	34.86-38.75
Microvascular	455	18.8	17.26-20.42
Retinopathy	126	5.2	4.31-6.12
Nephropathy	229	9.5	8.29-10.67
Polyneuropathy	482	20.0	18.34-24.57
Diabetic foot	151	6.3	5.27-7.24
Macrovascular	150	6.2	5.23-7.19

Table 4 shows the frequency of complications by type in registered cases of diabetes in Peru during 2022. Likewise, 89.5% of registered cases of diabetes have treatments specified by their doctor. Therefore, the most used medications are metformin and insulins, as well as sulfonylureas. The data was obtained from the National Center for Epidemiology, Prevention and Disease Control (CDC-PERU).

Table 4. Complications

Medication	N	%
Metformin	3892.0	86.5
Sulfonylureas	600	13.3
DPP-IV inhibitors	45	1.0
Human Insulin	769	17.1
Analog Insulin	289	6.4
Glitazones	0	0.0
Gliflozines	0	0.0
GLP1 receptor agonists	2	0.0

Table 5 shows the types of cases presented in all of Peru. Data was collected from each department of Peru, such as Amazonas, Ancash, Apurimac, Arequipa, Ayacucho, Cajamarca, Callao, Chanka, Cusco, Lima Centro, Lima Este, Lima Norte, Lima Sur, Huancavelica, Huánuco, Ica, Jaen, Junin, La Libertad, Lambayeque, Lima provinces, Loreto, Luciano Castillo, Moquegua, Morropon, Pasco, Piura, Puno, San Martin, Tacna, Tumbes, with new cases predominating in 1947, Lambayeque, Lima provincias, Loreto, Luciano Castillo, Moquegua, Morropon, Pasco, Piura, Puno, San Martin, Tacna, Tumbes with

1947 new cases and 3077 prevalent cases, with a total of 5024 [22]. The data collected was obtained from the source, the national center for epidemiology, prevention, and control of disease CDC-PERU.

Table 5. Types of cases in Peru

Type of cases			
Department	**New**	**Prevalent**	**Total**
Amazonas	30	5	35
Ancash	10	2	12
Apurimac	4	18	22
Arequipa	33	189	222
Ayacucho	100	14	114
Cajamarca	8	0	8
Callao	21	16	37
Chanka	8	24	32
Cusco	102	81	183
Lima Centro	32	115	147
Lima Este	64	0	64
Lima Norte	74	384	458
Lima Sur	70	419	489
Huancavelica	31	0	31
Huánuco	74	84	158
Ica	16	4	20
Jaen	35	8	43
Junin	227	202	429
La Libertad	161	560	721
Lambayeque	150	288	438
Lima Provincias	32	18	50
Loreto	267	176	443
Luciano Castillo	31	165	196
Moquegua	43	14	57
Morropon	26	52	78
Pasco	34	2	36
Piura	32	6	38
Puno	6	0	6
San Martin	57	10	67
Tacna	159	171	330
Tumbes	10	50	60
Total	1947	3077	5024

4.2 Diabetes mellitus type 2

In Peru, diabetes affects approximately 7% of the general population. However, people over 30 years of age tend to be more susceptible to contracting the disease and are at risk of death if it is not detected in time. The following is the data validated by the Ministry of Health (MINSA), as shown in Figure 5 [23].

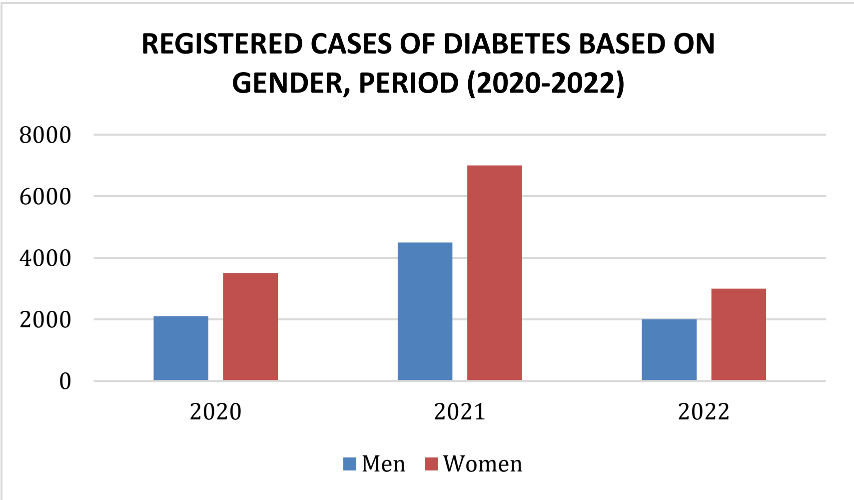

Fig. 5. Diabetes Mellitus Type 2

Figure 6 shows the welcome interface as well as the one to register a new account which requires entering the name, email, and password, so the patient can log in with the login credentials as this was previously registered in the database [24]. Also, if the user forgets his password, that will not be a problem as it can be easily reset.

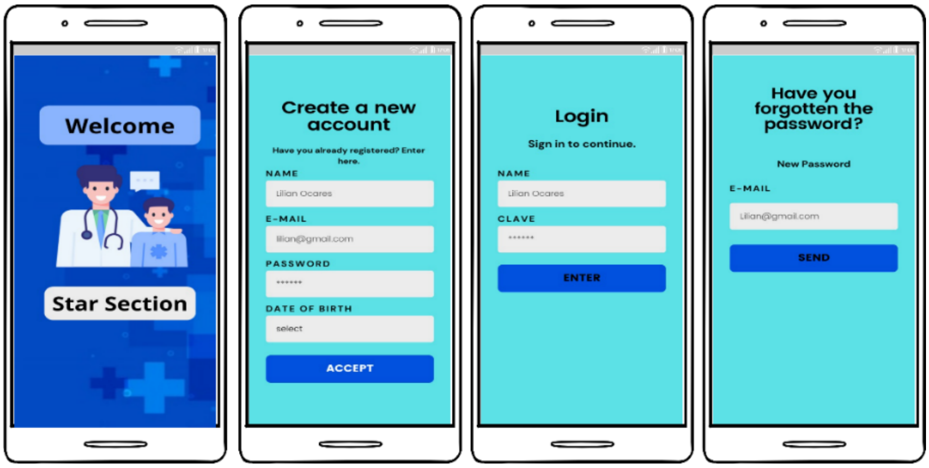

Fig. 6. Register, Login and reset your Password

Figure 7 shows the main interface of the mobile application, which is divided into sections such as patient data, diabetes control, monitoring, daily reports, and the emergency button in case the patient requires it. Also, it shows the data section of each patient registered in the application that indicates the name, surname, general data, and medical history, as well as allergies to have a better perspective of each patient. In this way, the mobile application works hand in hand with a specialized doctor for the patient's safety and well-being. Figure 8 shows the diabetes interface that specifies the date, time, glucose level, and the respective measurement of the diabetic person. Monitoring each patient, it is also observed detailed information of their medications such as name, amount, dose, time, and is recorded to trigger an alarm as a reminder to take their medication. This way, patients do not forget to take their doses to control diabetes. In addition, there is a food monitoring section so that each patient has a balanced diet to help in their treatment and reduce complications.

Figure 8 shows the reports obtained from the evaluation of each patient per day. In other words, there is detailed monitoring and control in real-time, so that it can be downloaded and sent to the respective doctor. In addition, there is an emergency section where the patient, in case of any complication, can be immediately attended to by the ambulance, hospital, or doctor.

Fig. 7. Main Menu and Diabetes control

Fig. 8. Monitoring, Reports, and Emergency

4.3 Responses from the testing phase

Table 6 shows the questions for people with type 2 diabetes mellitus, and this interaction will help us to know their opinion, as well as the importance of the app.

Table 6. Questions

Question about the prototype based on Type 2 Diabetes Mellitus	
ID	**Questions**
Question 1	Do you think the app will be of great help for monitoring and controlling diabetes in patients?
Question 2	Do you think the app is ideal for patients with Type 2 Diabetes Mellitus?
Question 3	Would you recommend a family member or acquaintance to use this mobile app to improve their diabetes management?
Question 4	Would you recommend hospitals and clinics to implement this mobile app to control and monitor in real-time diabetes in patients?

Figure 9 shows the response based on the survey to the questions mentioned above, where it was determined that in question 1, 80% was obtained, which is a favorable result, as well as in question 2 with 99% acceptance, in question 3 with 98% and finally in question 4 with 100%, thus demonstrating a great acceptance the prototypes have.

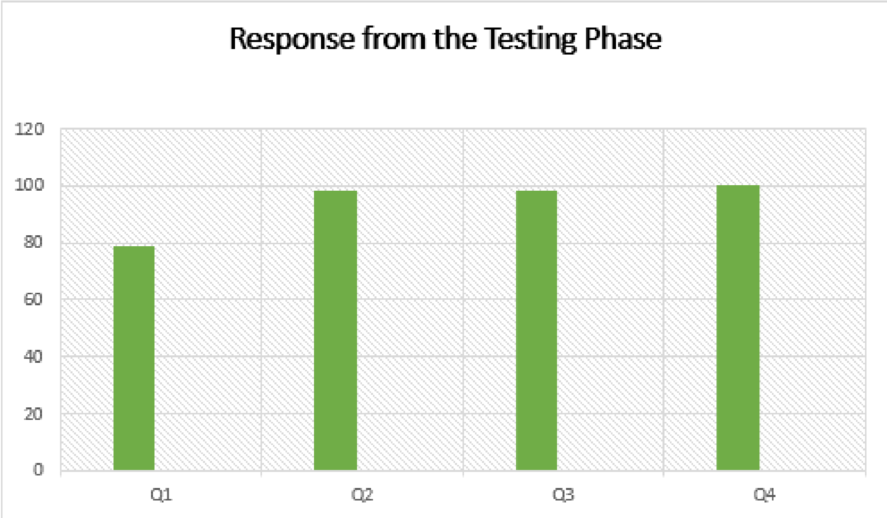

Fig. 9. Testing Phase

In Table 7 the Low, Moderate, and High scales were considered. Low will have a range of 0 to 49% indicating that it would not be accepted, Moderate will have a range of 50 to 79% indicating that the prototype can be improved, and High will have a range of 80 to 100% indicating that it would be an acceptable prototype.

Table 7. Level of Acceptance

Questions						
Experts	**Function**	**Usability**	**Consistency**	**Integration**	**Total**	**Level**
Expert 1	90%	80%	90%	95%	80%	High
Expert 2	85%	90%	75%	80%	90%	High
Expert 3	79%	93%	88%	85%	94%	High
Expert 4	95%	95%	96%	90%	84%	High

5 Discussion

The proposal of the design of a mobile app to monitor and control in real-time Type 2 Diabetes Mellitus in patients in Peru was analyzed to determine if this is a good strategy to combat the problem and provide better care and quality in the treatment of each patient, in order to lower the risk of complication. Likewise, analyzing the problems before devising a solution is of great benefit; agreeing with the author [25], who identified different problems in the healthcare system in Peru, which is highly deficient and does not provide quality care to people. Therefore, the use of a mobile app is an excellent tool as people use their mobile devices in such a way that they can benefit from technology, as proposed by the author [26].

6 Conclusion and future work

In conclusion, the design of the mobile application will help many Peruvian patients to carry out their treatment properly; in such a way that no complications arise. Likewise, the situation in Peru was analyzed in detail, per region, as well as the case numbers based on the data compiled by MINSA-2022. In this way, the problem of diabetes in Peru was observed and an idea was generated to solve the problem by developing prototypes for the creation of a mobile app. This will work hand in hand with a specialized doctor for the safety of each patient with type 2 diabetes mellitus. Likewise, the Design Thinking methodology was used because it focuses on solving society's problems and it fits perfectly with the research work. With this app design, we aim to implement the software in Peru in the future, as there are many difficulties in hospitals and patients do not have a proper follow-up and are at risk of complications with their treatment; therefore, the app will be of great benefit to diabetes type 2 patients in Peru.

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