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A Predictive Model for an Assistant System to identify Diabetes Mellitus

Elena Fabiola Ruiz-Ledesma [a,*], Laura Ivoone Garay-Jiménez [b], Elizabeth Acosta-Gonzaga [c]

[a] *Instituto Politécnico Nacional, Escuela Superior de Cómputo, Col. La Escalera, Mexico City, 07320, Mexico*
[b] *Instituto Politécnico Nacional, Unidad Profesional Interdisciplinaria en Ingeniería y Tecnologías Avanzadas, Mexico City, 07340, Mexico*
[c] *Instituto Politécnico Nacional, Unidad Interdisciplinaria de Ingeniería Ciencias Sociales y Administrativas, Mexico City, 08400, Mexico*
*Corresponding author: *eruizl@ipn.mx*

***Abstract*—Given the high incidence in Mexico of Diabetes Mellitus (DM), it seems impossible for all patients to be monitored by a specialist. Therefore, preventive action and primary care contact services are an urgent need for early detection of this disease. This paper aims at proposing a model to calculate the risk factor from the information provided by the participant without requiring clinical studies. Firstly, the principal causes of DM are identified via an initial state-of-art analysis about DM pre-screening, screening, diagnosis, and treatment. Then, a digital survey was applied to a sample of fifty participants, all of whom were asked about their knowledge of DM's causes. Afterward, an in-depth qualitative analysis of the answers was made. Results showed that only 36% of the interviewed subjects identified the main symptoms of DM, but 66% would be willing to consult with a doctor if they could identify the symptoms. The proposed digital system measures the perception of the user and provides quick information about the disease, considering DM Type 1 statistics. The system is based on conditional probability and clinic guides for prevention by identifying risk factors and pondering. Further extensive use of this assistance could raise awareness about the risk factor and provided a percentage of the probability of having DM Type 1, and the result could help detect DM in the early stages.**

***Keywords*— Predictive model; probability; chronic degenerative illness; early detection.**

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I. INTRODUCTION

Diabetes Mellitus is a chronic degenerative illness mainly identified as chronic hyperglycemia caused by a defect in insulin secretion, its action, or both [1]. It does not produce symptoms in its initial stages, which is why if it is not adequately treated or detected opportunely, it can lead to severe health damage such as blindness, heart attack, renal failure, lower limb amputation, and even an early death [2], [3]. Diabetes can be classified into three types: Type 1, which is most frequently found in children, teenagers, and young adults. Diabetes Mellitus Type 1 (DMT1) is considered an autoimmune, organ-specific illness, in which etiological factors of an immunological, genetic, and environmental kind take part [4]. It generally produces a dependency on insulin administered via injections from an early age [1]–[4].

Diabetes Mellitus Type 2 (DMT2) usually manifests in the adult age, and its origin is usually found in the obesity index. A diagnosed patient requires medical control with orally administered drugs and a special diet, although insulin shots must also be prescribed [2], [5]. Gestational diabetes mellitus is defined as an intolerance to carbohydrates, and it is identified firstly during pregnancy, though it sometimes disappears at the end of the puerperium [6]. Just as in DMT2, obesity has been suggested as an incidence factor [7].

World statistics show that the incidence of DMT2 has increased lately, and the increase has been more significant in countries with medium and medium-low incomes. In Mexico, the presence of DMT2 has increased in general, but it has shown a significant increase in the younger population, which has been associated with obesity, overweight and demographic behavior [5], [6], [8]–[12]. As changes in the population pyramid continue to occur, higher risk factors will come into play for the population's adult members [11]. According to the International Federation for Diabetes, in 2012, it is worth mentioning that Mexico occupied sixth place worldwide in the prevalence of Diabetes Mellitus, and projections based on recent reports highlight an increase in the disease incidence. Such tendencies will increase the demand for specialized medical attention in the short, medium, and

long term and increment medical attention costs, mainly in associated complications [10]–[13].

Even if on a clinical level it is considered that there is no way to predict the presence of Diabetes accurately, and even less to cure it, what is possible is to identify risk factors and variables that could directly interfere with the possibility of a person having a disease without their knowledge [1], [2], [5], [11], [14]. It is possible to revert DM's effects in a pre-diabetic stage due to the person frequently presenting values above typical population values, although the patient may not necessarily present symptoms. However, once the diabetic state is diagnosed, the patient will require keeping close control of their illness because lack of adequate care of the disease may drastically reduce the patient's quality of life in the short or medium-term [10]–[12], [14].

About DM detection, a problem is identified. The physician determines a person's risk of acquiring Diabetes on a revision date because he/she reports evident symptoms. Hence, they only count on information that the patient recalls and the screening test's laboratory studies, which only reflect an immediate precondition [11]. The pre-diagnosis tests are designed for their application at the first contact medical attention center, such as a clinic, and they require a specific specialization for their interpretation and cabinet studies [2], [13]–[15].

Given the magnitude of the population currently at risk of having DM, it seems impossible for all patients to be monitored by a specialist; therefore, primary care contact services must count on tools that may aid them in the approach, evaluation, and treatment of a diabetic patient, as well as on deciding when they should transfer a patient to a specialist's consultation [16], [17]. There are few tools available to assist a person in knowing about their probability of acquiring Diabetes Mellitus. In Mexico, the national surveys are carried out every six years, and an overall impact of the disease is reported [14], but people only tend to go to a clinic when they are feeling ill, and in this specific case is reported that a diabetic subject could be non-diagnosed at least five or seven years. It is reported that at least 50% of DM cases are not diagnosed. Furthermore, once the patient is diagnosed, there is low adherence to follow-up revisions to prevent the consequences of this chronic disease [13], [14].

The consequences of this faulty care system are that the symptoms are often not diagnosed in the early stages of DM development, resulting in occasional or partial diagnoses that often cause the indifference of people at risk. It is why a first-contact portable tool to assist the population in getting an early warning about Diabetes Mellitus is a requirement.

Nevertheless, in the prevention strategies, a possible option is the pre-screening method, which is generally performed using ambulant awareness campaigns and questionnaires. In Mexico, Izquierdo-Valenzuela et al. proposed a survey, and after been applied, it showed the relevance of these studies to know the current local prevalence of the disease in the zone [16]. It is the most used questionnaire for DM detection for pre-screening purposes by public health providers, besides an aggressive campaign in mass media. Recently, using the Information and Communication Technology (ICT), several online questionnaires are available: the MedlinePlus website is one, or a Brown Connolly proposal, but they are directed towards the United States population [18]. Nevertheless, all these efforts show the relevance of this type of quick survey as identification of a possible predisposition or pre-diagnostic of DM.

Therefore, it is proposed that the development of a computer system based on a probabilistic model will allow individuals to know the symptoms and self-identify the risk of acquiring Diabetes, prompting a visit to their nearest medical care center, and the request for a pre-diabetic or diabetic analysis in case of a necessity.

A. Preliminary Study

All types of Diabetes Mellitus share some specific characteristics, so it is necessary to perform a previous analysis to determine the risk factors to consider. Then, the following methodology was proposed:

- To collect data and obtain different visual global representations and tendencies, all establish the viability of the probabilistic model.
- To determine the influence that each variable performs in the habitants of a delimited geographical zone's probability of getting DM and understand the impact of each. Then to generate a results table for comparing with the statistic used in the model.

Finally, the information used to propose a probabilistic model focused on DMT1 and its implementation in a system.

B. Risk Factors

A risk factor can be defined as one which increments the probability of acquiring an illness. Considering that, the higher number of risk factors associated with Diabetes Mellitus, the higher the probability of contracting the disease [3], [5], [8]. It is usual among males and females, though it occurs more regularly if the patient possesses a father, mother, or sibling affected by DMT1. Diabetes is an autoimmune disease, meaning that the body's immune system attacks the cells in charge of producing insulin in the pancreas and somatostatin, which is the hormone responsible for regulating the production and liberation of glucagon and insulin [4].

The following list contains the leading causes of this disease:

- Physical or emotional stress.
- A diet high in nitrosamines and dairy products.
- Toxins.

There are congenital conditions, meaning that they could be there from the patient's birth, having been caused by a disturbance during embryonic development, birth, or as a result of a hereditary defect. All of them are risk factors for the development of Diabetes Mellitus Type 1, and some are listed below [6], [7]–[9], [19]–[25]:

- Being born from an elderly mother.
- Being born from a mother with high artery pressure.
- Being born from a mother with a Body Mass Index (BMI) of 30 or above.
- An early introduction to baby milk formula [23].

Nowadays, there are research studies on Diabetes Mellitus Type 1 that are conducted sporadically in Mexico, and throughout the country, Mexico lacks a periodic national registry for patients suffering from DMT1. It is believed that in Mexico, more than 600 thousand people live with Diabetes Mellitus Type 1, a much smaller quantity than the people who have Diabetes Mellitus Type 2, which affects more than 17

million people, but 50% of them have not been diagnosed [11], [13], [19].

In this last case, a study recently revealed that Diabetes is usually associated with eating habits: by analyzing the Food and Agriculture Organization (FAO) Food Balance Sheets (FBA), a change in the Mexican diet could be observed. While consuming energy from cereals and legumes, such as beans, has decreased in the latest years, increased meat, dairy, vegetable fats, and sugar-high products are presented [19]. This change has been reflected in an increase of the Body Mass Index (BMI), mainly in children and teenagers [12], [23], [24].

On the other hand, a recent study by the Organization for Economic Co-operation and Development (OECD) in its program Health "at a Glance 2017" reported that approximately 15.7% of the Mexican population has DM [26], but 35% of teenagers from 12 to 19 presents obesity. The kind of Diabetes that derives from obesity is far more common in Mexico than in other nations, as the OECD's estimated mean is 1.2% of the global population.

Diabetes is not hereditary, though a person can be genetically predisposed to it. External factors such as bad eating habits and a sedentary lifestyle can increase the possibilities of it manifesting [4], [23].

An estimation of the probability of inheriting a predisposition to Diabetes is proposed as follows:

- 6% probability if the mother has DMT1.
- 25% probability if both parents have DMT1.
- 14% probability if the mother has DMT2.
- 50% probability if both parents present DMT2

In this research, we pretend to model the risk factor by using probabilistic concepts to determine, from the presence of Diabetes in family members, a person's probability of having this illness. For this purpose, an application was created based on a quick questionnaire that allows the user to know their probability of getting Diabetes Mellitus. It also explains some of the illness's causes. Besides, if a patient already has DM, the digital application provides recommendations on how to take care of themselves and control the disease.

C. Problem Analysis

Focusing on Diabetes Mellitus's impact in childhood, three main questions were proposed: Which is the principal cause of childhood diabetes? Which is state of the art about this problem? Which strategies could be implemented to spread consciousness amongst the population about this disease?

We start identifying the possible causes of developing DMT1 in children. It was reported that DMT1 could be developed in adults, but its significant incidence is in children. Science has not yet discovered with certainty what produces this illness, but it has found several factors that contribute to DM incidence. It has been found that genes play a crucial role in its development, given that DM is an autoimmune disorder, and the tendency to develop this kind of disorder can be inherited. One of the predominant causes of this condition is that the pancreas is not generating a sufficient quantity of insulin, a hormone used to control glucose levels in the blood and commonly associated with sugar consumption. Another possible cause of Diabetes could be that the liver produces an excessive amount of glucose and secrets it into the blood without being used by the body. People with Diabetes present high glucose rates in their blood, as their body is not capable of transporting said glucose from the blood towards a muscle where it can be accumulated or used as an energy source [19], [20], [21]

To raise awareness about this problem in Mexico, a series of strategies based on mass campaigns that reach its target audience throughout the Mexican media were implemented. Many of these campaigns are currently carried out, such as "PrevenIMMS" [27] that was later complemented with "Chécate, Mídete, Muévete" (check, measure and move) and "Métete en cintura" (measure your waist) [27], [28], which were promoted by the Health and Public Health Services Secretariat. They have to face problems such as for overweight and obesity, so they aim at educating, monitoring, and promoting exercise because these factors are closely related to the prevention of Diabetes Mellitus Type 2 and cardiovascular health issues, which are both the first causes of death in Mexico City. Regarding Diabetes Mellitus Type 1, both diet and lifestyle are key factors that can increase this illness's probability. In both types of Diabetes Mellitus, the mother and the child's overweight are relevant [19]–[22].

On the other hand, as a response to the obesity problem related to the Mexican diet, the government has promoted several policies to improve this health problem. Recently a specific tax has been added to sugared drinks, the placement of labels with nutritional information on food products was made mandatory, and food advertised towards children has also seen new regulations. In 2012, a survey showed decreased children's overweight incidence compared to 2006 (7.1%), which went down to 3.6%, and the average glucose concentration on an empty stomach. Therefore, the growth rate of the prevalence of Diabetes is expected to decrease in the long term [18].

After implementing sugary drinks taxes, the purchase decreased by 5.5% in the first year and 9.7% in the second year. However, it was the most impoverished population, which significantly reduced their consumption, and they are also the most affected by any tax increases [24]. Reducing obesity requires more than one preventive action since only a real conscious change in health care will be achieved by implementing wide-ranging strategies addressing multiple health determinants simultaneously [24].

Regardless of the preventive efforts and detection and lifestyle campaigns with diet and exercise plans of the health services, it is crucial to reinforce these actions with systems that allow the self-identification of symptoms or risks so that the population can reach out to their first-contact health provider as soon as possible [10].

II. Materials and Methods

The definition of the probabilities was made using a deductive method combined with a perception survey in a random sample. It asked about the participant's knowledge of the risk factors related to Diabetes Mellitus. Then, the probabilities were set, and the model was proposed. This algorithm with a questionnaire was implemented into a mobile application. The procedure is shown in Figure 1 below.

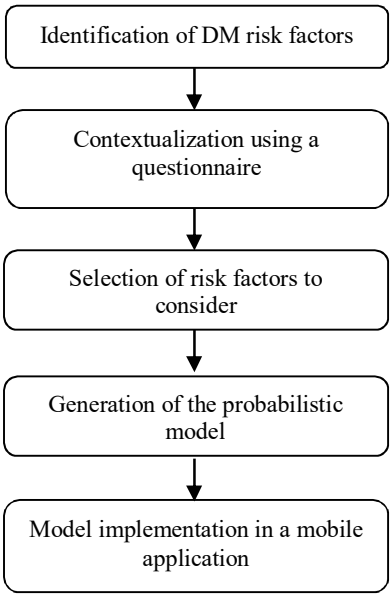

Fig. 1 Flowchart of the methodology research

1) Step 1: Identification of Diabetes' risk factor: In this stage, an in-deep analysis of the public health report and papers about the factors related to Diabetes Mellitus types were made. The results are presented in Section II, and they support the probabilistic model.

2) Step 2: Contextualization using a questionnaire: A questionnaire was designed to identify the knowledge of the risk factor associated with the Mexican population. The survey was applied to a random sample of 50 students ranging from 18 to 30 years old. The participants were invited to answer the questionnaire in a digital form. The questions and description of the results are reported in Section IV.

3) Step 3: Selection of risk factors to be considered: After the identification of the main misunderstanding of the risk factors or not mentioned in the answers, and a comparison with that proposed by the consulted papers, a set of risk factors were selected that did not require a clinical examination, but could be considered as warnings symptoms that should be considered by the participant to mention to the doctor at the next appointment.

4) Step 4. Generation of the probabilistic model: The probabilities definition followed the statistics mentioned in the 2019 Mexico public health reports or on an average of other countries when the data was not found [25]. A probabilistic model was proposed based on these results and the relationship among the risk factor considered in the revision about initial Diabetes Mellitus symptoms and risk factors.

5) Step 5. Model implementation in a mobile application: Finally, the survey and the model were inserted into a mobile application. This implementation is going to use the probabilistic model to give some general advice or further information.

III. Results and Discussion

A. Perception Survey

The questions can be seen in Table I. After that, a probabilistic model was built and tested in a mobile application.

TABLE I
SURVEY TO DETERMINE RELEVANT FACTORS

Question		Answers
1.	Did you know that Mexico is the first world place in the incidence of Diabetes?	Yes/No
2.	Did you have any family member, friend, or acquaintance with Diabetes?	Yes/No
3.	Do you know what Diabetes is?	Yes/No
4.	If your answer is yes in the previous question, then give a short explanation	Open
5.	Do you know which are the main symptoms?	Yes/No
6.	If your answer was yes, please name one of them	Open
7.	Do you know there are different types of Diabetes	Yes/No
8.	Do you know what Diabetes Mellitus Type 1 is?	Yes/No
9.	If your answer was yes, please explained shortly	Open
10.	Do you know how to live with Diabetes?	Yes/No
11.	If you were to suspect having Diabetes, would you go to your health provider	Yes/No

B. Survey results

The 50 answers were analyzed; fifty-eight percent of the interviewed people had the notion that Mexico is the first place in population with Diabetes Mellitus. It is noticed that the population has received the message from the awareness campaigns; see Figure 2. The fact that Mexico is the country with the largest diabetic population can be reflected in this question: 39 people out of 50, almost 80%, have a family member, friend, or acquaintance who has some Diabetes.

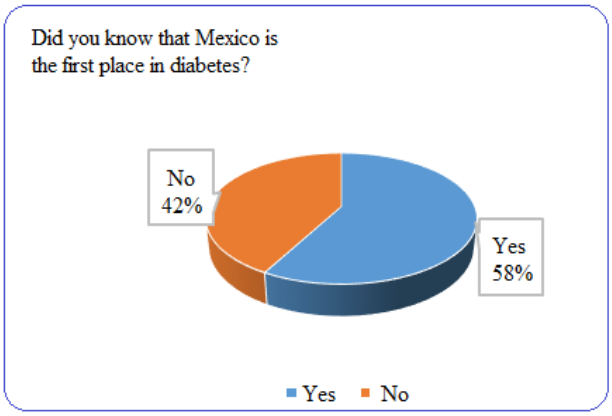

Fig. 2 Results of question 1 (percentages)

Analyzing the people's answers about Diabetes Mellitus definition, it can be noted that sixty-six percent answered that they know or have a notion of DM; this result reinforces our perception that the educational campaigns have a positive impact (Fig. 3).

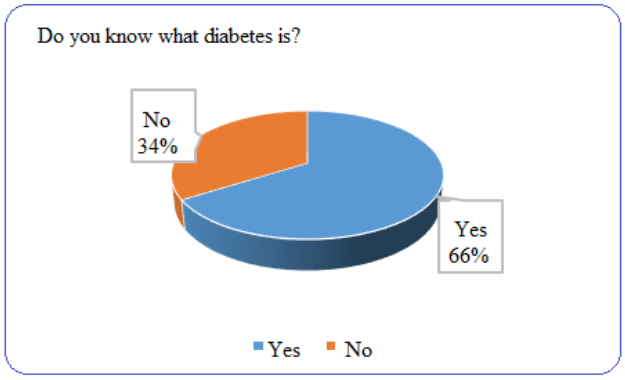

Fig. 3 Results from question 3

Table II shows the answers from the 33 people who said they knew or had an idea of what Diabetes is.

TABLE II
EXPLANATION OF WHAT DIABETES IS FROM THE SURVEY

Question 3: What is Diabetes?	
It is a disease about sugar excess in the blood	A pancreatic problem
It is when one has a high level of sugar in the blood	When someone has a high sugar level in their blood
Sickness in which the body cannot regulate the quantity of sugar in the blood	One has too much glucose in the blood, and the body cannot spread it all over the body
When you have a high level of glucose in the blood, and the body cannot expel all of the excess	Sugar excess in the blood
It is a problem of sugar in the organism	The pancreas cannot produce enough insulin
It is the presence of high sugar in the organism	The body has high levels of sugar or glucose, and the body cannot distribute large quantities
It is when one has a high level of glucose in the blood and not enough insulin to control the glucose levels.	Too much sugar in the blood
It is when one has a high level of sugar in the blood	Sugar excess in the blood
It is a problem of the organism which fails in controlling the presence or absence of insulin	Diabetes is when one has high levels of glucose in the blood
When in the body, there is a high level of sugar in the blood	The pancreas fails to control the insulin
A chronic condition in which the liver does not produce enough insulin	Sugar in the blood
Illness in which the glucose levels are too high	Diabetes is a sickness in which the body presents high sugar levels in the blood and does not have enough insulin to control these levels of sugar in the blood
Problems with insulin production	Fail of the pancreas to generate an insulin
It is a sickness that is produced by a lack of insulin.	It is a problem with sugar excess in the body.
A high concentration of sugar in the body	

After analyzing them, these were very close to a vague but correct explanation of what Diabetes is. In general, the term sugar is considered a synonym of glucose. The definition to which one could reach with these answers would be "diabetes is a problem generally caused by the lack of insulin in the body generated by the pancreas, which leads to an excess of glucose in the blood." In contrast, the definition that has been taken from the National Institute of Diabetes and Digestive and Kidney diseases website [29] for Diabetes Mellitus is: "A disease which presents itself when the glucose level in the blood is too high. Blood glucose is the main energy source and comes from food. Insulin, a hormone produced by the pancreas, helps glucose enter the cells to be used as energy. However, when the body does not produce enough or any insulin or does not use it adequately, glucose remains in the blood and does not arrive at the cells".

On the other hand, only 18 out of the 50 participants considered that they know about the main symptoms of Diabetes Mellitus (Fig. 4).

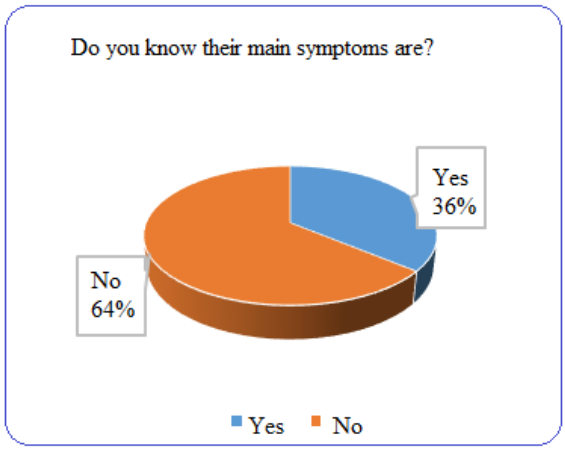

Fig. 4 Percentages of answers from question 5

In Table III, the symptoms identified by the surveyed can be read; they answered that the main symptoms of DM might be fatigue, thirst, and a constant need for using the toilet. Another relevant symptom reported is a remarkable weight loss; this last one could be mentioned because this disease is generally presented in overweight or obese people.

TABLE III
SYMPTOMS ABOUT OF DIABETES

Question 5: Do you know which are the main symptoms?	
Diabetes is characterized by the desire to consume sweets and much thirst	
Tiredness, weight loss.	
Fatigue, constant peeing and weight loss	Lack of appetite
Excessive hunger and headaches	
Slimming down, continually going to the bathroom, dry skin	Excessive Thirst, hyper and hypo-glycemia symptoms
Thirst, Constant need to use the toilet, sometimes a tired body	Tiredness and weight loss
Much thirst, being tired, weight loss	Much thirst and peeing
The person wishes to drink a lot of water, headaches and urinate a lot.	Thirst, Going to frequently to the restroom, hunger, tiredness, blurry vision
Fatigue, thirst, hunger	A lot of thirst and headaches

Without knowing the most common symptoms present when someone has Diabetes Mellitus, it is almost impossible to identify it and look for adequate treatment as soon as possible. The classic symptoms are polyuria, polydipsia, polyphagia, and unexplained weight loss, as well as a before-breakfast glucose reading superior or equal to 126 mg/dL and blood glucose equal or superior to 200 mg/dL [3], [5]. Moreover, in the US Department of Health webpage [17], the symptoms are shown subdivided by type of DM:

- Type 1: Constant necessity of urinating, unusual thirst, extreme hunger, unusual weight loss, extreme fatigue, and irritability.
- Type 2: Any of the Diabetes Mellitus Type 1 symptoms, plus frequent infections, blurry vision, cuts/bruises that take time to heal, tingling or numbness in hands or feet, recurrent infections in the skin, gums, or bladder.

Besides, Diabetes Mellitus also could be considered asymptomatic, and its identification is made through blood glucose levels, which is why medical control during pregnancy is so important, and random screening tests are recommended. Analyzing the answers, participants agree with the symptoms reported in both references, but almost nobody reported differences among DM types.

According to the previous answer, 28 out of the 50 participants did not know there are different types of Diabetes (Fig. 5). As it has been previously described, these types of Diabetes are Diabetes Mellitus Type 1, when the pancreas fails to produce insulin; Diabetes Mellitus Type 2, in which the body does not produce enough insulin or makes inefficient use of it; and Gestational Diabetes, which women suffer during pregnancy and, in most cases, disappears after the baby is born.

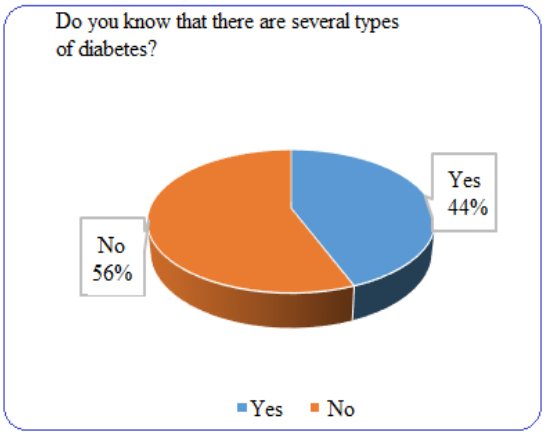

Fig. 5 Percentages of answers to question 6

There are other types of less common Diabetes Mellitus, like Monogenic Diabetes, which is hereditary, and Diabetes Mellitus, which is related to cystic fibrosis. In Figure 6, five participants knew or had an idea about DMT1, and in Table IV, given answers are presented. DMT1 is generally associated with immune problems, which destroy pancreatic β cells that produce insulin [21]. Even if it has been historically associated with children and teenagers, there is an increasing incidence in the latter days. The answers reflect the myths associated with DMT1, but they are according to the definition.

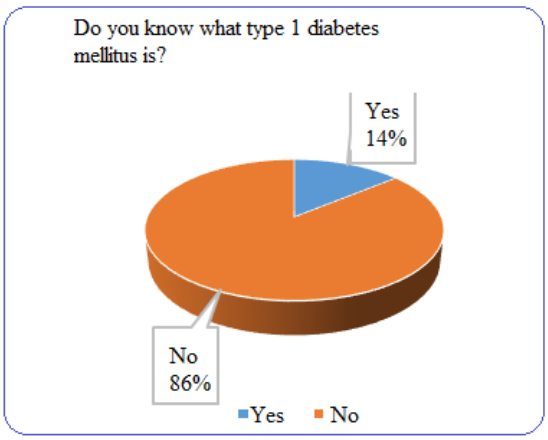

Fig. 6 Answers to question 7

TABLE IV
ANSWERS ABOUT THE IDENTIFICATION OF DIABETES MELLITUS TYPE 1

Answers to question 8	
It is when the pancreas cannot produce enough insulin in the body, and so there is a high presence of glucose in the blood.	It is when the pancreas produces little or no insulin.
Diabetes in the kids	The one that you start using the medicine before daily shots
Affects the pancreas, producing little or no insulin for the organism	

In contrast with the nearly 80% of the participant who knows someone with Diabetes Mellitus, 75% did not know how it is treated or followed up, or how to take care of patients and what diet they should follow (Fig. 7).

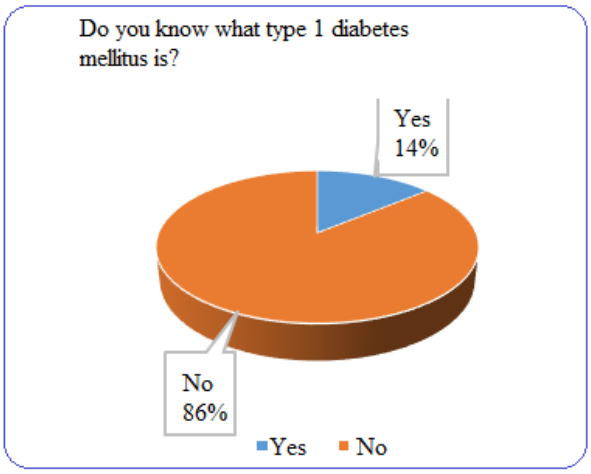

Fig. 7 Answers from question 8

If the participant suspects that they could have Diabetes, he/she will seek medical attention for preventing or being clinically diagnosed. The results are summarized in Figure 8.

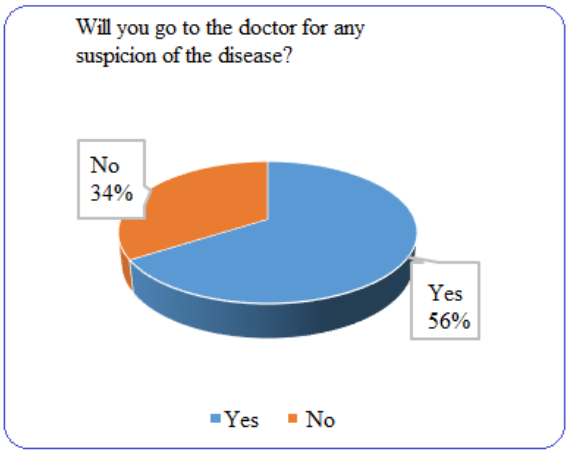

Fig. 8 Answers from question 11

C. Relevant Risk Factors

What are we referring to when we speak of a risk factor? "One can define a risk factor as a feature or exposure of an individual who could increase their probability of having an illness or injury [30]". It is estimated that everyone has a 0.4% probability of developing DMT1, and 11% suffer from DMT2. Moreover, it is added to every person's genetic history, as every patient inherits risk factors from both parents. These risk factors are prevalent in Caucasian people, who have an increased probability of having DMT1. Furthermore, It has also been reported that one of these disease's triggers is cold weather because DMT1 occurs more frequently in autumn and winter than in summer and cold climates [31].

Diet is also a significant risk factor during a person's first months of life, as Diabetes Mellitus Type 1 is less frequent in people who were breastfed and had solid food introduced at a later age [23]. Thirst is also frequently confused with hunger, which leads the person to eat instead of drinking water and elevates the body's demand for insulin, increasing the risk factor. A simple solution to this problem would be to drink water (without added sugars or flavors) and keeping a healthy diet.

In many people, the development of DMT1 can take several years to show the first symptoms [3], [7], [22]. However, there is an increased incidence between 5 and 7 years of age and during the first teenage years [21], [31]. It is essential to keep in mind that DM is often associated with overweight, and it is estimated that, for every extra kilogram, the risk of presenting any type of DM is increased by 16%. Furthermore, in DMT1, diet is not the main factor once it has been detected.

The lifestyle that could lead to this specific kind of Diabetes needs further research. It is estimated that 5-15% of adults who suffer DMT2 could have had DMT1 with damaged cell isles. If this was the case, up to 50% of the DMT1 cases have been misdiagnosed as Type 2, implying an underestimated prevalence [31], [32]. The most recent strategies promote screening studies with clinical tests in public health services, and it has allowed the identification of an increment of DMT1 cases [4], [11].

D. Probabilistic Model

A mobile application was implemented to evaluate the survey's responses and the analysis of the state-of-the-art diagnosis, screening, and pre-screening of DM to return the probability of developing Diabetes Mellitus based on identifying risk factors. This software sums up the pondered answers and computes the user's risk percentage, and then it provides guidelines according to the results. If a user's percentage is over a threshold value, they are recommended to visit their healthcare center as soon as possible.

In Table V, the probabilities associated with the symptoms are presented. They have been gathered by analyzing previous scientific research, though it is important to note that the reported values do not always match the reports. They may vary according to the year, geographical zone, and age range. The values proposed are an estimation focused on DMT1 because it has shown an increment in cases prevalence even in young adults. DMT2 cases could also use this mobile application because both types of DM shared several symptoms, as was previously discussed.

TABLE V
VARIABLES CONSIDERED FOR SYSTEM DEVELOPMENT.

Identifiers and variables	Probability
Without family background (G1)	0.04%
Father with DMT1 (G2)	6%
Mother with DMT1 developed after 11 years old and have given birth after 25 (G3)	4%
Mother with DMT1 developed after 11 years old and have given birth before 25 (G4)	1%
Mother with DMT1 developed before 11 years old and have given birth before 25 (G5)	8%
Mother with DMT1 developed before 11 years old and have given birth after 25 (G6)	2%
Both parents were diagnosed with DMT1 (G7)	10-25%
Monozygotic twin diagnosed with DM (G8)	50%
Diagnosed sibling (G9)	6%
Diagnosed dizygotic twin (G10)	8%
Born by caesarian section (C)	20%

A probabilistic model was proposed from the data obtained from the survey, and it was necessary to analyze each of the events to determine whether they are dependent or independent. Another factor to consider is if there are events that are mutually inclusive or exclusive. The previous studies showed that genetic predisposition is the most crucial factor for the development of DM. We will define whether mutually inclusive events exist in the events G1 to G10 or not. The event G1 that considers no family background is mutually exclusive with events G2 to G10 because if there is no family backstory, none of these events could happen simultaneously. Another set of mutual events are events G3 to G6, for the circumstances in each of them are very specific. Consider the following events:

G1 – No background - 0.04%.
G2 – Father - 6%
G3 - Mother, $d > 11$, $p < 25$ - 4%
G4 - Mother, $d > 11$, $p > 25$ - 1%
G5 - Mother, $d < 11$, $p < 25$ - 8%
G6 - Mother, $d < 11$, $p > 25$ - 2%
G7 – Both parents diagnosed, max=25%, min 10%
G8 – Monozygotic twin - 50%
G9 - Sibling - 6%
G10 – Dizygotic twin - 8%
C – Born by cesarean section - 20%

For which we will have the following mutually exclusive events, which has been considered in the probabilistic model:

G3, G4, G5 y G6 $G36=\{G3 \cap G4 \cap G5 \cap G6\}=\emptyset$ (1)

$$\{G2 \cap G3 \cap G4 \cap G5 \cap G6 \cap G7\}=\emptyset \quad (2)$$

$$G810=\{G8 \cap G10\}=\emptyset \quad (3)$$

Then, Not

$$(G1) \cap (G2 \cup G36 \cup G7 \cup G810 \cup G9) \quad (4)$$

The model's rules include the case of mutually inclusive events (Equation 5).

$$P(A \cup B)= P(A)+P(B)-P(A \cap B) \quad (5)$$

Furthermore, mutually exclusive event relations are presented in equations 6 and 7.

$$P(A \cup B)= P(A)+P(B) \quad (6)$$

$$P(A \cap B)= \emptyset \quad (7)$$

In the case of independent events, the criteria were defined in Equations 8 to 10.

$$P(A|B)=P(A) \quad (8)$$

$$P(B|A)=P(B) \quad (9)$$

$$P(A \cap B)= P(A)P(B) \quad (10)$$

Otherwise, the conditional probability is defined by Equation 11.

$$P(A|B)=P(A \cap B)/ P(B) \quad (11)$$

If G is a genetics event and P(G) is the probability associated with these genetic aspects (G1-G10); then p stands for Parents and P(p) is the probability of parents' disease, and Siblings are presented as h, with P(h) as the probability of siblings' disease (G7-G10).

We will first obtain P(G), each person's probability based on their family background. This probability will be given in two cases, without background (Equation 12) and with a background (Equation 13).

$$P(G)=P(G1) \quad (12)$$

Or

$$P(G)=P(p \cup h) \quad (13)$$

The probability of having DM because the parents have DM P(p) is defined according to Equations 14 to 17.

Case 1: The father is the only one with DM.

$$P(p)=P(G2) \quad (14)$$

Case 2: The mother is the only one with DM, with a *d* time since it was diagnosed, defined into $G3 \leq Gn \leq G6$. So

$$P(p)=P(Gn) \quad (15)$$

Case 3: Both parents, according to the probabilities of G36 mention in Eq.1, considering G2 and G7 and using Equation 6.

$$P(p)=P(G7) = [(P(G2) \cup P(Gn)] \quad (16)$$

If independent probabilities of each parent are increased, then the total impact in G7 is increased. Then, considering a maximum of 25% and a minimum of 10% for G7, a range of 15% varies according to G2 and Gn. On the other hand, the mother impact range is from 0% to 8%, so its relative impact is P(Gn)*15/8 %

Case 4: In the case that both parents have DMT1 in specific, then the probability of the child to have DM Type I increases from 10 % to 20 %, so, an initial probability of 10% was proposed, and the factors associated with the parents' condition, as defined by the following expression:

$$P(p)= 10\%+ P(G7) = 10\% + [(P(G2) + 15/8*P(Gn)] \quad (17)$$

Case 5: In another case

$$P(p)=0 \quad (18)$$

In siblings with DM, the following events are considered independent of the parents' condition. Therefore, the following rules are proposed:

Case1: Monozygotic Twin

$$P(h)=P(G8) \quad (19)$$

Case 2: Dizygotic twin

$$P(h)=P(G10) \quad (20)$$

Case 3: Sibling with DM, but not twin.

$$P(h)=P(G9) \quad (21)$$

Case 4: Siblings and twin diagnosed with DM.

$$P(h)=P(G9 \cup Gm), \text{ with } G8 \leq Gm \leq G10 \quad (22)$$

Another case

$$P(h)=0$$

Now, it is computed the joint probability associated with having a mother and a sibling with DM. So, considering G9 and Gn independent,

$$P(G9 \cup Gn) = P(G9) + P(Gn) - P(G9)*P(Gn) \text{ with } 3<n<6 \quad (23)$$

It is essential to consider that p and h are not mutually exclusive, which gives:

$$P(G) = P(p \cup h)$$

$$P(G) = P(p) + P(h) - P(p \cap h) \quad (24)$$

By considering independent the events corresponding to parents (p) and children (h), shows that.

$$P(p \cap h)=P(p)*P(h) \quad (25)$$

Eq. 25 in Eq. 24 was substituted and defined as the probability of presenting DM due to genetic reasons.

$$P(G) = P(p) + P(h) - P(p)*P(h) \quad (26)$$

Once the genetic probability has been calculated, it is included in the birth condition. P(d) is defined as the probability of developing DMT1, and finally, P(DM) has two cases:

Case 1: Natural Birth

$$P(DM)=P(G) \quad (27)$$

Case 2: Caesarean birth

$$P(DM)=P(G)+P(C) \quad (28)$$

E. Model implementation

The model's implementation through a mobile application that will be available as a web service will enable them to learn about their probabilities of developing Diabetes Mellitus based on this initial proposition. This pre-screening test is intended for awareness mainly about the incidence of DMT1.

To facilitate access to this tool, ICT was used. Nowadays, any intelligent device has a browser to access the internet, and practically all web browsers support the standard HTML language, JavaScript, and CSS. NodeJS is used to provide scalability to the page about the server, so in a future pilot test, it could include the rest of the characteristics associated with Diabetes Mellitus in case it is required or obtained. The test structure is composed of multiple-choice, closed questions to prevent erroneous entries. In this first stage, the questionnaire was designed to be quick to apply. The tool consists of a client-server architecture, as shown in Figure 9.

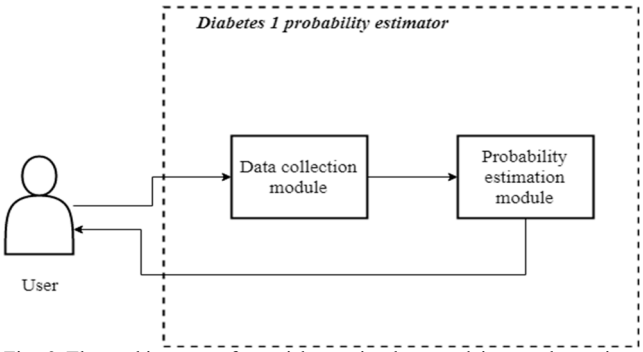

Fig. 9 The architecture of a quick test implemented in a web service. It provides the risk of having DMT1

As is appreciated in Fig. 10, the test consists of seven fields that have questions in a simple language. In this way, most of the users will be able to answer it correctly. Once the questionnaire is completed, the user's responses are sent to the server to calculate the probability of having DM, so it uses the processing task to the server and not to the user's device's resources.

Mutually exclusive events are evaluated in the server's algorithm so that even if the user tried to avoid mutual exclusion, the algorithm would validate the condition. At the end of the questionnaire, the user must press the "Get my score" button to access their probability of presenting DMT1.

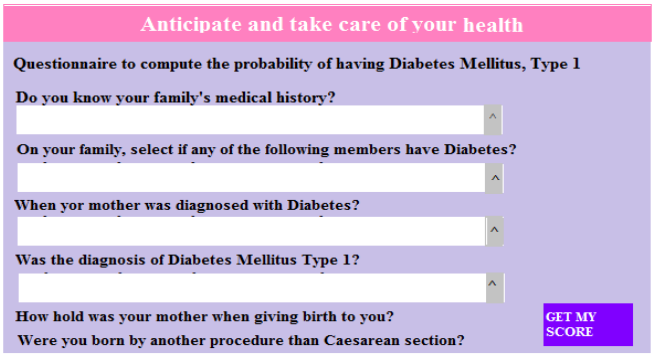

Fig. 10 Questionnaire

An example is shown in Figure 11. The probability percentage is shown on the screen with a button that allows going back to the questionnaire.

Fig. 11 Display of the user's result

Most of the participants in our test group know or have heard about Diabetes Mellitus, but not all of them know many fundamental aspects of this disease that significantly affects both the Mexican economy and society. By occupying fourth place globally, 42% of the respondents' group not knowing this fact led to better dimension the impact of Diabetes in Mexico.

A lack of knowledge in fundamental aspects was perceived that could represent a risk factor, beginning with the fact that 34 percent of the surveyed did not have an idea of what Diabetes is, and only a few knew how to lead a healthy lifestyle if they already have DM, or what it is like to live with it. Furthermore, 64% cannot identify the main symptoms, which is why they could be experiencing some of them and not suspecting that they might be ill. Even so, it is a good sign that 66% would be willing to approach a medical expert if they suspected they had DM.

Nowadays, ICT permits influencing faster and with broader coverage, especially with quick surveys, which is why a health policy guideline goes in that direction. These actions include providing more information via educational media campaigns to identify the early symptoms and be warned about unnoticed DM until it arrives at a stage where it is chronic and irreversible. Also, educational centers could use this program to evaluate their students' knowledge about DM and its symptoms or risk factors.

Another risk factor to consider is the hereditary one, and even if Diabetes as an illness is not entirely hereditary, having close relatives who present it has a high impact on the probability of a person developing it. In the survey, 78% of the people said they had a family member who had or had DM and other risk factors such as diet, physical activity, and general lifestyle.

In the case of pre-diabetics, it is necessary to determine the risk of having DM. So, the American Association for Diabetes implemented an ICT tool that allows the general population to know DMT2, self-evaluates their risks of contracting it, and provides information about control and follow-up methods for the diabetic patient. For this purpose, they use a digital questionnaire based on the Bang et al. work, which is focused on the North American population with at least 20 years of age [17], [33]. However, it has been reported that Diabetes Mellitus Type 1 has two main prevalence age ranges: between 4 and 6 years, and from 14 to 17 years, so these surveys could not be detecting DMT1, so this work is intended to provide a quick test focused in DMT1 [34].

This paper does not consider all the possible variables that can influence the development of DM, such as geographical zone, ethnic origins, specific genes test, skin tone, or virus that could increment the probability of contracting this disease due to this information not yet being statistically quantified to be

able to apply it in a probabilistic model. However, the tool was designed in a modular structure, so an update could be made once new data is obtained.

IV. Conclusion

The proposed mobile computer system based on a probabilistic model will allow individuals to know the symptoms and self-identify the risk of acquiring Diabetes, prompting a visit to their nearest medical care center and requesting a pre-diabetic or diabetic analysis in case of it being necessary. The fact that Mexico is in fourth place in the list of countries with most cases of DM is due to the lack of knowledge of the patients, poor diet habits, and hereditary effects. Besides, the proposed mobile computer system could be a useful tool in health prevention strategies applied in a broad sample to glimpse the current situation in the general population more quickly. In future work, the mobile application could be upgraded or reinforced because of its modular structure.

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