Challenges in Nutrition Education using Smart Sensors and Personalized Tools for Prevention and Control of Type 2 Diabetes

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***Abstract*—The incidence of type 2 diabetes is increasing throughout the world. For the first time in the history, there are 422 million diabetes patients, according to the World Health Organization (WHO) [1]. Medical records currently account for 350 million obese people in the world with more than half of European Union citizens being obese or overweight and with/or without the risk of developing diabetes. In the past 30 years, the number of diabetic individuals has tripled, all over the world, including Romania. We have developed an Intelligent System using Smart Sensors and constructed a Personalized Diet and education principles to improve health and quality of life for normal and type 2 diabetic patients.**

Keywords—Challenges in Nutrition Education, Prevention, Smart Sensors, Personalized Tools, Type 2 Diabetes (T2D)

I. INTRODUCTION: DIABETES-KEY FACTS

The contemporary world is suffering from most silent but griming health related issues [1]. The World Health Organization has projected very serious statistics on global health status. According to WHO [1], approximately one billion individuals are deprived of health care services worldwide, and 36 million deaths are due to the noncommunicable/ communicable diseases which includes cardiovascular disorders, cancer, diabetes, etc. The number of people with diabetes has grown from 108 million in 1980 to 422 million in 2014 [1]. Almost half of all deaths attributable to high blood glucose occur before the age of 70 years. WHO estimates that diabetes will be the seventh leading cause of death in 2030 [1]. Diabetes can be controlled and its effects prevented or delayed with proper diet, physical activity, medication and regular screening and treatment for its complications [2], [3].

The whole world is experiencing a type 2 diabetes (T2D) pandemic, due to westernized lifestyles, population aging, urbanization, resulting in changes in diet, adoption of a sedentary lifestyle and the development of obesity. The T2D prevalence differs significantly depending on the studied population, age, gender, socio-economic status and lifestyle. The predictions for 2025 are worrying, and according to WHO estimates, T2D prevalence will reach 9% [1]. An important element, which has led to an increase in the incidence of the disease in recent years, was the closer monitoring of the population and the improvement of diagnostic methods. However, there are at least 30% of cases with undiagnosed T2D. T2D accounts for 80-90% of all cases of diabetes and is more common in overweight or obese people. There are studies showing that at the time of diagnosis, more than half of the patients had one or more chronic complications of diabetes: hypertension, stroke, retinopathy. Diabetes mellitus is associated with a large number of chronic complications whose end result is reduced quality of life and premature mortality. Early diagnosis and treatment is the proposed strategy to minimize these effects.

II. E/M-HEALTH AND ITC CHALLENGES

Monitoring unhealthy people is one of the great challenges of modern society, especially as the number of active people who work and generate income in the public system is decreasing and the inactive population is growing. Life expectancy of older people has also increased due to the positive evolution of technology that has found increasingly effective solutions for treating chronic and specific diseases. For this reason, effective solutions are sought out to monitor and improve the lives of inactive people, reducing both the costs and the number of people involved in these processes. The ideal situation would be for people at risk to have their own tools to effectively control the illnesses they suffer and to live independently.

European Union member states collectively spend close to €4 billion on health care [4] and by 2025 more than 20% of Europeans will be 65 or older, with many in ill health and dependent on the work of others [4]. A great challenge is the finding of intelligent solutions to prevent and combat obesity, such as wireless sensors and intelligent systems that use both concepts: the e-health, m-Health and telemedicine applications. Several studies [4] - [16] present some applications of e / m-Health tools in patients with diabetes. Innovative digital technology of the type presented in the above articles eliminates the gap between patients who have difficulty traveling and extends access to high-quality medical services.

Type 2 diabetes usually occurs in obese people, so the first measure that can be taken is weight loss. This can be achieved through diet and physical activity. Regular exercises are very important because, when combined with caloric restriction, it helps to lose weight but also it lowers the blood sugar levels.

Therefore, monitoring diets and a personalized physical program are important for prevention and controlling of type 2 diabetes. The mobile applications, cloud technology and connected devices converge to create a new Artificial Intelligence that optimizes Diabetes and Pre-Diabetes Management [4]-[9]. There are numerous systems for diabetic patients, including SuperTracker^{TM} [12] that helps planning and monitoring diet compositon. SuperTracker^{TM} program [3] is available online and can be used free of charge from any digital media and represents a good educational tool that can be used by patients with diabetes (see example below).

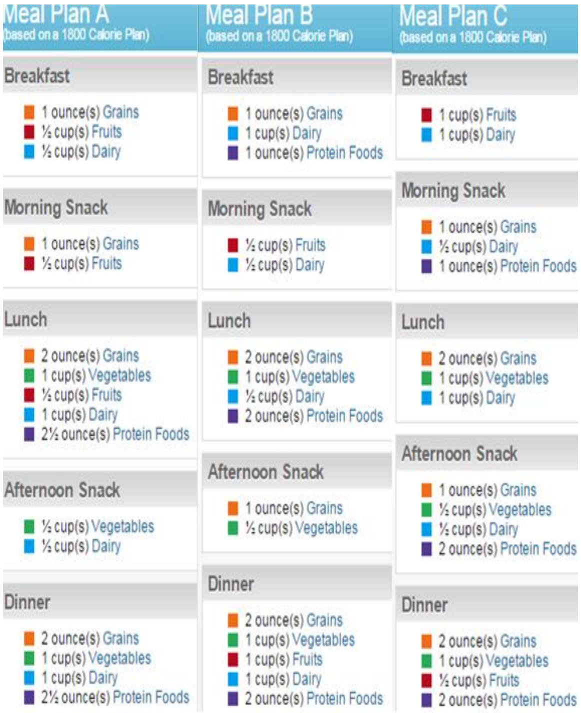


Fig. 1. SuperTracker^{TM} User Interface. Meal Plans. *(figure caption) [12]*

In addition to dietary monitoring, SuperTracker^{TM} users can also track physical activity, body weight, compare the vitamin and mineral content of over 8,000 foods, and eventually become more responsible and more determined to live up to a balanced diet (Figure 1). Through this tool, individuals have the opportunity to monitor their diet and implicitly the intake of macro and micro nutrients (vitamins and minerals), by comparing their intake with the RDD (recommended daily dose) for each of them and the percentage by which this requirement was covered by the diet.

III. Intelligent Health Care System for Patients with Diabetes

Telemedicine is the delivery of general and specialty m/e-clinical services to remote area, using Information and Communication Technologies (ICT) and networking. In recent years, due to the high demand for intelligent health services, researchers have focused on developing electronic health systems such as e-Health or m-Health systems. There have been developed also many wireless e-Health systems [10]-[16]. Also, over the past 10 years, many researches have been focused to developing connected wearable devices in order to improve health care delivery. Health care providers have increasingly become connected through the use of smart portable devices. A goal in fields such as Information and Communication Technologies and Internet of Things is to develop additional connectivity to improve not only communications between healthcare providers and patients but also real-time monitoring of patients' health [16].

An Intelligent System was designed for monitoring, alerting, reminding and evaluation of patients as well as storage, access and retrieval of medical and personal data for establishing treatment (Figure 3). This system offers users (patients or physicians) customized dietary plans, rehabilitation information and lifestyle information tailored to the needs of each individual, using intelligent sensors. The proposed system (INSPIRED) combines information about the patient's medical history, clinical examinations, anthropometric measurements (for example, using the KinectTM sensor for measuring abdominal circumference, arms and legs for obese patients), biochemical data or other medical tests and an algorithm capable of developing a personalized diet adapted to the type of diabetes, nutritional status and illness [11]. The TWR-K53 kit provided by Freescale is used to develop an application for patient monitoring. The applications presented can be used to monitor people with type 2 diabetes at their home and data can be viewed on a local computer or transmitted to a server using the Ethernet interface. The ZigBee wireless module is used when the network cable is not available or when the medical device has to be mobile in a coverage area. This platform provides hardware and software support in order to understand the functioning of representative medical applications and the development of customized monitoring applications. The Kinetis K50 families of microcontrollers (MCUs) have the ARM Cortex M-4 core and can be used to acquire patient medical data. After programming, it results a prototype of medical application, which can then be loaded into a miniaturized microcontroller and used to remotely monitor patients or for diagnosis.

The Sensors board is connected to the microcontroller via the Medical Connector interface and provides specific facilities for developing medical applications. So the MEDEKG module can be connected to the tower system to obtain an electrocardiogram signal and measure the heart rate. The system features sensors for Pulse Oximeter, Thermometer, Accelerometer, Electronic Weighing and Glucometer. It has been developed additional real-time data analysis functions of alert and patient assistive functions that help them to not overcome the safety values of arterial blood pressure or glucose during the day time and also during the sleep. Additional implemented functions are: monitoring the evolution of a fever or an imminent diabetic coma by oscillation between the minimum and maximum of the blood glucose values and detecting a fall using the Kinect^{TM} accelerometer.

This system can collect data from connected sensors depending on what needs to be monitored. Data can be transmitted via USB, Bluetooth or WiFi, to a local computer, cloud server or mobile phone. Cloud computing is a new concept used in information technology which provides flexible hardware and software resources as well as automated services using the local network or the internet. The data can be acquired simultaneously from multiple locations due to Cloud system high processing capability and the high speed of the communication network. The Cloud infrastructure allows the creation of optimized medical services to improve the interaction between patients, hospitals, emergency services, and doctors. Biomedical data are collected from patients at or outside the home and are automatically entered into the database of the distributed system [15]. An important aspect is the analysis of real-time monitoring data.

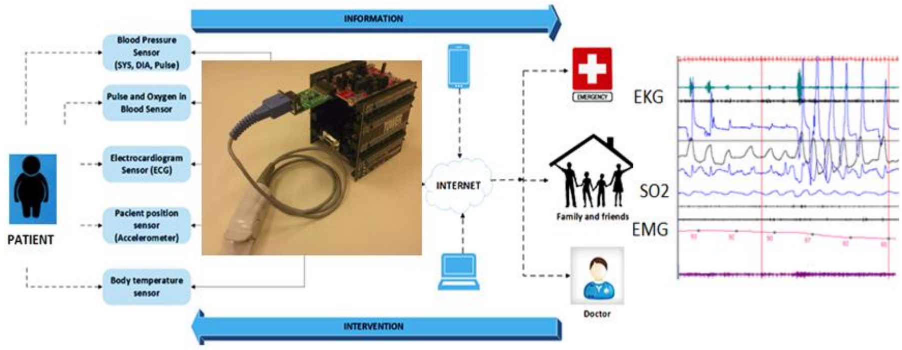


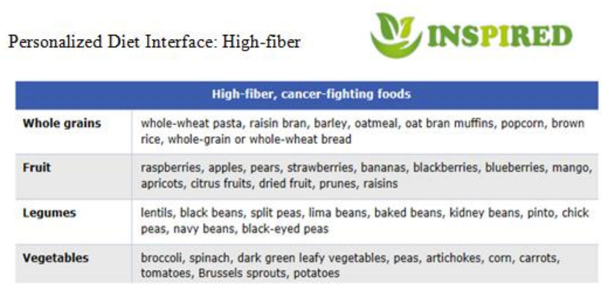
Fig. 2. The architecture of the INSPIRED System – a home health platform based on K53 Tower System for in-home monitoring of Type 2 Diabetes Patients

In previous research [13]-[15], a health care system for monitoring patients at risk in a smart environment was proposed, using an ICT-based solution. Here, we refer in particular to the obese patient or to the diabetes type 2 patients. A topic that raises a lot of questions and controversies in these patients is nutrition prior, during and after treatment.

The proposed system may be useful in monitoring the user's activity to prevent possible injuries or illnesses of at-risk persons. Patients can be evaluated and tracked in the recovery process. The TOWER system includes the acquisition modules: EKG, Pulse Oximeter, Thermometer, Spirometer, Accelerometer, Electronic Scale, Glucometer and Tensiometer. The proposed system can be easily used at the patient's home so that he/she can avoid the fear of a doctor's white gown and the data acquisition can be as close to reality as possible. In the case of patients with type 2 diabetes who are also obese, panic attacks and sudden increases in blood pressure can be prevented by continuous monitoring of pulse and blood pressure.

For some patients, an extended Holter tensiometer was used and automated measurements were performed every 60 minutes. Patients with type 2 diabetes have been monitored for 24 hours. It was found that the administered antihypertensive drug had an effect but only for a period of about 6-10 hours, after which the Arterial Tension (AT) increased again and decreased when the subjects fell asleep or relaxed. This experiment confirmed that the AT systolic values 160-165 mmHg are real and not emotionally induced, instead the prescribed treatment has no effect throughout the day. Both the patient and the doctor could check how the medicine works. Because of physical effort, many liquids or salt foods can alter blood pressure, but also patients have been asked to write down these data in a diary. Patients may also experience symptoms of hypoglycaemia, this being the most common side effect of oral hypoglycemic or insulin therapy.

The main causes of hypoglycaemia in the type 2 diabetes patient are: overdosage of oral antidiabetics or insulin (1), administration of Biguanides or thiazolidinediones (2), low carbohydrate intake or omitting a meal in the context of the patient receiving the hypoglycemic drugs or insulin (3), increased physical effort (4) and alcohol consumption (5). Patients should be educated to recognize the symptoms of hypoglycaemia, to carry sugar with them and to promptly intervene to correct hypoglycaemia. Elderly patients, those with long-standing diabetes, or renal impairment are at increased risk of hypoglycaemic coma due to the absence of symptoms of hypoglycaemia. The proposed system works as a Holter and saves the data in the database after each measurement, by providing the Bluetooth interface for real-time connection to the computer and sending data to the treating physician office that will act in a timely manner recommending the immediate administration of a drug or alert 112. By using a properly filled food consumption diary, the patient will know how to dose the level of carbohydrates, high fiber, water, and avoid the appearance of a diabetic coma (Figure 3).



Personalized Diet Interface: High-fiber

INSPIRED

High-fiber, cancer-fighting foods	
Whole grains	whole-wheat pasta, raisin bran, barley, oatmeal, oat bran muffins, popcorn, brown rice, whole-grain or whole-wheat bread
Fruit	raspberries, apples, pears, strawberries, bananas, blackberries, blueberries, mango, apricots, citrus fruits, dried fruit, prunes, raisins
Legumes	lentils, black beans, split peas, lima beans, baked beans, kidney beans, pinto, chick peas, navy beans, black-eyed peas
Vegetables	broccoli, spinach, dark green leafy vegetables, peas, artichokes, corn, carrots, tomatoes, Brussels sprouts, potatoes

Fig. 3. INSPIRED System - User Interface: Personalized Diet Interface

IV. CONCLUSION

Diabetes mellitus is associated with a large number of chronic complications whose end result is reduced quality of life and premature mortality. Early diagnosis and treatment is the proposed strategy to minimize these effects. These intelligent systems are equipped with low-cost network-connected sensors and food frequency analysis programs, prescription diets, or exercise programs by adopting a healthy lifestyle.

The therapeutic education should be accessible to all patients with diabetes, taking into account their cultural, ethnic, psychosocial and various deficiencies. By analyzing the food frequency questionnaires proposed by us, the diet is individualized according to age, sex, height, weight, degree of physical effort, preferences, local tradition, culture level, restriction of alcohol consumption and foods with a high sugar content, fat and salt. Patients are informed about the carbohydrate content of different foods and the way they are calculated and they are also trained to prevent and correct hypoglycaemia. Exercise is gradually introduced, depending on individual skills. It is encouraged to prolong the duration and increase the frequency of physical activity, and in the case of sustained physical effort, the patient treated with insulin or oral medication is trained to adjust his/her medication or insulin doses, or to supplement the carbohydrates, as appropriate.

The use of ITC and m/e-Health systems in medicine is a current challenge, especially with regard to monitoring bioelectric and biochemical parameters and also for personalized diets or physical programs in the prevention and control of type 2 diabetes. The proposed system can be easily used by any patient who has an Internet connection and a purchased sensor system. Unfortunately, most patients are elderly with modest incomes who do not have access to the necessary technology and for whom learning ITC to use these technologies (Digital Divide) poses a real challenge. This is why the nutritional and preventive education part of the young obese or middle-aged person who can use these technologies is very important.

The challenge for Romania is health education, application of preventive measures and periodic screening. In a recent PISA survey (program for international student assessment) conducted in 65 countries, young people (15-16 year old) showed low confidence in scientific methods, compared to other OECD countries. This represents another new educational challenge for those who have a high level of ITC competences and have access to scientific resources.

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