International Journal of Smart Home
Vol. 10, No. 8 (2016), pp. 201-212
http://dx.doi.org/10.14257/ijsh.2016.10.8.24

A Review on Mobile Based Intelligent Systems for Homecare Monitoring of Diabetic Mellitus Foot Ulcer

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Abstract

The diabetic foot might display numerous complexities when they are not monitored frequently. Diabetics will lead to foot ulcer which in future leads removal of foot parts. Persistent homecare observing of the diabetic foot is very important where a frameworks coordinated to a Smartphone helped Model for analysis are required by doctors to enhance early finding. This paper presents a review on diverse frameworks related to homecare based diabetic foot monitoring and procedures utilized for diagnosing diabetic's foot.

Keywords*: Amputation, Diabetes Mellitus, Foot Ulcer, Neuropathy, Smartphone*

1. Introduction

Diabetes is a chronic disease. Diabetes is a metabolism disorder. Diabetes is referred as Diabetes Mellitus (DM) that is People having high sugar for a long period and there is no known cure for diabetes. A person with diabetes has a condition in which the quantity of glucose in the blood is too elevated. This is because the body does not produce enough insulin, produces no insulin, or has cells that do not respond properly to the insulin the pancreas produces. This results in too much glucose building up in the blood. This excess blood glucose eventually passes out of the body in urine. So, even though the blood has plenty of glucose, the cells are not getting it for their essential energy and growth requirements. The rest of the paper is represents as follows: Section 2 describes background and elaborate better on the contribution of this survey on test cases generation.

1.1 Diabetes Mellitus

The term "diabetes" was first used in 230 BC by Greeks means "a passer through". It was a rare disease during Roman Empire time and it is the first disease described with an Egyptian manuscript. Indian physicians in 400-500 CE first identified Type1 and Type2 diabetes. Diabetes can be divided into two major divisions based on the insulin level and they areType1 and Type2.Detailed explanation of these types with symptoms and all related data's are given in Table1.

ISSN: 1975-4094 IJSH

Table 1. Presents the Detailed Description of Type1 and Type2 Diabetes

Major Diabetic types		
Features	**Type 1 Diabetes**	**Type 2 Diabetes**
Formally called	Juvenile-onset Or "Insulin-Dependent Diabetes Mellitus" (IDDM)	Adult-onset Or as "Non-Insulin-Dependent Diabetes Mellitus" (NIDDM)
Definition	Beta cells in pancreas are being attacked by body's own cells and therefore can't produce insulin to take sugar out of the blood stream. Insulin is not produced.	Diet related insulin release is so large and frequent that receptor cells have become less sensitive to the insulin. This insulin resistance results in less sugar being removed from the blood.
Symptoms	• Thirst • Hunger • Dry mouth • Blurred vision • Abdominal pain • Frequent urination	• Fatigue • Numbness • Frequent infection of skin • Urination • Sores that slowly heal • Thirst and Hunger
Insulin	Total lack of insulin	Too little insulin
Age	Young Between 5 - 25	Adults
Different proportion in age group	Adult- 10% Children- 98 %	Adult - 90 % Children - 2 %
Body physic type	Thin	Obese
Treatment	• Insulin Injections • Dietary plan • Regular sugar check • Treat chronic compilations	• Diet • Exercise • Medication
Life expectancy on average reduced	>20 years	Up to 10 years
Prone ethnic groups	All	• African American • Native American • Asian or • Pacific Islander
Cure	None	Gastric surgery lifestyle/medication

1.2. Diabetic Statistic Around the World

Diabetic statistics in the year 2014 in India and worldwide are given in Table2 where there is a constant growth in the diabetic population. Despite putting huge money related weight on people and their families because of the expense of insulin and other vital pharmaceuticals, diabetes likewise has a generous financial effect on nations and national wellbeing frameworks. This is a direct result of an expanded utilization of wellbeing administrations, loss of profitability and the long-term bolster expected to overcome diabetes related difficulties, for example, kidney disappointment, visual deficiency or heart issues. The larger part of nations spend somewhere around 5% and 20% of their all-out wellbeing consumption on diabetes. With such a high cost, the illness is a huge test for human services frameworks and a hindrance to manageable financial advancement.

Table 2. Global and National Diabetic Statistics

The current statistic of diabetes mellitus					
Worldwide				**India**	
387 Million people worldwide in 2014 8.3% of adult population Type2 - 90%Type1 - 10%				Percentage of population being affected in Indian Cities	
North America	39 Million	11.4 %		Kolkata	11.7 %
South and Central America	25 Million	6.4 %		Kashmir	6.1 %
Africa	22 Million	5.1 %		Delhi	11.6 %
Middle East and North Africa	37 Million	9.7 %		Mumbai	9.3 %
Europe	52 Million	7.9 %		Chennai	13.5 %
South and East Asia	75 Million	8.3 %		Hyderabad	16.6 %
Western Pacific	138 Million	8.5%		Bangalore	12.4 %

International Diabetes Federation (IDF) diabetes Atlas for 2015 statistics is given in Table3 based on the gender and region. More than 0.5 M children were affected with Type1 diabetes in 2015 where China, India and United States Stand in the top three countries with diabetes.3,42,000 death cases were recorded in 2014 due to diabetes.

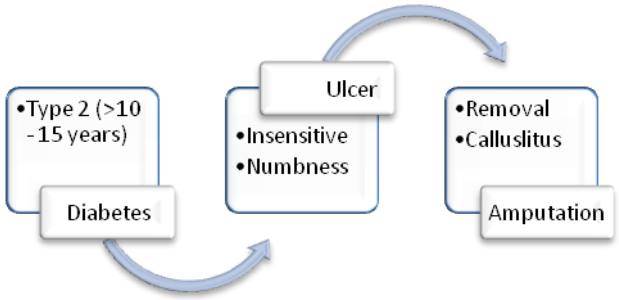
Table 3. IDF Atlas Statistics (Seventh Edition)

		2015	2040
Diabetic by Gender	Men	215.2 M	328.4 M
	Women	199.5 M	313.3 M
Diabetic in Rural and Urban	Rural	145.1 M	163.9 M
	Urban	269.7 M	477.9 M
Diabetic population by region(20 - 79) years	North America	44.3 M	60.5 M
	South America	29.6 M	48.8 M
	Africa	14.2 M	34.2 M
	South East Asia	78.3 M	140.2 M
	Europe	59.8 M	71.1 M
Top 3 countries with Diabetes	China	109.6 M	150.7 M
	India	69.2 M	123.5 M
	United States	29.3 M	35.1 M

2. Neuropathy

Uncontrolled diabetes can harm one's nerves. On the off chance that one has harmed nerves in his legs and feet, he won't not feel heat, icy, or torment. This absence of feeling or deadness in the sole or heel of the foot is called 'sensory diabetic neuropathy'. On the off chance that one does not feel a cut or sore on his foot as a result of neuropathic deadness, the cut could deteriorate and in the end get to be contaminated. The muscles of the foot may not work appropriately, in light of the fact that the nerves that make the muscles work have been harmed. This could bring about the foot to not adjust appropriately and make an excess of weight in one territory of the foot. It is assessed that up to 10% of individuals with diabetes will create foot ulcers in light of nerve harm and peripheral vascular disease. 250 million individuals were determined to have foot ulcer and the greater part of the foot ulcers lead to amazing removal. Removal death rate is 39 to 80%. The following figure illustrates Type 2 diabetes leads to amputation if the patients have diabetics for more than fifteen years.

Figure 1. Type 2 Diabetic to Amputation



The diabetic foot might display numerous entanglements on the off chance that it is not consistently controlled. Measurements demonstrate that 25% of diabetics that create

fringe neuropathy will build up a foot ulcer, more than half of them will get to be tainted and 80 % require non-traumatic removal. Based on the organs being affected, neuropathies are classified into four major categories. The explanation for all the types of neuropathy and the organs which it affects are detail given in the Table4.

Table 4. Neuropathy Types with List of Organs being Affected in each Type

Types of Neuropathy with affected organs list		
Neuropathy Type	**Explanation**	**Organs affected**
Peripheral neuropathy affects	The nerve problem affects the nerves outside of the brain and spinal cord. These nerves are part of the peripheral nervous system.	• Toes • Feet • Legs • Hands • Arms
Autonomic neuropathy affects	Damage to the nerves of the involuntary nervous system, the nerves that control the heart and circulation	• Heart and blood vessel • Digestive system • Urinary track • Sex organ • Sweat gland • Lungs
Proximal neuropathy affects	The proximal muscles are affected.	• Hips • Buttocks • Thighs • Legs
Focal neuropathy affects	Restricted to one nerve or group of nerves, or one area of the body.	• Eyes • Facial muscles • Ears • Pelvis and lower back • Chest

3. Surviving Mobile Based Intelligent Systems for Analyzing Diabetic Foot Ulcer

Several techniques and intelligent systems have been used for detecting ulcers and this section discusses the following systems being used by the diabetic patient for detecting the foot ulcer at home using intelligent systems.

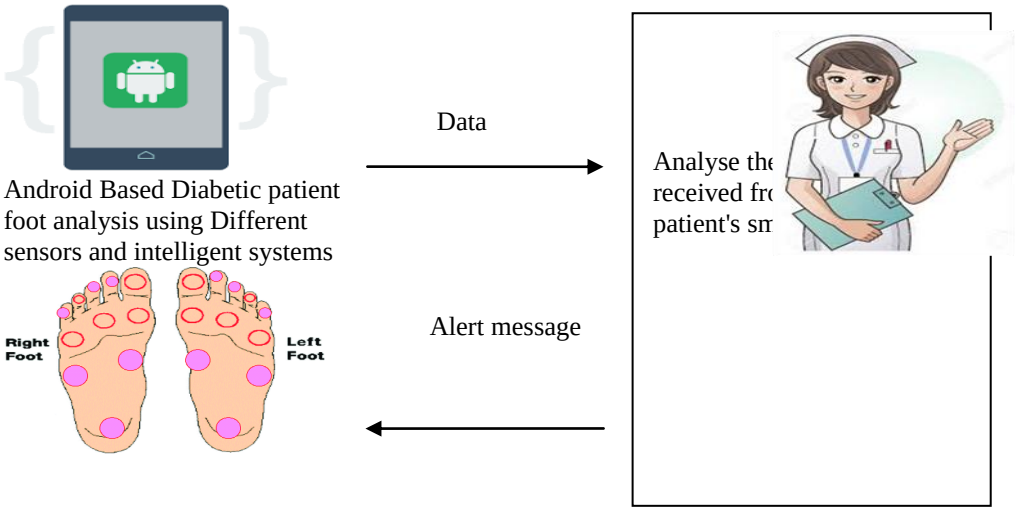


Figure2. Illustrates the basic Strategy being Followed in Homecare Diabetic Foot Monitoring

3.1 An Instrumented Shoe

For the diagnosis of foot ulcer in real-time, Anwar S. Benbakhti (2014) has designed and developed an Instrumented shoe through which foot amputation can be avoided where 80% of the foot ulcers lead to amputation. This instrumented shoe consist of multiple number of different sensors like Humidity sensor, three temperature sensors and six Insole pressure distribution sensors. Using these sensors sweating rate, friction rate and ulcer point pressures can be determined through which ulcer formation can be prevented. There are six high pressure points in the foot and all these points are placed with Force Sensing Resistors through which the pressure at those points can be identified and based on the pressure each point is differentiated by different colors like blue and red. Data's being collected from those sensors are sent through Bluetooth to the Android phone. If the data values show any variations then alerts are being sent to the healthcare.

3.2 Intelligent Footwear

To measure both temporal plantar pressure and Spatial plantar pressure, intelligent footwear have been developed by Shu Lin (2012) through which real time data's of diabetic can be obtained. This intelligent footwear has been tested and has tried to find the difference between the diabetic and healthy subject in every activities they perform. F Scan is used for identifying the area in foot where the pressure is high and they have identified eight areas. These eight areas are being concentrated in this research. Dynamic information of foot is analyzed. Both healthy and diabetic people with different age, height and weight were elected for this project. Temperature, humidity and centre of pressure were calculated. This instrumented shoe can be continuously used for about twenty hours a day by charging the shoe once and where a port is available in this intelligent shoe for the charging. Once data's are collected, using Bluetooth they are sent to the PC. Results show that the fore foot and the lateral foot areas of diabetic are more prone to ulcer formation. Locations of ulcers are being identified and they are at high pressure.

3.3 SoleScan

An Android application namely SoleScan has been designed for online monitoring both diabetic pressure points and callus formation has been developed by ArindamDulta (2013). Insole surface were analysed using Gabor filters. Image processing algorithm are used for online analysis of sole of the diabetic foot and also for the calculating the pressure. Image processing algorithm can run on Android application. Image of the diabetic foot are captured through the mobile and the sole scan application detect the level of pressure and upload the image being captured to the data server. Offline analysis is done once the images are sent to the server to identify the hot spots. Colors are used for differentiating the pressure areas.

3.4 Plainpes

A sensor board is designed by Samuel Pfaffen (2011) to monitor diabetic foot in real time. Thecentres of our framework are to give a shabby answer for exact estimations without weakening the versatility of the patient. With a specific end goal to decrease the aggregate expenses of the Planipes framework and to build its adaptability, we chose to depend on the client's smart phone fordata's.

3.5 Heel Pad

The correlation between heelpad properties and parameters is proposed by Panagiotis E. Chatzistergos (2014) using Ultrasound probe and Dynamometer. 17 Non diabetic and 35 diabetic subjects were used for this research. Result shows that Type 2 diabetic subjects have higher stiffness and Loading does not influence heel pad mechanical properties.

3.6. Plantar Pressure Sensitivity System

One of the advances utilized for pressure estimations Loran Platform is designed by Martha Zequera, was utilized to assess repeatability amid unshod remaining in diabetic and non-diabetic subjects, for future diabetic foot clinical assessment coordinated in the outlined PC model.

3.7 Electronic Orthotic Shoe System

To segregate the diabetic patient based on the feet motion FoadDabiri (2008) proposed a system using Electronic orthotic system. Pressure sensor sheets and 3 axis accelerometer are used for monitoring the motion and pressure distribution of feet. Five points in feet were taken for testing this system for thirty seconds and the pressure in those five points was measured using non-invasive sensor. This framework is composed and created utilizing lightweight remote installed frameworks and non-invasive sensors. Besides, we outlined so exploratory results demonstrating how we can extricate the pressure underneath the foot and how we can utilize this data for characterization and step examination. This framework empowers constant checking and gives input to the patient/parental figure.

3.8. Smart Socks

The first washable and wearable smart socks has been designed and developed by A.Perrier (2010) to prevent ulcer formation. A completely remote, adaptable and launder able "smart sock" has been planned. It is made of a material which strands are sewn in a way they give estimations of the pressure applied under and all around the foot, all things considered, conditions. This gadget is combined with a subject specific Finite Element

foot display the pressure tissues of the foot. Different varieties of fabrics wrapped with silver and Piezo resistive are combined for making the socks to detect the pressure in foot.

3.9 Ultrasonic

In request to consistently screen the mechanical properties of plantar delicate tissue amid physical exercises Bruno M Trindade (2014) used ultrasonic technique and sensors that can be use between the foot and shoe insole. The power was measured by the plate and the weight values at the heel were figured. Plantar tissues strain was figured utilizing the plantar thickness variety got from the gained ultrasound information concerning the connected weight amid the estimation. The outcomes were approximated by an exponential capacity.

3.10 Four Insoles

To evaluate differing insoles plantar pressure impact Martha L Zequera (2010) recommended and produced with different methods on a subjective gathering of patients with diabetes mellitus in the early phases of the infection. Thirteen diabetic patients were chosen for the insole evaluation and ten foot areas were selected for testing. Four sorts of insoles were composed and made by techniques accessible in the business sector; the PC model proposed on this undertaking was utilized as a part of request to plan and produce the insole. The outcomes demonstrate that each persistent requires an individual evaluation and frequently a customized insole.

Table 5. Table Shows Mobile based Intelligent Systems

Ref/ Year	Mobile based Intelligent Systems	Predict	Sensors and Techniques used	Foot Points Considered for study	Results	Subjects Involved
[1] / 2014	Instrumented shoe	To monitor foot ulcer	-Temperature sensor -Humidity sensor -Force sensing resistors	6	Only based on the foot properties of the diabetic, ulcer formation points can be obtained	10 healthy subjects
[2]/ 2012	Intelligent footwear	Nonstop dynamic foot observing in everyday life of diabetic	-F scan -Temperature sensor -Humidity sensor	8	1.Ulcer formation in the diabetic foot where the pressure are very high 2. Fore foot and Lateral side of foot are more prone to Ulcer formation 3. Sensitive data have been generated	10 healthy 10 non healthy(diabetic)
[3]/ 2013	Solescan	For recognizing hot spot in shoe insole	- Gabor filters -Image processing algorithm	whole foot	High pressure spots are hot spots	single subject

[4]/ 2011	Plainpes for gain and foot pressure analysis		Force sensing resistors Sensor insole Sensor board	16	Measure foot pressure distribution in spatial density	
[5]/ 2014	Heel pad	To find the correlation between heel pad properties and parameters	Ultrasound probe Dynamometer	Heel	1. Type 2 diabetic subjects have higher stiffness 2. Loading does not influence heel pad Mechanical properties	17 Non diabetic 35 diabetic subjects
[6]/ 2013	Plantar Pressure sensitive system	Diabetic foot syndrome	Loran EPS/R1 Platform			6 diabetic 8 non diabetic
[7]/ 2008	Electronic Orthotics Shoe system	Supervise feet motion	-Pressure sensor sheets -3 Axis Accelerometer - MedNode	5		
[8] / 2014	Smart Diabetic socks	To foil foot ulcer	-Finite Element model -Eight Pressure sensors	Whole foot	1.Washable smart socks 2.High internal strain near bone	Single subject
[9] / 2014	Ultrasonic sensor	To gauge plantar tissue thickness	- Ultrasonic sensor	Heel	Heel thickness measured with variable pressure	
[10]/ 2010	Insole performance	To assess different insoles using pressure	- Four types of insole - CAD/CAM	10	Insole should be prepared based on the personalized assessment of the diabetic patient	6 diabetic subject (>15 years of diabetic) 7 diabetic subject (>5 years of diabetic)

4. Conclusion

In this survey various homecare based diabetic foot monitoring systems have been studied to obtain better life for the diabetic people. All the above homecare based diabetic foot monitoring systems work effectively. But they do not include Vibrators for predicting the sensitivity in diabetic foot. An Android based mobile application can be designed in this contest and this helps to all public to take care of their foot in real time. The

application will contain an image of the points on the sole of the foot. The pressure points will be highlighted and the degree of pain at each point specified. The application will also contain various graphs and tables to aesthetically display the data. Based on the various results in the data, the application will provide medical recommendations and conclusions to the user. Alerts will be formed on the basis of the sensors' values and the user will be informed the condition of his foot along with the possibility of an eventual risk of the diseases and disorders caused by these parameters.

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