PLANTAR FOOT PRESSURE MONITOR FOR DIABETIC PATIENT

Sakthivel B [1]
Department of Biomedical Engineering
Dr. N. G. P. Institute of Technology
Coimbatore, India
sakthibala00232@gmail.com

Sneha R [2]
Department of Biomedical Engineering
Dr. N. G. P. Institute of Technology
Coimbatore, India
sneharamasamy23@gmail.com

Vijayalakshmi M[3]
Department of Biomedical Engineering
Dr. N. G. P. Institute of Technology
Coimbatore, India
Vijimanoharan02@gmail.com

Vidhya B [4*]
Department of Biomedical Engineering
Dr. N.G.P. Institute of Technology
Coimbatore, India
vidhyamkumar@yahoo.com

Abstract — **The most common diabetic consequences are diabetic foot injuries, which usually result in reduced life expectancy of the patient and amputation. Blisters or sores on the feet or lower extremities are typically the first symptoms of a diabetic foot ulcer. Hence, it is important to identify foot ulcers as soon as possible because doing so can help to prevent diabetes-related foot problems. Peripheral neuropathy, the primary risk factor for diabetic foot ulcers (DFU), is connected to exceptionally high plantar pressures and is associated with a lack of protective sensation. The objective of proposed system is to develop and fabricate a non- invasive plantar foot pressure monitoring device for diabetic patients. The system provides real-time information on the distribution of foot pressure using sensor technologies. In a clinical context patient with diabetes, accuracy and dependability of the system were assessed, and comments from users and healthcare experts were gathered to enhance the design and performance. Through early identification and intervention, the proposed system has the capability to enhance the standard of living for diabetes patients by reducing the likelihood of foot injuries and consequences.**

Keywords— Diabetic foot injuries, Plantar foot pressure monitoring, Non-invasive device, Sensor technology.

I. INTRODUCTION

Diabetes accounts for the majority of peripheral artery disease (PAD) with Diabetic Foot Ulcers (DFU) contributing for up to 85% [8]. DFU is linked to a decreased life expectancy. DFU is a significant threat to the health of human mankind, with a remarkable percentage resulting in amputation. According to the International Diabetes Federation, it was observed that around forty-two crores of people have diabetes globally in 2017, which is one crore higher than the count that was measured three years before [8]. When the current patterns continue, the proportion of humans suffering from this disorder may approach sixty-two crores by 2045 [9].

Nevertheless, once abscessed, the incidence rate of DFU is 40% during the first year and up to 65% after five years [11]. Diabetic peripheral neuropathy, which is closely linked to foot deformity and trauma, constitutes the most prevalent cause for DFU.Diabetic peripheral neuropathy (DPN) is a prominent diabetic impact that impels patients to foot ulcers and amputations.

Stokes et al., [12] conducted the pioneering investigations on plantar pressure (PP) in diabetes patients with the help of pedobarography which is the area of pressure that interacts among the surface of the foot with the supportive material, in 1975. Foot pressure data is collected by the system utilizing FSR, which will be positioned on the top of the shoe's sole. Integration of FSR with Arduino and the LabVIEW is performed. This software allows the victim's information to be entered and saved, and if utilized, the acquired information of the pressure is translated to a virtual layout and a pedobarography image will be created. The greatest maximal load was observed to be concentrated in the location of ulcers. It was demonstrated that high levels of pp are useful in predicting diabetic foot ulcer.

The aim of the proposed work is to provide diabetes patients with an alternative approach to recognize the rhythm of plantar or foot pressure using LabVIEW software in order to identify an early onset of foot ulcers. The system implements the DFU loading surveillance system that is reusable and financially viable, which necessitates the application of designs and components that are suitable for sanitation, disinfection between users, suitable for all environmental conditions, user friendly with minimal load and reduce the effect of the foot ulcer by treating it in advance.

II. EXISTING WORK

A printed sole relying on the sensor technology was developed to approach practical deployment. Two methodologies were used to effectively construct the potential plantar pressure system of measurement:

- top-down approach
- bottom-up approach

A gait analysis research was conducted as part of the top-down method. Earlier studies had shown that different diseases resulted in varied foot roll-over patterns. As a result, the gait analysis investigation sought to determine particular needs and architectural principles for the measurement of pressure, such as the spatial resolution required [9]. The measurement of load at the plantar fascia has been suggested for a range of sensing devices. Research settings frequently employ a wide range of sensing techniques, comprising capacitive, resistive, optical fiber, inductive, and piezoelectric, methodologies. Few of these sensing techniques are built with single measurement axes that can track pressure and shear stress. The majority of these sensing techniques feature a single measurement axis that is targeted at sensing plantar pressure [10] The results of certain cross-sectional studies that only measured forefoot pressures while wearing bare feet adhere to an identical sequence to that of entire-foot examinations, with the ulcerated population showing noticeably higher peak PP. Both forefoot and rear foot pressure appeared much higher in cases of mild to severe neuropathy, which are typically at increased ulceration threat. However, don't have multiaxial measurement, and they're frequently too pricey for regular clinical use. Research-based systems, in contrast, are less advanced, particularly in terms of spatial resolution and coverage [11]. The rise of increased plantar pressures may be influenced by biomechanical factors, that is restricted joint dynamic band and foot deformities, and could be used to identify those who are at threat of issues brought on by pressure. The study included around one hundred and thirty adolescents with diabetes (roughly around fifty male, mean age of sixty eight years)[38] Participants underwent barefoot and in-shoe plantar pressure testing, assessment of weight-bearing ankle dorsiflexion, hallux range of motion, lesser toe deformities, and the Hallux Abducto (HAV) scale. To determine the impact of these four biomechanical parameters, neuropathy, and Body Mass Index(BMI) on PP variables, the researchers employed multivariate multiple linear access. They also compared the plantar pressure characteristics of persons with two or more foot biomechanical disorders to those with fewer than two diseases using non-parametric bootstrapping. [17]

III. METHODOLOGY

In medical diagnostics, the distribution of pressure in the human foot provides important information. The distribution of human plantar pressure data is influenced by factors related to the foot, including foot structure, function, overall physical position management, and gait. A deeper comprehension of the pathophysiology of an infected foot with incorrect pressure distribution will result from the device data, which will also significantly support in diagnosis, surgery cost estimation, and other activities. The device measures foot pressure using force-sensitive resistor (FSR) sensors located on the top of the shoe sole. The Arduino is connected to these sensors. LabVIEW is used to construct a specialized piece of software, where the software allows the input and stores the information of the patient, and when it is used, it converts the acquired data gathered into a vital layout and produces a pedobarography.

A. Software Description

Arduino Uno R3 is unrestricted microcontroller. It is designed to be simple to use, with a range of features and capabilities that make it ideal for beginners and experienced users alike. One of the primary advantages of the Arduino Uno R3 is its ease of use. The Arduino Uno R3 is highly versatile and can be used in a wide range of projects, from controlling simple LED displays to building complex robotic systems. The platform is compatible with a wide range of sensors and other electronic components, making it easy to integrate with existing hardware systems.

LabVIEW is a software platform developed by National Instruments for designing and controlling complex engineering systems. The LabVIEW platform provides a visual programming environment that allows users to create custom applications and user interfaces with ease. One of the key benefits of LabVIEW is its ability to quickly prototype and test complex systems. The platform allows users to rapidly create custom control and data acquisition systems without the need for traditional coding. LabVIEW is also highly customizable, with the ability to create custom user interfaces and add functionality through the use of plug-ins and modules.

B. Hardware Description

PERFBOARD

A dot PCB board, also known as a printed circuit board, is a hardware device used to connect electronic components and circuits. It is a thin, flat board made of an insulating material, such as fiberglass, with conductive traces printed on its surface. Dot PCB boards are commonly used in a wide range of electronic devices, from simple circuits to complex electronic systems. They offer a reliable and cost-effective way to connect electronic components and circuits, making them an essential tool in the field of electronics.

A FORCE SENSOR is used to gauge the magnitude of the force being exerted to a surface or an object. It is typically made up of a sensing element, which is designed to detect the force, and an electronic circuit, which processes the signal generated by the sensing element.

10K OHM CARBON FILM RESISTORS is a passive electronic component that is used to provide resistance to the flow of electric current in a circuit. The 10k ohm resistor is rated to withstand a certain amount of power, which is usually indicated on the body of the resistor. When connected in a circuit, the 10k ohm resistor resists the flow of current and produces a voltage drop across its terminals. The amount of resistance it provides is determined by its physical properties and the amount of current flowing through the circuit.

THE RELIMATE CONNECTOR is designed to be compact and easy to use, with a simple locking mechanism that ensures a secure connection between the male and female terminals. The connector is suited for a broad spectrum of uses because it is offered in a range of dimensions and layouts. It is also available in different pitch sizes, with the most common pitch size being 2. 54mm.The Connector is known for its reliability and durability, with a high resistance to shock and vibration.

C. Block Diagram

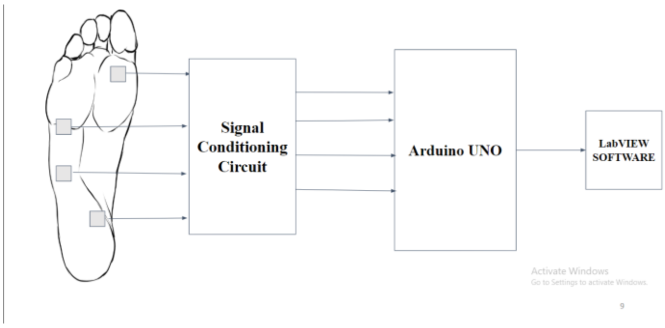

Fig.1 Schematic representation of the proposed system

Fig.1 shows the Schematic representation of the proposed system, it consist of the force sensor, which measures the force applied to it and converts the force to an electrical signal that can be read and analyzed, is attached to the sole and the signal is directed to a signal conditioning circuit which consists of a 10k resistor to resist the flow of current. The resistance value determines how much the flow of current is reduced for each sensor in the dot board, and 2 pin wire is used to connect the dot board and sensor, followed by 4 pin wire to connect the dot board and Arduino UNO. The sensors used to measure the distribution of foot pressure may generate weak or noisy signals that must be conditioned before they can be precisely recorded and analyzed. The sensor output may need to be amplified, filtered, and transformed into a digital format so that the Arduino UNO R3 can read and analyze it. Then, the Arduino is connected to the LABVIEW software which enables communication with other instruments and devices, real-time data collecting and display, data logging, data analysis, and data visualization. Data gathered by the force sensor and processed by the Arduino UNO R3 is uploaded to a computer, which comprises the LABVIEW software and the high pressure at the plantar foot.

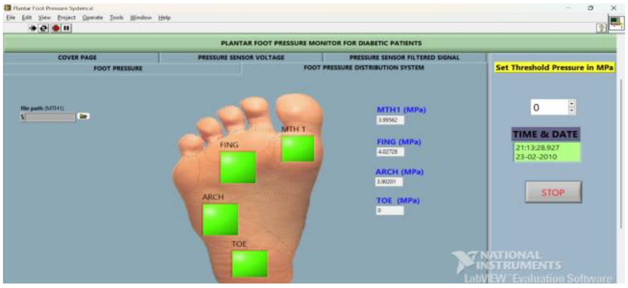

Fig.2 Foot pressure gradient system

The Fig.2 shows the pressure gradient across each foot-mounted sensor and the threshold value for describing the foot ulcer.

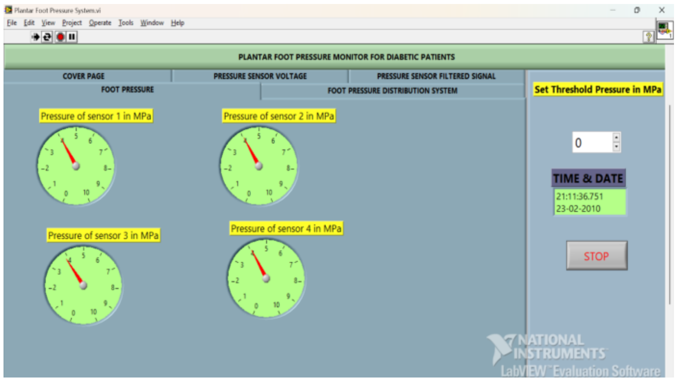

Fig.3 Foot pressure

Fig.3 displays the pressure in each sensor (in MPa), with respect to the foot pressure. The top left indicator represents the pressure value of the MTH 1 sensor placed on the sole, the top right indicator depicts the pressure value of FING, the bottom the left indicator shows the pressure value of the ARCH, and the bottom left indicator represents the pressure value of the TOE sensor.

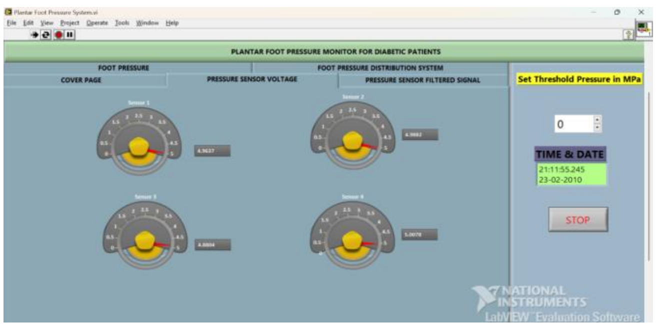

Fig.4 Pressure sensor voltage

Fig.4 displays the pressure sensor voltage in each sensor, with respect to the foot pressure. The top left indicator represents the pressure sensor voltage of the MTH 1 sensor placed on the sole, the top right indicator depicts the pressure sensor voltage of FING, the bottom the left indicator shows the pressure sensor voltage of the ARCH, and the bottom left indicator represents the pressure sensor voltage of the TOE sensor.

Fig.5 Pressure sensor filtered signal

Fig.5 displays the pressure sensor filtered signal in each sensor, with respect to the foot pressure. The top left graph represents the filtered signal from the pressure sensor of the MTH 1 sensor placed on the sole, the top right graph depicts the filtered signal from the pressure sensor of FING, the bottom left graph shows the filtered pressure signal sensor of the ARCH, then the bottom left graph represents the filtered pressure sensor signal in the TOE sensor.

IV.RESULTS AND DISCUSSION

Diabetes is usually linked to gait issues that can be evaluated with plantar measuring equipment. Despite the fact that any decision involving a foot complexity depends on the pressure, current analysis and market based solution lack reliable techniques that can simultaneously collect plantar pressure for monitoring feet. In this work, we created a prototype for a smart sole which collects data of foot pressure from numerous points. The proposed prototype has uses in a number of fields, including rehabilitation, healthcare, sports, and others. Connection between each sensor has been reduced by using a variety of software and hardware-based strategies, allowing the system to be highly accurate even with a loosely packed array of force sensors on a sole.

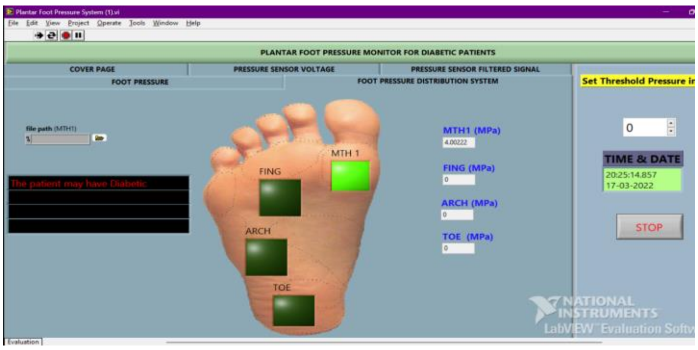

Fig.6 Output pressure

This Fig.6 shows the pressure distribution across each foot-mounted sensor and MTH1 is highlighted because the pressure in that particular area is high.

The findings indicate that the subjects with diabetes had greater pressure sensor readings at the toe, having a maximum reading of 4.00022 MPa (Mega Pascal), as opposed to the normal individuals, who had a least value of 2 MPa. The system demonstrates how effective the technology for measuring plantar pressure can identify diabetes patients who may develop foot ulcers.

TABLE I. Average threshold values of the individual person

WEIGHT (in Kg)	**BELOW 50**	**50-75**	**75-100**	**ABOVE 100**
Threshold value(MPa)	3-3.5	3.6-4	4.1-4.5	4.6-5.5

For diabetic patients, monitoring plantar foot pressure is especially important because they are at hazard of developing foot problems such as ulcers, infections, and even amputations. TABLE I. represents an average threshold range based on body weight. These threshold ranges may vary depending on the individual's unique circumstances, such as age, gender and medical history. It's important for diabetic patients to work closely with their healthcare team to develop a personalized foot care plan, including regular foot exams and proper foot hygiene, to prevent foot problems and promote overall foot health.

It is also important to note that the observed foot pressure value can vary depending on factors such as the weight of the individual and the type of activity they are engaging in. For example, the pressure on the foot may be higher when standing or walking compared to when sitting or lying down. The voltage value obtained from the sensor is given in table 4.2 and 4.3 for the individuals with Type II diabetics and without diabetics respectively. The plantar pressure can be determined using the pressure values, in order to obtain the accurate pressure value, the voltage value is converted into its equivalent pressure in LabVIEW software by using the formula, which is given in the below equation

$$y = ((0.9615*X)-0.7692)$$

where X is the voltage value obtained from the sensor. The converted pressure value is shown in the TABLE IV and V. The maximum pressure value obtained as the result of conversion is the maximum pressure exerted at the particular region of the foot.

TABLE II. Observed pressure sensor voltage for the patients without diabetics

PERSON	WEIGHT (Kgs)	OBSERVED PRESSURE SENSOR VOLTAGE (V) FOR THE PATIENTS WITHOUT DIABETICS			
		MTH1	FING	ARCH	TOE
1	48	5.0029	4.9931	5.0029	4.9343
2	53	5.0029	4.9833	4.9735	4.7089
3	69	5.0029	4.9441	4.6803	4.9637
4	72	5.0029	4.998	4.8804	4.9588
5	78	5.0029	4.8755	4.9735	4.9931
6	90	4.9951	4.9840	4.9040	5.0040
7	103	5.0029	5.0000	5.0029	4.9343
8	37	5.0029	4.9981	5.0040	4.9432
9	108	5.0029	4.8845	5.0000	4.9400
10	35	5.0041	4.9931	5.0055	4.9343

The TABLE II. represents the average foot pressure values for different areas of the foot for the patients with and without diabetics, based on their weight. It is observed that the pressure in the toe is greater than the other region on the foot for the patients with diabetes. For example, a person with 90 kg weight should have the threshold below 4.1, as stated in TABLE I. When the threshold value is greater than the average value, the excess feeling of pressure in a certain foot region can be determined which makes diagnosis easier and customized footwear for individuals can be prescribed.

TABLE III. Observed pressure sensor voltage for the patients with Type II diabetics

PERSON	WEIGHT (Kgs)	OBSERVED PRESSURE SENSOR VOLTAGE (V) FOR TYPE II DIABETICS PATIENTS			
		MTH1	FING	ARCH	TOE
1	48	4.9951	4.9840	4.9040	5.0040
2	53	5.0029	5.0000	5.0029	4.9343
3	69	5.0029	4.9981	5.0040	4.9432
4	72	5.0029	4.8845	5.0000	4.9400
5	78	5.0041	4.9931	5.0055	4.9343
6	90	5.0035	4.9832	5.0000	4.9343
7	103	5.0029	4.9764	5.0021	4.9342
8	37	5.0030	4.7654	5.0030	4.9346
9	108	5.0049	4.8834	5.0022	4.9341
10	35	5.0011	4.5684	5.0015	4.9348

The TABLE III shows the values of foot pressure and corresponding voltage readings taken from a pressure-sensitive insole. It shows the pressure voltage values, measured using a sensor that is placed on the foot, for patients with and without diabetes. The table displays values for different areas of the foot, allowing for a comparison of pressure distribution between the two groups.

TABLE IV. Observed foot pressure distribution value for the patients without diabetics

PERSON	WEIGHT (Kgs)	OBSERVED FOOT PRESSURE DISTRIBUTION (MPa) FOR THE PATIENTS WITHOUT DIABETICS			
		MTH1	FING	ARCH	TOE
1	48	2.8826	3.06191	3.2197	3.3545
2	53	3.8983	3.67334	3.99091	3.2197
3	69	3.6785	3.87456	3.65432	3.5467
4	72	4.0329	4.0264	4.01744	4.0220
5	78	4.3567	4.2096	4.2145	4.4098
6	90	3.8983	3.97335	4.03529	4.04033
7	103	4.0295	4.0319	4.00363	4.0384
8	37	3.0290	3.1899	3.04057	3.02903
9	108	4.0350	4.01744	3.59920	4.04095
10	35	3.0174	3.02354	3.01329	3.0367

TABLE V. Observed foot pressure distribution value for the patients with Type II diabetics

PERSON	WEIGHT (Kgs)	OBSERVED FOOT PRESSURE DISTRIBUTION (MPa) FOR TYPE II DIABETICS PATIENTS			
		MTH1	FING	ARCH	TOE
1	48	3.16754	3.98456	3.456783	3.09875
2	53	3.76453	3.69845	4.2345	3.59834
3	69	4.11096	3.7543	3.89546	4.3456
4	72	4.67893	4.76543	4.39856	4.4567
5	78	4.43567	4.37845	4.23456	4.67543
6	90	4.73489	4.03427	4.07453	4.04563
7	103	4.08567	4.04563	4.58745	5.00293
8	37	4.00235	3.0056	3.40983	4.0874
9	108	5.73467	4.03457	4.04738	4.03278
10	35	4.03465	3.59837	4.08736	4.03267

TABLE V. represents the average foot pressure values for different areas of the foot for the patients with Type II diabetics, based on their weight. It is observed that the pressure in the toe is higher than the other region on the foot for the patients with diabetes. For illustration purposes, a patient with 90 kg is considered, the average threshold value should be between 4.1 to 4.5 MPa. In the observed value of person 6 in table 4.5, MTH 1 sensor value is 4.73489 which is higher than the average threshold value. It shows that the excess of pressure exerted in the particular area of the foot (MTH 1). It is also observed that the pressure in other points (FING, ARCH, TOE) have the normal value and uniform distribution. It helps to diagnose easier and customize footwear for individuals. Continuous usage of the customized foot wears will help the patient to prevent the foot ulcer.

Likewise, these measurements can be helpful in identifying the areas of high pressure on the foot of the diabetic patient that may be causing pain or discomfort. These values allow the podiatrist to track changes over time and monitor the effectiveness of any treatments or interventions that are recommended. A system for measuring foot pressure has been effectively constructed in the proposed work and it makes use of the pressure data obtained to differentiate the healthy and unhealthy feet. Diabetic patients are at an increased risk of developing foot ulcers due to their impaired ability to feel pain and reduced blood flow to the feet. Monitoring foot pressure distribution is an essential aspect of managing diabetic foot, as high pressure in a particular area can indicate the presence of an ulcer.

To validate the performance of the proposed system, comparison was done with the existing system with circular force sensor of 14.7mm. The pressure values observed for the persons with same weight were analyzed for both Type II diabetic and non-diabetic cases. From the experimental results, it was observed that the existing system produced 83.2% accuracy while the proposed system produced an accuracy of 92%. So it is obvious that the proposed system outperforms the existing system in terms of accuracy.

V. CONCLUSION

A serious side effect of diabetes that can result in amputation and a reduced quality of life are DFU. Diabetic foot ulcers can occur in both Type 1 and Type 2 diabetes. Type 1 diabetes is an autoimmune disease that affects the pancreas's ability to produce insulin, while Type 2 diabetes is a metabolic disorder characterized by insulin resistance and impaired insulin secretion. In order to give real-time data on foot pressure distribution using sensor technologies, a non-invasive plantar foot pressure monitoring device has been developed, by determining the maximum pressure on particular area of the foot. The maximum pressure on the foot is determined by comparing the observed pressure values with the normal pressure values of the individuals. The number of persons tested is 100 including normal and Type II diabetic patients. From the experimental results, it was observed that the existing system produced 83.2% accuracy while the proposed system produced an accuracy of 92%. So it is obvious that the proposed system outperforms the existing system in terms of accuracy. By reducing the risk of foot injuries and their consequences, this device may improve the quality of life for people with diabetes.

VI. FUTURE WORK

Further advancement of non-invasive plantar foot pressure monitoring technology for diabetic patients has a lot of potential in the future. The system could proceed in several directions, one of which being the incorporation of AI and ML algorithms, enabling more precise and individualized pressure mapping and analysis. A benefit is the capacity to administer specialized medicines and more precisely identify those who are most likely to get foot ulcers. Wearable technology may potentially be developed to integrate the plantar foot pressure monitoring device with other health monitoring devices, such as blood glucose monitors, to give a complete picture of a patient's health state. This can allow for real-time monitoring of changes in foot pressure and other vital indicators by patients and healthcare professionals, enabling early identification and fast management. The device's downsizing, which would make it easier for patients to use on a regular basis and more portable, is another topic for future research.

REFERENCES

[1] Abdul Hadi Abdul Razak, “Foot Plantar Pressure Measurement System” in Pubmed central,vol 12(7), pp 9884–9912 Doi: 10.3390/s120709884.2012

[2] Altayyar SS ,“BareFoot and In-shoe Plantar Pressure in Diabetic Males and Females”in Dove press Vol:14 ;pp 271—276 ,Doi:10.2147/MDER.S312739 .2021

[3] Armstrong D.G., “Diabetic Foot Ulcers and Their Recurrence”;in Pubmed N. Engl. J. Med.;Vol 376; pp:2367–2375. doi: 10.1056/NEJMra1615439.2017

[4] S.J.M. Bamberg, “Kinetic gait analysis using a low-cost insole,” IEEE Trans. Biomed.Eng.vol.60(12),pp3284–3290,Doi:https://doi.org/10.1109/TBME.2013.2250972.2013

[5] S. A. Bus, “Innovations in plantar pressure and foot temperature measurements in diabetes”,in wiley; Vol 32 , Pp(221-226), Doi: doi.org/10.1002/dmrr.2760; 2015

[6] K. Deschamps, et al., “Classification of forefoot plantar pressure distribution in persons with diabetes: a novel perspective for the mechanical management of diabetic foot”, PLoS One vol. 8 (11), e79924, Doi:https://doi.org/ 10.1371/journal.pone.0079924.2013

[7] Doupis J., “Management of diabetic foot ulcers”, Diabetes Ther.vol 3:4. doi:10.1007/s13300-012-0004-9.2012

[8] Glen Cooper , "Monitoring of Dynamic Plantar Foot Temperatures in Diabetes with Personalized 3D-Printed Wearables"in PubMed Central,Vol 21(5): 1717.Doi: 10.3390/s21051717, 2021.

[9] C. Gerlach , "Printed MWCNT-PDMS-Composite Pressure Sensor System for Plantar Pressure Monitoring in Ulcer Prevention," in IEEE Sensors Journal, vol. 15, no. 7, pp. 3647-3656, doi: 10.1109/JSEN.2015.2392084. 2015

[10] Heidi J. Siddle, "wearable sensor systems to monitor plantar loading in the assessment of diabetic foot ulcer" in IEEE transactions on biomedical engineering, vol 67(7), pp 1989-2004. Doi: 10.1109/TBME.2019.2953630.2020

[11] Katie E. Chatwin, "The role of foot pressure measurement in the prediction and prevention of diabetic foot ulceration"in Pubmed central;vol 36(4) e3258; Doi: 10.1002/dmrr.3258.2020

[12] Kernozek T, "Plantar loading asymmetry in American Indians with diabetes and peripheral neuropathy, with diabetes only, and without diabetes". J Am Podiatr Med Assoc.;vol103(2) pp:106–12. [PubMed] [Google Scholar] DOI: https://doi.org/10.7547/1030106 .2013

[13] Kerr M., "The cost of diabetic foot ulcers and amputations to the National Health Service" in England PubmedMed.; Vol(36),pp:995–1002. Doi: 10.1111/dme.13973.2019

[14] A. Khandakar, et al., "Design and implementation of a smart insole system to measure plantar pressure and temperature," Sensors vol. 22 (19) 7599 (Available), Doi:https://www.mdpi.com/1424-8220/22/19/7599.2022

[15] K. Kong, "A gait monitoring system based on air pressure sensors embedded in a shoe," IEEE/ASME Trans. Mechatron. vol. 14(3),pp 358–370,Doi: 10.1109/TMECH.2008.2008803. 2009.

[16] Margolis D.J., "Medical conditions as risk factors for pressure ulcers in an outpatient setting. Age Ageing" 2003; vol 32 pp:259–264. [PubMed] [Google Scholar] Doi:https://doi.org/10.1093/ageing/32.3.259

[17] Martin J. Spink," Clinical foot measurements as a proxy for plantar pressure testing in people with diabetes"in Journal of Foot and Ankle Research Vol 56; pp(1757-1146), Doi:10.1186/s13047-021-00494-4.2021

[18] Martín-Vaquero J., "Review on wearables to monitor foot temperature in diabetic patients". Sensors PMC free article;Vol19; pp:776. Doi: 10.3390/s19040776.. 2019

[19]Mohammad Ahsan, "Plantar Pressure Distribution Among Diabetes and Healthy Participants: A Cross-sectional Study" in pubmed central,Vol 12 ;Pp 88; Doi:10.4103/ijpvm.IJPVM_257_20.2021

[20] L. Motha, "Instrumented rubber insole for plantar pressure sensing (Available)," Org. Electron. vol. 23 pp 82–86, Doi:https://doi.org/10.1016/j. orgel.2015.04.020. 2015

[21] Najafi B., "Leveraging smart technologies to improve the management of diabetic foot ulcers and extend ulcer-free days in remission"Diabetes Metab. Res. Rev.[Google Scholar];Vol36:e3239. Doi: 10.1002/dmrr.3239. 2020

[22] Nalini Singh "Preventing foot ulcers in patients with diabetes" in Pub med National library of medicine, Vol 293(2) ; pp:217-28; Doi: 10.1001/jama.293.2.217.2005

[23] Naresh K Tyagi , "A study of dynamic foot pressure measurement in diabetic patients" in Journal of the scientific society ,Vol 44;Pp (76-79);DOI:10.4103/jss.JSS_23_17.2017

[24] Niemann U., " Plantar temperatures in stance position: A comparative study with healthy volunteers and diabetes patients diagnosed with sensory neuropathy", EBioMedicine.Google Scholar;Vol 54 :102712. Doi: 10.1016/j.ebiom.2020.102712 .2020

[25] A.N. Nithyaa , "A Real Time Foot Pressure Measurement for Early Detection of Ulcer Formation in Diabetics Patients Using Labview"in Procedia Engineering, Elsevier, vol 64, pp(1302-1309) , DOI:10.1016/j.proeng.2013.09.211.2013

[26] Olfat A Fawzy, " Plantar Pressure as a Risk Assessment Tool for Diabetic Foot Ulceration in Egyptian Patients with Diabetes"in pubmed central, vol 7:pp (31–39),Doi: 10.4137/CMED.S17088. 2014

[27] Periyasamy R, "Prevalence of standing plantar pressure distribution variation in north Asian Indian patients with diabetes mellitus". Proc Inst Mech Eng H.;vol 227(2)pp:181–9.[GoogleScholar],Doi:10.1177/0954411912460806.201

[28] Reeves N.D et al., " Leveraging smart technologies to improve the management of diabetic foot ulcers and extend ulcer-free days in remission"; Diabetes Metab. Res. Rev CrossRef.;vol 36:e3239. Doi: 10.1002/dmrr.3239. 2020

[29] Robert G. Crowther, " The Importance of Foot Pressure in Diabetes" in springer ,pp 759–787, Doi:10.1007/978-3-319-14418-4_39. 2018

[30] Singh N et al, " Preventing foot ulcers in patients with diabetes". JAMA CrossRef; Google Scholar.;Vol 293 pp:217–228. Doi: 10.1001/jama.293.2.217.2005.2006