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Assessing Foot Temperature in Diabetic Peripheral Neuropathy across Different Environments

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Abstract: ***Diabetic Peripheral Neuropathy (DPN) reduces sensation and temperature control in the feet, increasing the chances of ulcers and infection. This study examines how foot temperature changes in people with DPN when exposed to different environmental conditions. Using non-invasive temperature measurement, readings showed that individuals with DPN had less ability to adjust foot temperature compared to healthy subjects. These results suggest that surrounding temperature can affect foot readings and may hide early warning signs of complications. Considering environmental conditions during assessment may improve early detection and help prevent foot problems in people with DPN.***

Keywords: Diabetic Peripheral Neuropathy (DPN), Foot Temperature, Temperature Variation, Environmental Temperature, Diabetic Foot

I. INTRODUCTION

Diabetic peripheral neuropathy is a common problem faced by people with diabetes. It occurs when high blood sugar levels over a long period of time cause damage to nerves, especially in the feet, leading to a loss of feeling [1] [2]. Nearly 50% of people with diabetes suffer from nerve damage known as diabetic neuropathy [3]. One of the most important ways to manage diabetic neuropathy is to keep an eye on blood flow in the feet and catch signs of complications early. Checking foot temperature is key to doing this, as it can give clues about nerve damage and circulation problems [4]. Patients with diabetic neuropathy have higher foot temperatures (32-35°C) compared to those without neuropathy (27-30°C)[5][6]. In diabetic peripheral neuropathy, temperature changes especially in the feet and toes. But many times, the temperature of the feet and toes can be change because of environmental and physical activities can also affect body temperature [7]. To determine the exact foot temperature in individuals with diabetic peripheral neuropathy, or to understand how environmental temperature can affects our foot temperature varies in different environments, we collected data in different sessions without controlling room temperature.

II. LITERATURE SURVEY

Nigel A. S. Taylor et al. studied foot and hand temperatures and measured their changes in different environmental conditions to determine how ambient temperature affects body temperature. Their results showed that mean skin temperature increases by approximately 0.7 °C for every 1 °C rise in air temperature, with smaller changes observed at the hands (0.46 °C per 1 °C) and slightly larger changes at the feet (0.8 °C per 1 °C). They also stated that blood flow to the hands and feet represents their primary source of heat [7].

D. Hernandez-Contreras et al. studied the diabetic foot using thermal patterns based on the morphological pattern spectrum. The objective of their work was to develop a neural-network-based classifier capable of identifying temperature patterns corresponding to the control group and the diabetic (DM) group. A total of 120 samples were used for the study 60 from the control group and 60 from diabetic patients. The left and right feet were segmented from each thermogram, and each foot was considered a separate sample. According to the study, patients with diabetic neuropathy exhibited higher foot temperatures (32–35 °C) compared to those without neuropathy (27–30 °C) [8].

Nigel A. S. Taylor et al. studied the temperatures of the foot and hand under different environmental conditions to determine how environmental temperature affects body temperature. Their results showed that mean skin temperature increases by approximately 0.7 °C for every 1 °C rise in air temperature, with smaller changes observed in the hands (0.46 °C per 1 °C) and slightly larger changes in the feet (0.8 °C per 1 °C). They also stated that blood flow to the hands and feet serves as their primary source of heat [9].

Bagavathiappan et al. investigated plantar foot temperature and diabetic neuropathy using an infrared thermal imaging technique. For this study, they collected data from 112 subjects with type 2 diabetes. A thermal camera was used for data acquisition, and the room temperature was maintained at 25 °C during the process.

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Both foot and hand temperatures were recorded, with hand temperature serving as the reference. According to their findings, subjects with diabetic neuropathy exhibited higher foot temperatures compared to those without neuropathy. The foot temperature of neuropathic subjects ranged from 32–35 °C, whereas that of non-neuropathic subjects ranged from 27–30 °C [10].

III.DATABASE

The primary aim of this experiment is to collect a database of the same subject during different seasons, specifically winter and summer, to study how environmental changes impact human body temperature.

All data was collected from a total of 30 participants who fell within the age group of 30 to 60 years. It's important to note that the room temperature could not be controlled during the data collection process. Instead, all data were recorded in the natural outdoor environment.

TABLE 1: DATABASE

Number of Subjects	30
Age	30-60 years
Room temperature	Natural outdoor environment temperature

Data collection involves the use of four DS18B20 temperature sensors. Among these, two sensors are measuring the temperature of the right foot, while the remaining two sensors are responsible for measuring the temperature of the left foot. All four temperature sensors are attached to a single slipper. The diagram illustrates the slipper with the integrated temperature sensors



Fig 1: Data collection points where sensors are attached

A. Method

During the process of collecting data for our database, specific instructions were given to the subjects participating in the study. The instructions were as follows:

1) Footwear and Foot Clothes Removal: Subjects were requested to remove their footwear and any clothing covering their feet. This step was taken to ensure direct contact between the temperature sensors and the skin of the feet

2) Cleanliness of the Foot: It was important that the foot should be clean before proceeding further. This is important to prevent any external factors, such as dirt or debris, from disturbing the accuracy of the temperature measurements. A clean foot surface ensures that the sensors can make direct contact with the skin for accurate readings.

3) Placing the Foot on the Slipper: Once the foot was cleaned, subjects were instructed to place their foot onto a slipper. This slipper was attached DS18B20 temperature sensors. By placing the foot on the slipper, the sensors could make direct contact with the skin of the foot, helping accurate temperature measurement. Figure 2 shows the position of foot at the time of data collection.

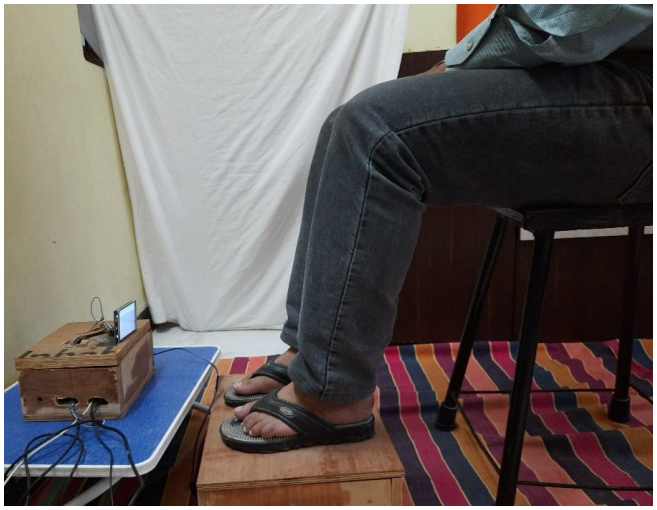


Fig 2: Position of subject at the time of data collection

B. Methodology

1) Collected the database in winter

During the winter months of December and January, the environmental temperature was around 24 ± 2°C. It's important to note that we were can not control or adjust the room temperature during the data collection sessions.

For each data collection session, participants were instructed to sit in a relaxed position within the room for a period of 10 to 15 minutes. This allowed them to adjust to the room's temperature and reach a state of comfort before proceeding with the data collection process. After that database are collected.

Following table shows the foot temperature of subjects in winter

TABLE 2: Database collected in winter

Sr. No	Foot temperature	Room Temperature	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to pathology report	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to our research
1	28°C	24 °C	Non Diabetic Neuropathy	Non Diabetic Neuropathy
2	29°C	24 °C	Non Diabetic Neuropathy(subject have a diabetes)	Non Diabetic Neuropathy(subject have a diabetes)
3	29°C	24 °C	Non Diabetic Neuropathy	Non Diabetic Neuropathy
4	33°C	24 °C	Diabetic Neuropathy	Diabetic Neuropathy
5	32°C	24 °C	Diabetic Neuropathy	Diabetic Neuropathy

Patients with diabetic neuropathy have higher foot temperatures (32–35 °C) compared to those without neuropathy (27–30 °C).

2) Collected the database in Summer

During the warmer months of April and May, the outdoor temperature ranged between 30 to 35°C. It's important to note that we were can not control or adjust the room temperature during the data collection sessions. For each data collection session, participants were instructed to sit in a relaxed position within the room for a period of 10 to 15 minutes. This allowed them to adjust to the room's temperature and reach a state of comfort before proceeding with the data collection process. After that database are collected.

Following table shows the foot temperature of subjects in summer

Table 3: Database collected in summer

Sr. No	Foot temperature	Room Temperature	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to pathology report	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to our research
1	31°C	35 °C	Non Diabetic Neuropathy	Non Diabetic Neuropathy
2	33°C	35 °C	Non Diabetic Neuropathy(subject have a diabetes)	Diabetic Neuropathy(subject have a diabetes)
3	32°C	35 °C	Non Diabetic Neuropathy	Diabetic Neuropathy
4	38°C	35 °C	Diabetic Neuropathy	Diabetic Neuropathy
5	37°C	35 °C	Diabetic Neuropathy	Diabetic Neuropathy

Patients with diabetic neuropathy have higher foot temperatures (32–35 °C) compared to those without neuropathy (27–30 °C). However, in the above table, the foot temperature of all subjects lies between 31–37 °C. This is because room temperature was not maintained during the measurements. Since room temperature was not controlled, the results are not accurate. To obtain appropriate and reliable results, it is necessary to maintain a controlled room temperature during data collection.

Now compare the foot temperature of both sessions.

The following table compared the results of foot temperature in winter and foot temperature in summer

Table 4: Compare the results table 1 and table 2

Sr. No	Foot temperature in winter season (Room temperature 24 ±1 °C)	Foot temperature in summer season (Room temperature 35 ±1 °C)	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to pathology report	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to our research(result in Winter)	Subject is Diabetic Neuropathy/ Non Diabetic Neuropathy according to our research(result in Summer)
1	28°C	31°C	Non Diabetic Neuropathy	Non Diabetic Neuropathy	Non Diabetic Neuropathy
2	29°C	33°C	Non Diabetic Neuropathy(subject have a diabetes)	Non Diabetic Neuropathy(subject have a diabetes)	Diabetic Neuropathy(subject have a diabetes)
3	29°C	32°C	Non Diabetic Neuropathy	Non Diabetic Neuropathy	Diabetic Neuropathy
4	33°C	38°C	Diabetic Neuropathy	Diabetic Neuropathy	Diabetic Neuropathy
5	32°C	37°C	Diabetic Neuropathy	Diabetic Neuropathy	Diabetic Neuropathy

IV. RESULT

According the outputs of this experiment which is shown in the above table 4 it is clear that, when the temperature of environment are change there is variation in the temperature of foot. For avoiding this problem and getting a correct value it is necessary to maintain the room temperature. In above table the result of subject 2 in winter the according to their foot temperature it is a Non Diabetic Neuropathy but when see the foot temperature in summer this subject have a diabetic neuropathy. So for knowing the correct result we take a foot temperature of this subject when a room temperature was constant 25 °C and then the foot temperature was 29 °C. It means this subject is Non Diabetic Neuropathy.

In the above table, the result for Subject 2 shows that in winter, the foot temperature indicates non-diabetic neuropathy. However, in summer, the same subject's foot temperature suggests diabetic neuropathy. To find the correct result, the foot temperature was measured again when the room temperature was kept constant at 25 °C. At this time, the foot temperature was 29 °C. This confirms that the subject does not have diabetic neuropathy.

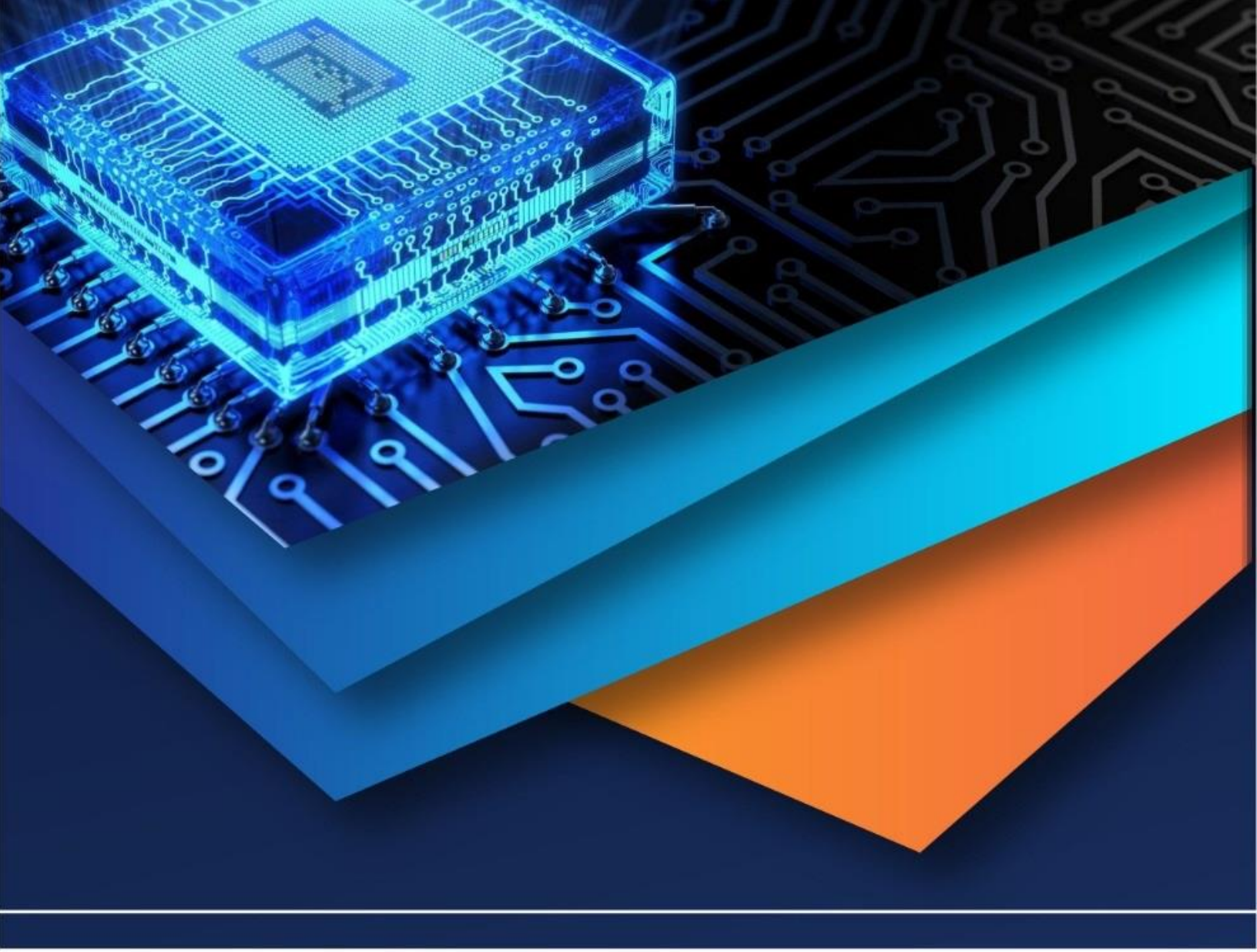
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V. CONCLUSION

This study shows that people with DPN cannot control their foot temperature well, especially when the outside temperature changes. Because of this, the temperature around them can affect the readings and may hide early signs of foot injury or infection. So, when checking foot temperature, it is important to consider the surrounding environment for correct results. Doing this can help identify problems sooner and may lower the chances of ulcers, infections, and other foot issues in people with DPN.

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