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A comparative study on cutaneous temperature difference between body and foot among patients of diabetic neuropathy and normal individuals

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ABSTRACT

Background: As diabetic neuropathy progresses, the pain subsides and eventually disappears, but a sensory deficit persists and a motor deficit may develop. Loss of protective sensation and distal sensory polyneuropathy are major risk factors for foot ulceration and falls due to small and large nerve fiber dysfunction, which predispose to lower extremity amputation. **Aims and Objectives:** We did a comparative study on the cutaneous temperature difference between the body and foot among patients of diabetic neuropathy and patients of diabetes without neuropathy to establish the role of pedal temperature monitoring in preventing complications of diabetic neuropathy. **Materials and Methods:** The study was done at Maharani Laxmi Bal Medical College, Jhansi, between April 2021 and November 2022, including two groups of patients (Group A: 100 patients with diabetes without neuropathy and Group B: 100 patients with diabetes as well as with neuropathy). **Results:** In our study, in group A (diabetic patients without neuropathy), 9% were in 18–30 years, 14% in 31–40 years, 19% in 41–50, 29% in 51–60, and 29% in >60 years. In group B (diabetic patients with neuropathy), 2% were in 31–40 years, 16% in 41–50, 35% in 51–60, and in 46% in >60 years. In our study, the mean foot temperature in group A (diabetic without neuropathy) was 97.35±0.625 and in group B (diabetic patients with neuropathy) was 99.19±1.375. There was a significant difference between the groups on the basis of mean changes in foot temperature ($P \geq 0.01$). **Conclusion:** Based on the above study, we came to the conclusion that foot temperature is significantly higher in diabetic patients with neuropathy. An infrared thermometer can be used as a home-based tool as well as in an outpatient department setting to avoid the dreaded complications of diabetic neuropathy or at least to delay the progression of the same.

Key words: Diabetic neuropathy; Mean foot temperature; Type 2 diabetes

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INTRODUCTION

The worldwide prevalence of diabetes mellitus has risen dramatically over the past two decades, from an estimated 30 million cases in 1985 to 463 million in 2019. The countries with the greatest number of individuals with diabetes in 2019 were China (116.4 million) and India (77 million), among other countries.[1]

In the most recent estimate for the United States in 2020 the Centers for Disease Control and Prevention estimated that 10.5% of the population had diabetes.[2]

The American Diabetes Association recommends annual screening for distal polyneuropathy, beginning with the initial diagnosis of diabetes, and annual screening for autonomic neuropathy.[3]

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As diabetic neuropathy progresses, the pain subsides and eventually disappears, but a sensory deficit persists and a motor deficit may develop. Loss of protective sensation and distal sensory polyneuropathy are major risk factors for foot ulceration and falls due to small and large nerve fiber dysfunction, which predispose to lower extremity amputation.[4,5]

Despite preventive measures, foot ulceration and infection are common and represent a serious problem. Due to the multifactorial pathogenesis of lower-extremity ulcers, management of these lessons in multidisciplinary and often demands expertise in orthopedics, vascular surgery, endocrinology, podiatry, and infectious disease.

The plantar surface of the foot is the most common site for ulceration. Ulcers may be primarily neuropathic (no or minimum infection) or infective.[6]

It is a well-established fact that the most common complication of diabetes mellitus is diabetic peripheral neuropathy.[6]

A delay in the diagnosis and management of neuropathy leads to the formation of foot ulcers, Charcot joints, and limb loss. All this results in enlarged figures of morbidity, mortality, and financial loss.[6]

In this study, we compared the temperature of both feet and the temperature of the feet with the body temperature in diabetic patients with neuropathy and diabetic patients without neuropathy.[6]

We studied the feasibility and efficacy of infrared thermography in detecting the site at risk for developing diabetic foot ulcers (DFU). Preventive measures like footwear modification, surgical and non-surgical offloading were done based on this study.

Aims and objectives

We did a comparative study on the cutaneous temperature difference between body and foot among patients with diabetic neuropathy and patients of diabetes without neuropathy to establish the role of pedal temperature monitoring in preventing complications of diabetic neuropathy.

MATERIALS AND METHODS

Ethical

The ethical committee's approval was duly taken. Data were collected in the department of general surgery from the bedside tickets of the patients after obtaining a short history and informed consent from the patient.

Source of data

The study was done at Maharani Laxmi Bal Medical College, Jhansi, between April 2021 and November 2022, including two groups of patients. Each group of 100 patients, i.e.,

1. 100 patients with diabetes without neuropathy
2. 100 patients with diabetes as well as with neuropathy.

Patients had been chosen from those attending the diabetic clinic, surgery out-patient department (OPD), and inpatient department at Maharani Laxmi Bai Medical College, Jhansi.

Inclusion criteria

- Age >18 years
- Type 2 diabetes with peripheral neuropathy
- Type 2 diabetes without peripheral neuropathy.

Exclusion criteria

- DM with Gangrene
- Malignancy
- Type 2 diabetic patients with major critical illnesses
- Type 2 diabetic patients with osteomyelitis.

Material used (Figure 1)

- Commercially available infrared thermometer.

(Technical specifications: Resolution 0.1°C, Accuracy±0.4°C, Response time <I second, measuring distance <1 cm, Power- -9v dry cell, °C/°F. Display selection and laser targeting)

- Semmes-Weinstein monofilaments
- 128 Hz tuning fork.

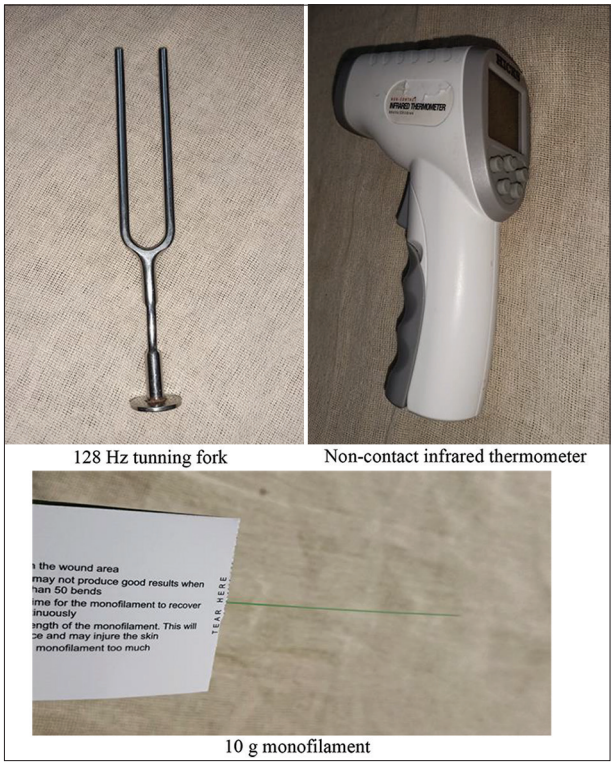

Figure 1: Material used in this study

Methods

History

We took a detailed history comprising symptoms and signs of diabetes, keeping in mind foot complications of diabetic neuropathy.

Key components of the history included previous foot ulcerations or amputations. Other important assessments in the history include neuropathic or peripheral vascular symptoms, impaired vision, or renal replacement therapy.

General inspection

A careful inspection of the feet in a well-lit room was carried out after the patient had removed shoes and socks. Examples of inappropriate shoes include those that are excessively worn or are too small for the person's feet (too narrow, too short, toe box, too low), resulting in rubbing, erythema, blisters, or calluses.

Dermatological assessment

The dermatological assessment included a global inspection, including interdigital spaces, for the presence of ulceration or areas of abnormal erythema. The presence of callus (particularly with hemorrhage), nail dystrophy, or paronychia was recorded.

Musculoskeletal assessment

The musculoskeletal assessment included an evaluation for any gross deformity. Common forefoot deformities like metatarsal phalangeal joint hyperextension with interphalangeal flexion (claw toe) or distal phalangeal extension (hammer toe) and Charcot arthropathy.

Neurological assessment

Neurological assessment included the study of sensory function, leg muscle strength, and ankle reflexes.

Semmes-Weinstein monofilaments were used to diagnose sensory loss.

Four sites (1st, 3rd, and 5th metatarsal heads and the plantar surface of the distal hallux) were tested on each foot.

Nylon monofilaments are constructed to buckle when a 10-g force is applied; loss of the ability to detect this pressure at one or more anatomic sites on the plantar surface of the foot has been associated with loss of large-fiber nerve function.

Vibratory sensations were tested over the tip of the great toe bilaterally using a 128-Hz tuning fork.

A disposable pin was applied just proximal to the toenail on the dorsal surface of the hallux, with just enough pressure to deform the skin. The inability to perceive pinpricks over either hallux was regarded as an abnormal test result.

The ankle reflex was tested with the help of a tendon hammer. Total absence of ankle reflexes either at rest or upon reinforcement was regarded as an abnormal result.

Vibration perception was tested with the help of a 128 Hz tuning fork over the pulp of the great toe.

Temperature was measured on the sole of the foot, 1st, 3rd metatarsal head, great toe, central midfoot, heel, and dorsum of the foot, and the average was taken as foot temperature.

The average temperature of the forehead, right axilla, and left axilla was taken as the average body temperature. The temperature was recorded with an infrared thermometer.

The differences in average pedal temperature from average body temperature were noted. Measurements were performed at a constant room temperature, and a 10-min interval for patient acclimatization after the removal of socks and shoes was allowed. In cases where we encountered patients with active ulcers, surgical interventions like amputations, osteotomies, or flap reconstructions were performed.

Statistical analysis

The data were summarized as mean values with standard deviations. The statistical analysis was performed using the student t-test and Chi-square. The statistical package for social sciences (SPSS) 26.0 for Windows computer software (SPSS Inc., Chicago, IL) was used for statistical analysis. $P<0.05$ was considered significant.

RESULTS

In our study, in group A (diabetic patients without neuropathy), 9% were in 18–30 years, 14% in 31–40 years, 19% in 41–50, 29% in 51–60, and 29% in >60 years. In group B (diabetic patients with neuropathy), 2% were in 31–40 years, 16% in 41–50, 35% in 51–60, and 46% in >60 years (Table 1).

The mean age of patients in group A was 54.70±16.452 years and in group B was 58.21±6.826 years (Table 2). There was no significant difference between the three groups on the basis of age distribution ($P\geq0.49$), and the maximum number of patients was 51–60 years of age in both groups.

Sex

In our study, in group A (diabetic patients without neuropathy), males were 55% and females were 45%, and in group B (diabetic patients with neuropathy), males were 66% and females were 34% (Table 3).

Dermatological changes

In our study, in group A (diabetic without neuropathy), dermatological changes were present in 7% of patients,

and in group B (diabetic patients with neuropathy), dermatological changes were present in 17%. There was a significant difference between the groups on the basis of dermatological changes (P≥0.02) (Table 4).

Musculoskeletal deformity

In our study, in group A (diabetic without neuropathy), 9% had claw toes, 5% had charcot preeminent metatarsals, and 2% had muscle wasting. In group B (diabetic patients with neuropathy), 23% had claw toes, 23% had charcot preeminent metatarsals, and 1% had muscle wasting (Table 5).

Body and foot temperature

In our study, mean body temperature in group A (diabetic patients without neuropathy) was 97.45±1.692 and in group B (diabetic patients with neuropathy) was 97.73±1.194. There was no significant difference between the groups on the basis of mean changes in body temperature (P≥0.09) (Table 6).

In our study, mean foot temperature in group A (diabetic without neuropathy) was 97.35±0.625 and in group B (diabetic patients with neuropathy) was 99.19±1.375. There was a significant difference between the groups on the basis of mean changes in foot temperature (P≥0.01) (Table 6).

Body and foot temperature in ulcer patient with neuropathy

In our study, mean body temperature in ulcer patient with neuropathy was 97.0±0.555 and mean foot temperature in ulcer patient with neuropathy was 101.4±0.688 between the groups on the basis of mean changes in body and foot temperature ulcer (P<0.05) (Table 7).

Table 1: Age wise distribution in our study

Age (in years)	Group A (diabetic without neuropathy)		Group B (diabetic with neuropathy)	
	n	%	N	%
18–30 years	09	09.00	00	00.00
31–40 years	14	14.00	02	02.00
41–50 years	19	19.00	16	16.00
51–60 years	29	29.00	35	35.00
>60 years	29	29.00	46	46.00

Table 2: Mean age wise distribution in our study

Age (in years)	Group A (diabetic without neuropathy)	Group B (diabetic with neuropathy)	P-value (t-test)
Mean±standard deviations	54.70±16.452	58.21±6.826	0.56

Table 3: Sex-wise distribution in our study

Age (in years)	Group A (diabetic without neuropathy)		Group B (diabetic with neuropathy)	
	n	%	N	%
Male	55	55.00	66	66.00
Female	45	45.00	34	34.00
Total	100	100	100	100

Table 4: Dermatological changes in our study

Dermatological changes	Group A (diabetic without neuropathy)		Group B (diabetic with neuropathy)	
	n	%	N	%
Present	07	07.00	17	17.00
Absent	93	93.00	83	83.00
Total	100	100	100	100

The Chi-square statistic is 4.7348. The P=0.02

DISCUSSION

In our study, we took the mean pedal temperature as an average of the first metatarsal head, the third metatarsal head, the fifth metatarsal head, the great toe, the central midfoot, the dorsum of the foot, and the mean body temperature as an of both axilla and forehead.

Table 5: Musculoskeletal deformity in our study

Musculoskeletal deformity	Group A (diabetic without neuropathy)		Group B (diabetic with neuropathy)	
	n	%	N	%
Claw toes	9	9.00	23	23.00
Charcot preeminent metatarsals	5	5.00	23	23.00
Muscle wasting	2	2.00	1	1.00

Table 6: Body and foot temperature with and without neuropathy (n=17)

Temperature (°F)	Group A (diabetic without neuropathy)	Group B (diabetic with neuropathy)	t-value	P-value
Body mean temperature	97.45±1.692	97.73±1.194	−1.341	0.090
Foot mean temperature	97.35±0.625	99.19±1.375	−12.183	<0.001

Table 7: Body and Foot temperature in ulcer patient with neuropathy (n=17)

Temperature (°F)	Body mean temperature	Foot mean temperature	t-value	P-value
Ulcer patient with neuropathy (n=17)	97.0±0.555	101.4±0.688	−20.169	0.0001 (S)

We used a non-invasive, non-contact device to measure temperatures, i.e., a handheld digital infrared thermometer, keeping feasibility in mind.

Our study shows that patients classified as having diabetic neuropathy (we used the diabetic neuropathy index for the same) consistently showed higher foot temperatures as compared to patients without neuropathy.

Hile and Veves[7] reviewed thermal measurement techniques specific to the diabetic foot, such as electrical contact thermometry, cutaneous thermal discrimination thresholds, IRI, and liquid crystal thermography.

Armstrong et al.,[8] compared the skin temperatures of patients with asymptomatic peripheral sensory neuropathy, neuropathic ulcers, and charcot's arthropathy using the contralateral limb as a control. Their study concluded that monitoring of the corresponding contralateral foot site can provide clinical information before other clinical signs of injury can be identified.

Deng and Liu[9] proposed a novel approach to effectively enhance the skin thermal expression of a tumor by induced evaporation on the skin surface. Systematic studies on home temperature monitoring of foot ulcers in high-risk patients with diabetes revealed that high-temperature gradients between can predict the onset of neuropathic ulceration and reduce the risk of ulceration.

The diabetic neuropathic foot is considered warm, with palpable pulses and distended veins, indicating increased blood flow in the affected limb. It has been reported that microcirculation is stable or even reduced due to sluggish blood flow to the foot.[10]

The ability to increase blood flow depends on the existence of a normal neurogenic vascular response. Due to impaired neuro-vascular responses in diabetic neuropathy subjects, a significant reduction in blood flow under conditions of injury or infection is observed.[11]

A systematic study shows that the nerve-axon-related vasodilatory response to iontophoresis of acetylcholine was significantly reduced in diabetes patients when compared with healthy subjects or diabetes patients without complications.[12]

In all these studies, only relative and not absolute temperatures are significant, and the relative temperatures have to be measured at many points on the skin; in this sense, the infrared sensor (IR) sensing device has many advantages over conventional devices.[13]

One disadvantage of IR devices seems to be their higher cost than other temperature monitoring devices.

However, as it is a non-contact device, it can be considered to be used for multiple subjects suitable for an OPD scenario. Furthermore, results are displayed quite quickly adding another merit to it.

In our study, we took 100 patients without neuropathy as cases, of whom 17 patients had DFU. We observed that there is a significant difference between mean pedal temperatures and average body temperature in the patients with neuropathy.

This difference was even more in patients with active ulcers over their feet; however, the degree to which ulceration effects this difference figure cannot be established clearly.

We advised some of the patients having trophic ulcers in their initial stages about silicon soft insoles and other foot care measures regarding the prevention of further complications.

The patients who presented to the OPD with active ulcers were planned for surgical interventions like rotation flaps, offloading oseteotomies, and debridement with significant positive results (Figures 2 and 3).

Figure 2: Deep trophic ulcers need to be managed by surgical means like flap reconstruction

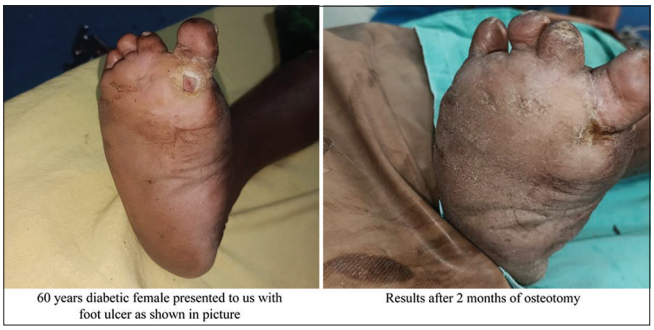

Figure 3: Sometimes part of bone have to be removed to avoid continuous pressure leading to diabetic foot ulcer

The mean age of diabetic patients with neuropathy was 58.21 years, compared to 54.7 years for patients without neuropathy, as neuropathy develops as a complication of diabetes later.

We have used a 10 g Semms-Weinstein monofilament and a 128 Hz tuning fork for vibration assessment as a path of neurological assessment, and patients are classified as having neuropathy on the basis of the diabetic neuropathy index.

The graph of pedal temperature sits higher than the body temperature graph in individuals with neuropathy.

Furthermore, individuals with active ulcers over the foot had quite high placed pedal temperatures than average body temperatures, with a mean difference of =4.4°F in our study among 17 patients who were also having DFU.

Limitations of the study

Study were small sample size, short study duration, and difficult logistics.

CONCLUSION

On the basis of the above study, we came to the conclusion that foot temperature is significantly higher in diabetic patients with neuropathy.

An infrared thermometer can be used as a home-based tool as well as in an OPD setting to avoid the dreaded complications of diabetic neuropathy, or at least to delay the progression of the same.

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REFERENCES

1. International Diabetes Federation. IDF Diabetes Atlas. 9th ed. Brussels, Belgium: International Diabetes Federation; 2019.
2. National Diabetes Statistics Report; 2020. Available from: https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf [Last accessed on 2020 Feb 24].
3. Pop-Busui R, Boulton AJ, Feldman EL, Bril V, Freeman R, Malik RA, et al. Diabetic neuropathy: A position statement by the American Diabetes Association. Diabetes Care. 2017;40(1):136-154. https://doi.org/10.2337/dc16-2042
4. Jameson JL, Fauci A, Kasper D, Hauser S, Longo D and Loscalzo J. Harrison's Principles of Internal Medicine. United States: McGraw-Hill Education; 2018.
5. Amin N and Doupis J. Diabetic foot disease: From the evaluation of the "foot at risk" to the novel diabetic ulcer treatment modalities. World J Diabetes. 2016;7(7):153-164. https://doi.org/10.4239/wjd.v7.i7.153
6. Powers AC, Stafford JM and Rickels MR. Diabetes Mellitus: Complications. Harrison's Principles of Internal Medicine. 20th ed., Ch. 398. United States: McGraw Hill; 2018.
7. Hile C and Veves A. Diabetic neuropathy and microcirculation. Curr Diab Rep. 2003;3(6):446-451. https://doi.org/10.1007/s11892-003-0006-0
8. Armstrong DG, Lavery LA, Liswood PJ, Todd WF and Tredwell JA. Infrared dermal thermometry for the high-risk diabetic foot. Phys Ther. 1997;77(2):169-175. https://doi.org/10.1093/ptj/77.2.169
9. Deng ZS and Liu J. Enhancement of thermal diagnostics on tumors underneath the skin by induced evaporation. Conf Proc IEEE Med Biol Soc. 2005;7:7525-7528. https://doi.org/10.1109/IEMBS.2005.1616253
10. Murray HJ and Boulton AJ. The pathophysiology of diabetic foot ulceration. Clin Podiatr Med Surg. 1995;12(1):1-17.
11. Jörneskog G, Brismar K and Fagrell B. Skin capillary circulation severely impaired in toes of patients with IDDM, with and without late diabetic complications. Diabetologia. 1995;38(4):474-480. https://doi.org/10.1007/BF00410286
12. Arora S, Smakowski P, Frykberg RG, Simeone LR, Freeman R, LoGerfo FW, et al. Differences in foot and forearm skin microcirculation in diabetic patients with and without neuropathy. Diabetes Care. 1998;21(8):1339-1344. https://doi.org/10.2337/diacare.21.8.1339
13. Vainer BG. FPA-based infrared thermography as applied to the study of cutaneous perspiration and stimulated vascular response in humans. Phys Med Biol. 2005;50(23):R63-R94. https://doi.org/10.1088/0031-9155/50/23/R01

Author's Contribution:
NM, SK, ASY -Concept and design of the study, prepared first draft of manuscript; interpreted the results; reviewed the literature and manuscript preparation; concept, coordination, preparation of manuscript and revision of the manuscript.

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