ORIGINAL RESEARCH PAPER
Volume - 13 | Issue - 12 | December - 2024 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

REDUCING THE IMPACT OF DIABETIC FOOT ULCER IN WORKING AGE GROUP PEOPLE OF RURAL INDIA BY SCREENING PLANTAR PRESSURE BY FOOT IMPRINTS

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ABSTRACT

This study, funded by ICMR (Indian Council of Medical Research) investigates the relationship between plantar pressure distribution and diabetic foot ulcers, aiming to predict patient outcomes. The findings have significant implications for early intervention and management of high-pressure areas to prevent ulcer formation and improve prognosis.

Key Highlights:

1. High plantar pressure gradient found in forefoot, hindfoot, and 1st toe of both feet in diabetic foot ulcer patients.
2. Commonest sites of ulcer formation: forefoot, hindfoot, and toes.
3. Association between deformities, callosities, and limited ankle joint mobility with high plantar pressure.
4. Poor prognostic index for diabetic foot ulcer patients with recurrent or non-healing ulcers.

The Importance of This Study Lies in its Potential to:

1. Identify high-risk patients for early intervention and prevention of foot ulcers.
2. Inform targeted treatment strategies for reducing plantar pressure and promoting ulcer healing.
3. Enhance patient outcomes and quality of life by minimizing the risk of complications.
4. Contribute to the development of personalized care plans for diabetic patients.

By understanding the relationship between plantar pressure distribution and diabetic foot ulcers, paves us the way for improved management and prevention of various debilitating complications.

KEYWORDS

Diabetic Foot Ulcer, Plantar Pressure, Diabetes Mellitus, Reducing The Impact

INTRODUCTION

Diabetes mellitus (DM) is one of the leading non communicable disease in the current scenario whose incidence may double in the upcoming years. Almost half of the patients with diabetes are undiagnosed, which results in increased burden of undetected diabetics in the society. (1) It is considered to be a chronic metabolic disease characterized by hyperglycaemia, which in later stages will cause damage to nerves, vasculature, eyes and kidney. (2) More than 90% of the cases are of type 2 DM, a condition characterized by deficient secretion of insulin by islet β-cells of pancreas, Insulin resistance of tissues and inadequate compensatory secretion of insulin and obesity (2,3). An estimated 537 million adults aged 20–79 years worldwide (10.5% of all adults in this age group) have diabetes. (4) Diabetic foot ulcer is a serious complication of DM associated with major mortality, morbidity, and reduced quality of life. (5) About 15% of people who have Diabetes mellitus, develop foot ulcer in their lifetime and the annual incidence is 2-3%. (6) This is attributed to various cultural practices and social behavior such as poor socioeconomic conditions, barefoot walking and insufficient facilities for diabetic education and care. (7) Regular evaluation and providing early treatment should be implemented to reduce the risk of developing foot complications. Early detection of the diabetic foot at risk should be a high priority to achieve such aims. (8). There is prolongation of inflammatory phase in these patients, this causes delayed formation of mature granulation tissues which ultimately decreases the wound healing. There is increased possibility of contracting infections in these patients, as the immune response of these patients are suppressed, this further results in occurrence of more complications, which ultimately increases the morbidity. Amputation becomes the only scope of treatment in these kinds of patients, which is deemed to limit the ability of an individual. (9,10) There is a requirement for an interdisciplinary approach, for better prognosis of a patient with diabetic foot ulcer. (10) Some risk factors that have been found to be associated with DFU are previous ulceration, peripheral neuropathy, limited joint mobility and high dynamic plantar foot pressure. (11) It has been found that the diabetic foot ulcerations occurred almost exactly at the sites with raised plantar pressure gradient. Also, in cases of healed ulcers, it has been found that there are high rates of recurrence in places with raised plantar pressure gradient. This ultimately concludes the necessity of assessing the plantar pressure in . formation of foot ulcer due to the increased plantar pressure gradient. (26) It has been found that diabetes itself is one of the important risk factors responsible for the causation of limited joint mobility in the ankle, when compared to the non-diabetic patients. (27) Delbridge et al. has shown that LJM predisposes to foot ulcer in susceptible neuropathic feet. (28) The limitation of the joint mobility is found to occur in a wide range of age groups who are diagnosed as diabetics, the limitation of joint moments has a gradual increase with age. (29) Autonomic neuropathy causes collagen glycation, which leaves to limited joint mobility especially in the foot. (30,31)

Rationale

This study focuses on one of the most prevalent complications of diabetic mellitus, that is diabetic foot ulcer which results in higher levels of morbidity and disability in the patients. In this study, after comparing the regions of foot with raised plantar pressure distribution with the most common site of occurrence of ulcer and the reason for non-healing of the ulcers at these common sites, we can further determine the raise in plantar pressure gradient and their association with the reason behind the raise in the plantar pressure. After this study we will have a forehand grip on the determination of the prognosis in the diabetic patients which may be implicated for the purpose of proper well guided health education to these patients along with a proper treatment plan to reduce the burden of diabetic foot ulcer in the society. This will have a positive impact on families with a sole breadwinner who are suffering from the shortcomings of this disease. This also helps in predicting the outcome of the patients suffering from diabetes mellitus, by the usage of least number of resources of the hospital, hence using the hospital resources in a judicious way.

Review

1. Fernando ME, Crowther RG, Lazzarini PA, Sangla KS, Wearing S, Buttner P, Golledge J, study on plantar pressures in diabetic foot ulcers patients compared to controls despite a longer stance phase duration was done, from this study it reveals that the commonest regions of occurrence of diabetic foot ulcer were the regions with raised plantar pressure gradient. This conclusion is hence used for predicting the commonest sites of occurrence of diabetic foot ulcer based on the plantar pressure gradient of the foot.

2. a). Z. Pataky, A. Golay, L. Faravel et al., study on the impact of callosities on the plantar pressure in patients with diabetes mellitus, it is concluded that raise in plantar pressure is seen at the site of presence of callosity, which decreases on removal of the callosity from that site of the foot.
b. A. C. Duffin, R. Kidd, A. Chan, and K. C. Donaghue, study on high plantar pressure and callus in diabetic adolescents, we can conclude the raised plantar pressure in presence of callus is seen in younger age group people.
c. H. B. Menz, G. V. Zammit, and S. E. Munteanu, study on higher plantar pressures on callused regions of the foot in older people, we can infer that regional raise in plantar pressure in presence of callus in foot was significantly higher in older people.
From these studies the association between the raised plantar pressure gradient and the presence of callosity is studied for its significance across various areas of the foot.
3. Tang UH, Zügner R, Lisovskaja V, Karlsson J, Hagberg K, Tranberg R did a study on Foot deformities, function in the lower extremities, and plantar pressure in patients with diabetes at high risk to develop foot ulcers, this study concludes that the presence of foot deformity raises the chances for foot ulceration by raising the plantar pressure. The association of foot deformity in each region of foot with the raise in plantar pressure gradient in different regions of foot and its significance is studied.
4. Zimny S, Schatz H, Pfohl M., study on the role of limited joint mobility in diabetic patients who were at higher risk, infers us that limitation in joint mobility increases the plantar pressure gradient of the foot.

Aims and Objectives:
Aim: To assess the plantar pressure in diabetic and diabetic foot ulcer patients and predict their outcomes.
Objectives
1. To study the plantar pressure distribution in a diabetic foot ulcer patient.
2. To grade the plantar pressure distribution in patients.
3. To find the most common sites of occurrence of diabetic foot ulcers based on the plantar pressure findings.
4. To study the prognosis of diabetic foot ulcer disease based on the plantar pressure distribution.

MATERIALS AND METHODS:
Materials:
Study Design: An Observational study
Sample Size: 331 cases
Study Site: Tertiary care hospital in a rural district
Period Of Study: 1 May 2022 to 31 June 2022
Duration Of Study: 2 Months

Inclusion Criteria
1. Patient with uncontrolled type 2 diabetes mellitus.
2. Healed or active diabetic foot ulcer patients.

Exclusion Creiteria:
1. Psychiatric patients.
2. Patients not giving consent.

Methodology
After getting the ethical committee clearance from the institutional ethics committee, the study was done in a tertiary care hospital in a rural district, which was funded by the ICMR (Indian Council of Medical Research). After the patients were informed about the objectives of the study, a written consent was obtained from the patient before collecting the blood samples, assuring confidentiality of the data collected. The patient was recruited from the Surgery Out Patient Department based on the inclusion and exclusion criteria. A detailed history regarding the onset of disease and the duration of treatment was recorded, after which blood samples were taken to analyse HbA1c, fasting blood sugar (FBS) and postprandial blood sugar (PPBS) levels. Then the patient was clinically examined by inspection and palpation for the presence of ulcers in the foot, deformity in forefoot; midfoot; hindfoot, callosities, fissures, cracks present in the foot and for any restrictions in the range of movements of the ankle joint by using a goniometer. Then the plantar pressure of the patients was recorded by taking foot imprint using Harris Mat. The patients were asked to step on the Harris Mat on their third step of walking to get the foot imprint. The foot imprints taken are then analysed in a computer software, analysing foot imprints and the plantar pressure distribution was graded based on the colour coding's.

Grading Of Plantar Pressure Distribution:

PLANTAR PRESSURE DISTRIBUTION	COLOUR CODING
Very high-pressure distribution	Red colour
High pressure distribution	Orange colour
Mild pressure distribution	Yellow colour
Normal pressure distribution	Green colour
Minimum pressure distribution	Blue colour
No contact area	White colour

Statistical Analysis
Statistical analysis will be done using SPSS (Statistical Package of Social Science) software.

It would be used to enter and analyse data. The quantitative variables are expressed as a mean +/- standard deviation (S.D), whereas qualitative data was presented by frequency and percentages. The Student Chi - square test was applied to determine the significant difference between the groups. All statistical analysis will be carried at 5% level of significance and P value less than 0.05 will be considered statistically significant.

OBSERVATION AND RESULTS:
Sociodemographic Details:
A total of 331 patients were included in the study which included both the genders, out of which 231 patients were only diabetic and 100 patients had diabetic foot ulcer along with diabetes. [FIGURE 1]
FIGURE 1:

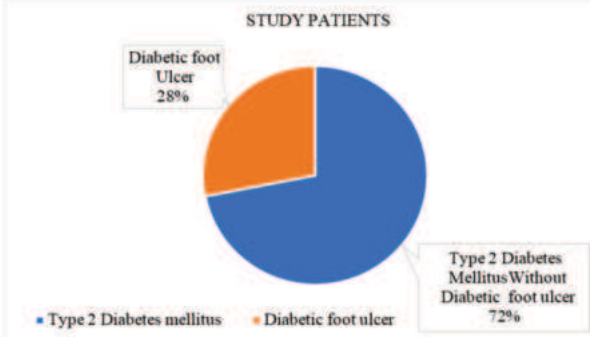


Table 1: General Characteristics Of The Patients:

	MEAN	STANDARD DEVIATION
Average Age	55.1994	11.18371
Average BMI	24.9819	1.81628
HbA1c	8.2208	1.51890
FBS	162.6073	37.87375
PPBS	218.2991	53.01502

1. Plantar pressure distribution in Diabetic foot ulcer patients:
The table below shows the Plantar Pressure gradient distribution of forefoot, midfoot, hindfoot, 1st toe, 2nd toe, 3rd toe, 4th toe and the 5th toe of both right [TABLE 2A] and left foot [TABLE 2B], which occurred with the maximum frequency in the patients with diabetic foot ulcer.

Table 2a:

RIGHT FOOT	MODE	FREQUENCY
Forefoot	Red	48%
Midfoot	Blue	31%
Hindfoot	Red	40%
1st toe	Red	29%
2nd toe	Blue	31%
3rd toe	Blue	36%
4th toe	Blue	43%
5th toe	Blue	33%

Table 2b:

LEFT FOOT	MODE	FREQUENCY
Forefoot	Red	45%
Midfoot	Red	25%
Hindfoot	Red	51%
1st toe	Red	45%
2nd toe	Yellow	29%

3rd toe	Blue	32%
4th toe	Blue	44%
5th toe	Blue	45%

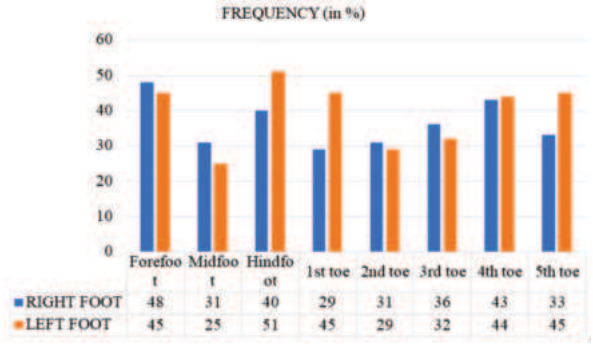


Figure 2:

From this [FIGURE 2] we can conclude that, the forefoot, hindfoot, 1st toe of right foot and forefoot, midfoot, hindfoot, 1st toe of left foot have a very high-pressure gradient in most of the patients with diabetic foot ulcer.

2. Plantar Pressure Distribution In Diabetic Patients:

The table below shows the Plantar Pressure gradient distribution of forefoot, midfoot, hindfoot, 1st toe, 2nd toe, 3rd toe, 4th toe and the 5th toe of both right [TABLE 3A] and left foot [TABLE 3B], which occurred with the maximum frequency in the patients with only diabetes mellitus.

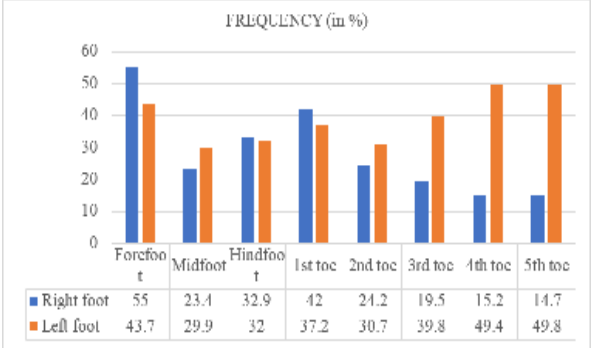
Table 3a:

RIGHT FOOT	MODE	FREQUENCY (IN%)
Forefoot	Red	55%
Midfoot	Green	23.4%
Hindfoot	Red	32.9%
1st toe	Red	42%
2nd toe	Yellow	24.7%
3rd toe	Blue	32%
4th toe	Blue	39%
5th toe	Blue	45%

Table 3b:

LEFT FOOT	MODE	FREQUENCY (IN%)
Forefoot	Red	43.7%
Midfoot	Yellow	39.9%
Hindfoot	Red	32%
1st toe	Red	37.2%
2nd toe	Green	30.7%
3rd toe	Blue	39.8%
4th toe	Blue	49.4%
5th toe	Blue	49.8%

FIGURE 3:



From this [FIGURE 3] we can observe that the forefoot, hindfoot, 1st toe of both the right and the left foot have a very high plantar pressure gradient in a patient who is diabetic without any diabetic foot ulcers.

3. Commonest Sites Of Occurrence Diabetic Foot Ulcer Based On The Plantar Pressure Findings:

No. of people with diabetic foot ulcer in right foot [TABLE 4A]: 57
No. of people with diabetic foot ulcer in left foot [TABLE 5A]: 43

Table 4a: Sites Of Foot Ulcer In Right Foot:

RIGHT FOOT ULCERS	NO. OF PEOPLE	FREQUENCY (in %) [FIGURE 4]
Forefoot	14	14%
Midfoot	2	2%
Hindfoot	8	8%
Toes	7	7%
Forefoot & midfoot	6	6%
Midfoot & hindfoot	6	6%
Forefoot, toes	10	10%
Forefoot, midfoot, hindfoot	1	1%
Forefoot, midfoot, toes	3	3%
TOTAL	57	

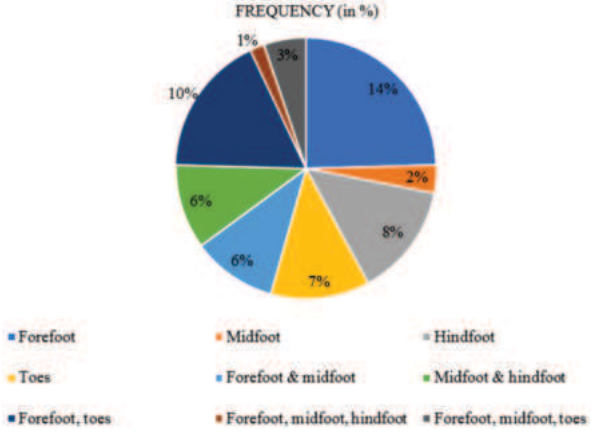


Table 4b: Plantar Pressure Gradient Of Right Foot:

RIGHT FOOT	MODE	FREQUENCY (in%)
Forefoot	Red	52.9%
Midfoot	Blue	25.1%
Hindfoot	Red	35%
1st toe	Red	38.1%
2nd toe	Red	24.2%
3rd toe	Blue	33.2%
4th toe	Blue	40.2%
5th toe	Blue	41.4%

From this [TABLE 4B] we can observe the commonest sites for ulcer to develop are the forefoot, hindfoot and the toes, corresponding to the raised plantar pressure gradient.

Table 5a: Sites Of Foot Ulcer In Left Foot:

LEFT FOOT ULCERS	NO. OF PEOPLE	FREQUENCY (in%) [FIGURE 5]
Forefoot	11	11%
Midfoot	2	2%
Hindfoot	9	9%
Toes	4	4%
Forefoot & midfoot	3	3%
Midfoot & hindfoot	3	3%
Forefoot, toes	6	6%
Forefoot, midfoot, hindfoot	1	1%
Forefoot, midfoot, toes	4	4%
TOTAL	43	

FIGURE 5:

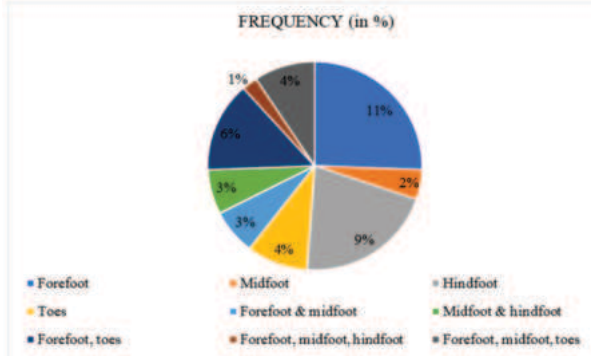


Table 5b: Plantar Pressure Gradient Of Left Foot:

LEFT FOOT	MODE	FREQUENCY OF PEOPLE
Forefoot	Red	45%
Midfoot	Red	25%
Hindfoot	Red	51%
1st toe	Red	45%
2nd toe	Yellow	29%
3rd toe	Blue	32%
4th toe	Blue	44%
5th toe	Blue	45%

From this [TABLE 5B] we can observe that forefoot, hindfoot and the toes were commonly the sites of ulcer formation, corresponding to the raised plantar pressure in these areas.

4. Prognosis Of Diabetic Foot Ulcer Based On Plantar Pressure Findings:

A) Association between deformities and plantar pressure in different regions of the foot:

Table 6a: Right Foot:

Regions of foot	P value
Forefoot	0.406
Midfoot	0.065
Hindfoot	0.071
1st toe	0.023
2nd toe	0.002
3rd toe	0.000
4th toe	0.050
5th toe	0.061

Table 6b: Left Foot:

Regions of foot	P value
Forefoot	0.221
Midfoot	0.336
Hindfoot	0.078
1st toe	0.361
2nd toe	0.534
3rd toe	0.629
4th toe	0.898
5th toe	0.050

B) Association between callosities and plantar pressure in different regions of the foot:

Table 7a: Right Foot:

Regions of foot	P value
Forefoot	0.000
Midfoot	0.635
Hindfoot	0.036
1st toe	0.018
2nd toe	0.000
3rd toe	0.013
4th toe	0.001
5th toe	0.000

Table 7b: Left Foot:

Regions of foot	P value
Forefoot	0.634
Midfoot	0.047
Hindfoot	0.009
1st toe	0.132
2nd toe	0.007
3rd toe	0.000
4th toe	0.000
5th toe	0.013

C) Association between range of movements of ankle joint and plantar pressure in different regions of the foot:

Table 8a: Dorsiflexion Of Right Foot:

Regions of foot	P value (Significant if P ≤ 0.05)
Forefoot	0.001
Midfoot	0.533
Hindfoot	0.498
1st toe	0.041
2nd toe	0.008
3rd toe	0.229
4th toe	0.116
5th toe	0.003

Table 8b: Plantar Flexion Of Right Foot:

Regions of foot	P value
Forefoot	0.533
Midfoot	0.082
Hindfoot	0.100
1st toe	0.000
2nd toe	0.161
3rd toe	0.140
4th toe	0.147
5th toe	0.027

Table 9a: Dorsiflexion Of Left Foot:

Regions of foot	P value
Forefoot	0.076
Midfoot	0.362
Hindfoot	0.225
1st toe	0.367
2nd toe	0.001
3rd toe	0.462
4th toe	0.441
5th toe	0.000

Table 9b: Plantarflexion Of Left Foot:

Regions of foot	P value
Forefoot	0.006
Midfoot	0.001
Hindfoot	0.462
1st toe	0.130
2nd toe	0.004
3rd toe	0.135
4th toe	0.522
5th toe	0.004

DISCUSSION

Out of the 331 diabetic patients who were part of the study, 100 patients were found to have foot ulcer.

Chatwin KE, Abbott CA, Boulton AJM, Bowling FL, Reeves ND, did a study on the role of foot pressure measurement in the prediction and prevention of diabetic foot ulceration, and concluded that an increased foot pressure was found in patients with diabetic foot ulcer (13).

In this study in diabetic foot ulcer patients, it was found that 48% of people had a very high plantar pressure in their right forefoot, followed by 40% very high plantar pressure in the right hind foot and 29% very high plantar pressure in the right 1st toe (TABLE 2A, FIGURE 2). Similarly, 51% of people had a very high plantar pressure in their left hindfoot, 45% of people were found to have a very High Plantar pressure in their left fore foot and 1st toe of their left foot. 25% of the people were found to have very high plantar pressure in their left midfoot (TABLE 2B, FIGURE 2). This tells us the reason for the poorer prognostic index of the diabetic foot ulcer patients who present with recurrent ulcers or the non-healing of ulcers present in these sites.

Another group of patients who participated in the study were patients with only diabetes mellitus and did not have any foot ulcer. In this group of patients, it was observed that 55% of the people had very high plantar pressure in their right forefoot, 42% of people had very high plantar pressure in their right 1st toe, and 32.9% had a very high plantar pressure in their right hind foot (TABLE 3A, FIGURE 3). Similarly, 43.7% of people had very high plantar pressure in their left fore foot, 37.2% had very high plantar pressure in their left 1st toe and 32% of people had a very high plantar pressure in their left hind foot (TABLE 3B, FIGURE 3). This infers us to the conclusion that these patients who are suffering from diabetes mellitus, and who has a very high plantar pressure in these areas are at a higher risk of developing a non-healing ulcer if at all an ulcer develops due to any of the causes like peripheral neuropathy, trauma causing ulcer superimposed by infections, etc.

In an overall aspect we can say that the commonest sites for very high plantar pressure raise in the right foot are the forefoot, 1st toe and the hind foot; and in the left foot are the fore foot followed by the 1st toe and then the hind foot in diabetic patients without foot ulcer.

Fernando ME, Crowther RG, Lazzarini PA, Sangla KS, Wearing

S, Buttner P, Golledge, did a study on plantar pressure comparing people with diabetic foot ulcer and the control despite a longer stance phase duration, it was inferred that the sites of occurrence of diabetic foot ulcer were at the regions of raised plantar pressure gradients (12). And so to study the most commonest site of occurrence of diabetic foot ulcer in diabetic population, the group of patients with diabetic foot ulcer were assessed for the sites of occurrence of the diabetic foot ulcer, 14% of the patients had ulcer in their right forefoot alone, followed by 10% of patients who had ulcer in their right forefoot and toes combined, 8% had ulcer in their right hind foot, 7% had ulcer in their right toes, 6% of people had ulcers in their forefoot and midfoot combined, and another 6% of people had ulcers in their midfoot and hindfoot combined, 3% of people presented with ulcers in their forefoot, midfoot and the toes combined, 2% had ulcer only in their midfoot, and the last 1% had ulcer in their forefoot, midfoot and the hindfoot combined in their right foot (TABLE 4A, FIGURE 4). Comparing this data with the foot pressure gradients seen in diabetic people in general, we can notice that the commonest sites where the foot ulcers developed and those that were not be able to heal properly are the sites with very high plantar pressure gradients (Red) which are forefoot (52.9%), 1st toe (38.1%), hindfoot (35%), and at last the 2nd toe (24.2%) (TABLE 4B). So, concluding from this we can say that the commonest sites of occurrence of diabetic foot ulcer are the forefoot followed by the greater toe, followed by the hindfoot, and the 2nd toe. Ulcers occurring in these areas also usually not heal easily vowing to the fact that the plantar pressure is raised far enough to cause constant pressure in these regions which delays the process of wound healing.

Similarly, we can draw the same conclusion in the left foot. By assessment of the commonest sites of presence of diabetic foot ulcer we can observe that 11% of the patients had ulcer in their left forefoot, 9% in the left hindfoot, 6% had ulcer in their left forefoot and toes combined, 4% had ulcer in their left toes alone, other 4 % had ulcer in their left forefoot, midfoot, toes combined, 3% had ulcer in both their left forefoot and midfoot and another 3% had ulcer in their left midfoot and hindfoot, 2% had ulcer in their left midfoot, and at last 1% had ulcer in their left forefoot, midfoot, and their hindfoot combined (TABLE 5A, FIGURE 5). This when compared to the plantar pressure gradient of diabetic patients in general of the left foot in which 51% of the patients were found to have a very high plantar pressure gradient in their left hindfoot, followed by 45% of patients with very high plantar pressure in their left forefoot, similarly 45% had a very high plantar pressure in their left 1st toe, 25% of patients had a very high plantar pressure in their midfoot too (TABLE 5B). This helps us to conclude that the commonest sites of formation of diabetic foot ulcer and also the sites which forms non-healing ulcers are hindfoot followed by the forefoot, toes and the midfoot in the left foot.

The prognosis of diabetic foot ulcer patients is dependent on the plantar pressure gradient of the foot. Therefore, factors responsible for the raise in plantar pressure can be assessed and their association should be found to predict the prognosis of the diabetic foot ulcer patients by finding it's significance of impact on rising the plantar pressure gradient of the foot. Some of the factors responsible for the rise in plantar pressure gradient are the presence of deformities, callosities of foot, limited range of movements.

Tang UH, Zügner R, Lisovskaja V, Karlsson J, Hagberg K, Tranberg R., did a study on foot deformity, raised plantar pressure and formation of foot ulcer in diabetics, from this study there is a raise in plantar pressure gradient in presence of deformity in the foot which were also the commonest place for formation of ulcers (25). In our study the association of deformities and raised plantar pressure was found to be statistically significant in the 1st toe, 2nd toe, 3rd toe and the 4th toe of the right foot, also in the left foot it was found to be statistically significant in the 5th toe (TABLE 6A, TABLE 6B). which implies that the presence of deformities in these regions were found to be the reason for raised plantar pressure in the selected group of patients. So, the cause of non-healing of ulcer may occur if at all some deformity is present in this region of the right foot, and recurrences of ulcer may occur. These regions are also prone for newer ulcer formation, due to the presence of higher plantar pressure regions which were caused by the deformity.

In general, the non-association of the deformity to the raised plantar pressure gradient in some areas of the foot can be substantiated to other causes of raise in plantar pressure in these areas of the foot which may cause the non-healing, occurrence, or recurrence of ulcer in these areas of the foot.

Z. Pataky, A. Golay, L. Faravel et al., did a study on the presence of callosity and the raise in the plantar pressure gradient, it was inferred that there was a raised plantar pressure gradient at the sites of callosity of the foot (20). An association between the presence of callosities and the raise in plantar pressure gradient was done to find the significance of the callosities in raising the plantar pressure gradient. So, the association of callosities and the raised plantar pressure gradient of the right foot was found to be statistically significant in the forefoot, hindfoot, 1st time, 2nd toe, 3rd toe, 4th toe and the 5th toe of the right foot. And in the left foot the association between the presence of callosities and the raised plantar pressure gradient was found to be significant in the midfoot, hindfoot, 2nd toe, 3rd toe, 4th toe and the 5th toe (TABLE 7A, TABLE 7B). This indicates that the raise in plantar pressure in this region are associated with presence of callosities, which has an increased chance to ulcerate and turns out to be a non-healing diabetic foot ulcer.

In regions of the foot where the rise in the plantar pressure gradient was found not to be associated with the presence of callosities, can be attributed to other cause like deformities and limited ankle joint motility for the raise in plantar pressure gradient in the selected group of patients.

Zimny S, Schatz H, Pfohl M., did a study on the limitation of joint motility in diabetic patients and its association with increased risk, we can infer that the raise in plantar pressure gradient is also linked with the restriction in range of moments (26). Similar results at varying regions of foot were obtained in this study. The restricted range of movements of the ankle joint was assessed and their association with the raised plantar pressure gradient was determined for their significance. It was found that the association of restricted dorsiflexion of the ankle joint and the raised plantar pressure gradient of the right foot was statistically significant in the forefoot, 1st toe, 2nd toe and the 5th toe (TABLE 8A). Restriction in the plantarflexion of the ankle joint and its association with the raised plantar pressure gradient was found to be statistically significant in the 1st toe and the 5th toe of the right foot (TABLE 8B). This concludes that the non-healing of diabetic foot ulcer can be attributed due to the presence of limited joint motility in the ankle, and the occurrence of ulcer has a positive association with the limited joint motility. The limitation in dorsiflexion of ankle joint has a far more significant associations in increasing the plantar pressure gradient in the right foot in the patients under study.

Similarly in the left foot the association between the limited dorsiflexion of the ankle joint and the raised plantar pressure gradient was found to be statistically significant in the 2nd toe and the 5th toe (TABLE 9A). The restriction in the plantarflexion of the left foot and its association with the raised plantar pressure gradient of the left foot was found to be statistically significant in the forefoot, midfoot, 2nd toe and the 5th toe (TABLE 9B). Surprisingly it was also found that the plantarflexion had a more significantly associated areas, in comparison to the dorsiflexion of the left foot in my study patients, which may have caused the non-healing of ulcer in some of these patients. This also gives us a strong association between the occurrence of ulcer in the regions of raised plantar pressure gradients and the restricted range of moments of that foot.

The areas of foot where the raise in plantar pressure gradient was not associated with restricted range of moments of the ankle joint, may have occurred due to the other causes like presence of callosities, deformities which may have increased the plantar pressure gradient in the foot of the patients present in the study.

CONCLUSION

Diabetes is one of the major problems faced by countries of lower socioeconomic status and it is a major burden to the society. People with this metabolic condition lacks adequate awareness and proper healthcare facility for the proper treatment. Most of the patients go for further complications, of which diabetic foot ulcer becomes the commonest one. Early screening of diabetic patients for the raise in plantar pressures; detection of the associated cause for the raise in plantar pressure like deformity, callosities, limited joint motility; and early correction of the etiologic factors will help in bringing down the incidences of occurrence of diabetic foot ulcer in the society. Health care services in the form of education to the diabetic patients on glycaemic control should be given. Patients with active non healing diabetic foot ulcers can be advised to follow adequate foot care which will prevent the further progression of the pathology.

Below topics are suggested for the further study:

1. Similar detailed studies focused on the causes of raise in plantar pressure gradient of the foot can be done.
2. A sociodemographic study can be done to further understand the effectiveness of regular screening of patients with diabetes and diabetic foot ulcer.

Summary:

There were 331 patients who volunteered for the study.

The mean age group of the patients were 55.1994 with a standard deviation of 11.18371, the mean BMI of the patients were 24.9819 with a standard deviation of 1.51890. The mean HbA1C, FBS, PPBS were found to be 8.2208, 162.6073, 218.2991 respectively.

In this study,

1. The plantar pressure gradient in patients with diabetic foot ulcer were found to be higher in the forefoot, hindfoot, 1st toe of the right foot and forefoot, midfoot, hindfoot, 1st toe in the left foot. This infers one of the reasons for non-healing of ulcers in these parts of the foot.
2. The plantar pressure gradient in patients with only diabetes was found to be higher in forefoot, hindfoot and the 1st toe of both the right and the left foot. These regions are more prone for non-healing of ulcer if an ulcer develops in these regions.
3. Based on the raised plantar pressure gradients of the forefoot, hindfoot and the toes of both the right and the left foot, and the presence of ulcer most commonly in these areas of both the right and the left foot ,we can conclude that the forefoot followed by hindfoot and the toes are the commonest sites of formation and non-healing of ulcer.
4. To assess the prognosis of the diabetic foot ulcer patients, they were evaluated for,

a. the association between the raise in plantar pressure gradients and deformities which were found to be statistically significant in the 1st toe, 2nd toe, 3rd toe, 4th toe of the right foot and the 5th toe of the left foot.
b. The association of the raise in plantar pressure gradients and the presence of callosities in the foot, which were found to be statistically significant in the forefoot, hindfoot, 1st toe, 2nd toe, 3rd toe, 4th toe of the right foot and the midfoot, hindfoot,2nd toe, 3rd toe, 4th toe, 5th toe of the left foot.
c. The association of the raise in the plantar pressure gradients and limited joint motility due to limitation in the dorsiflexion of ankle was found to be statistically significant in the forefoot, 1st toe, 2nd toe ,5th toe of the right foot. And the association of the raise in plantar pressure and limited joint motility due to limitation in the plantar flexion was found to be statistically significant in the 1st and the 5th toe in the right foot.
d. The association of the raise in plantar pressure and limited joint motility due to restriction in the dorsiflexion of the left foot was found to be statistically significant in the 2nd toe and the 5th toe. The association of the raise in plantar pressure and limited plantarflexion of the left foot was found to be statistically significant in the forefoot, midfoot, 2nd and the 5th toe.

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