

Nonweight-Bearing Exercise on Diabetic Foot Ulcer Healing, Risk Assessment and Health Related Quality of Life Among Patients with Diabetic Foot Ulcer

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KEYWORDS

Diabetic foot ulcer, non weight-bearing exercise, risk assessment, health related quality of life

ABSTRACT

Background and Objectives: Literature search does not find much study on nonweight-bearing exercise in ulcer leg. Active or passive exercise keeps the joint mobile and enhances blood flow. The objectives of the study were to assess the effectiveness of nonweight-bearing exercise on diabetic foot ulcer healing, risk assessment and Health Related Quality of Life (HRQOL).

Materials and Methods: A quantitative research with evaluative approach was used. 242 patients with diabetic foot ulcer 121 in each group were recruited who were fulfilling the inclusion criteria. Simple random technique was used for the distribution of the participants. Information on background variables, ulcer healing, blood flow, risk assessment on unaffected foot and health related quality of life was obtained as a baseline data. The study group participants were taught about nonweight-bearing exercise practiced on both the legs for 4 weeks and information pamphlet on foot care practices were distributed along with the routine care. Patients were followed for 2 months and assessment was done at the end of each month. The intra-group and inter-group comparisons were carried out using and t-tests and RMANOVA respectively, at 5% significance level.

Results: The results show a highly statistically significant difference in the diabetic foot ulcer healing score, blood flow, risk assessment and health related quality of life in the study in contrast to the control group. Correlation exists between ulcer healing and blood flow. As the blood flow increased the wound size decreased.

Conclusion: The inclusion of nonweight-bearing exercise as part of diabetic foot ulcer management strategies holds promise for improving healing outcomes and reducing the burden of DFU-related complications.

Categories: Nursing

1. Introduction

The lifetime incidence of diabetic foot ulcers occur in up to 25% of patients and for every 30 seconds a lower limb is lost to amputation somewhere in the world as a consequence of diabetes [1]. Diabetic foot ulcer although a devastating complication of diabetes mellitus, it can be prevented or delayed by following simple measures and lifestyle changes. The risk of lower limb amputation for the diabetic foot ulcer patient is 6% at 20 and 11% at 30 years of age and the five year mortality rate of those who develop first time diabetic associated foot ulcers has been reported between 43% and 55% and reach up to 74% for those with subsequent lower limb amputation [2,3].

Patients living with DFU showed a low quality of life due to the burden caused by the disease [4]. The unhealed DFU group had a greater reduction in overall physical health compared to patients with diabetes and no history of ulcer. The researchers also found that depression appeared to have a major effect. Patients with depression showed less ulcer improvement or healing by the end of the 24th week [5].

Sri Ramachandra Hospital is a tertiary care centre with wide range specialties to its credit. A separate diabetic foot clinic was initiated in the year 2011 and it actively functions in the surgical outpatient

department on every Friday. On an average, 10-15 diabetic foot ulcer patients come to surgical outpatient department for wound dressing every day. The standard wound care provided includes debridement, offloading, infection control, saline-moistened gauze dressings and antimicrobial impregnated dressings. Advanced treatment includes cytokines, negative pressure therapy and skin grafts. There is very little research available on nonweight-bearing exercise and diabetic foot ulcer healing due to the fear that exercise can disturb the normal wound healing process. It is scientific that exercise promotes blood flow and improves joint flexibility. This motion is influenced by several structures namely configuration of bone surfaces within the joint, joint capsule, ligaments, tendons and muscle acting on the joint. These exercises are performed by the patients under the supervision to check for the limitation and proceed further. These are simple movements given over ankle and metatarsophalangeal joints. [6] a pilot study on nonweight-bearing exercise on ulcer healing found that there was a significant reduction in wound size.

Measures like nonweight-bearing exercise with supportive evidence will help the patient to recover faster and prevent future reulceration. Poor circulation is one of the important factors for delayed healing. Exercise therapy promotes the use of muscular contraction and bodily movement to ultimately improve overall functioning. Exercise has been shown to cause an immediate rise in blood flow. [7] The ankle dorsiflexion, plantarflexion, subtalar inversion and eversion concluded that an exercise combining active ankle and subtalar movements produced the greatest increase in mean and peak velocity blood flow measured using strain gauge plethysmography. Active ankle flexion resulted in a peak velocity increase of 33% and active subtalar movements increased peak velocity by 38%. This improvement in venous hemodynamics was maintained up to 30 minutes after exercise.

[8] exercise also helps in the production of nitric oxide. Nitric oxide is known as an important stimulator of cell proliferation, maturation and differentiation. Thus, nitric oxide increases fibroblast proliferation and thereby collagen production in wound healing. Also, L-arginine and nitric oxide are required for cross linking of collagen fibers, via proline, to minimize scarring and maximize the tensile strength of healed tissue. Endothelial cell specific nitric oxide synthase (EcNOS) is activated by the pulsatile flow of blood through vessels. Nitric oxide produced by EcNOS, maintains the diameter of blood vessels and proper blood flow to tissues. [9] nitric oxide also regulates angiogenesis, which plays a major role in wound healing.

The present study has used Model ES-100V3 Bidop to obtain popliteal artery blood flow velocities. This was achieved through the capture of ultrasound waves transmitted from probe placed to patient at popliteal artery of affected limb and reflected by the blood. The velocity was detected as audible sounds through a speaker or headset and blood flow velocity waveforms are displayed on the screen. The changes in blood flow velocity in the radial artery after local dynamic exercise. A pocket Doppler ultrasound device was used for measurements. Resting baseline values of overall maximum blood flow velocity, mean blood flow velocity and Pulsatility Index (PI) were assessed for the whole group. There was a typical change in velocity waveform after exercise was noted. [10].

Though many nursing studies are available in the world literature on risk prevention and foot care practices still a fewer nursing studies are identified in diabetic foot ulcer healing. The nurse takes a major role when a patient comes with an active ulcer starting from assessment of the wound, classification, infection identification, daily dressing, offloading, monitoring healing to education. This gap should be filled by nurses and they should come up with more ideas on managing patients with ulcer. Moreover, the attitude of the patient after development of ulcer with dressing tends to avoid movement over the foot which is actually not required. Weight-bearing is restricted to prevent more damage to the wound, enhance healing and avoid unnecessary contamination which can lead to infection. Literature search does not find much study on this topic and that led the researcher to test nonweight-bearing exercise in ulcer leg with the intention to keep joint mobile and enhance blood flow for healing. Further risk reduction in the unaffected limb too is added to prevent recurrence of

ulceration and as a nurse chance of imparting education was not missed.

2. Materials and Methods

Study Design

A quantitative research with evaluative approach was used. The experimental research design adopted was Randomized controlled trial. The technique adopted for this study was simple randomization. Subjects were randomly assigned to the study and the control groups through lottery method. All the subjects who fulfilled selection criteria during the period of study were included as samples.

Inclusion Criteria

Patients with diabetic foot ulcer who were

1. > 36 yrs of age
2. any gender
3. having neuropathic ulcer
4. having ulcer in plantar aspect of foot
5. able to understand Tamil or English
6. having non-infected wound

Exclusion Criteria

Patients who were having

1. any type of amputation of lower extremity
2. ulcer on both legs
3. recurrent ulcer
4. signs of ischemia
5. less than 4 weeks of DFU
6. current practice of nonweight-bearing exercise

Data Collection

All the subjects of the study and the control group were assembled in the procedure room of surgical OPD and interviewed on the day of selection to obtain background information, Pressure Ulcer Scale for Healing score, English/ Tamil version of Diabetic Foot Ulcer Scale for Quality of life. The researcher explained about the statements in the scale and asked the patients to give a tick mark against the statement according to their status; Risk assessment on unaffected foot was measured using "Diabetic foot risk assessment form". Vascular assessment of foot was done using Bidop.

Study group patients were explained about the nonweight-bearing exercise and vascular assessment. The active assistive exercise was taught to the patients for 10 min. The patients were allowed to do the exercise under supervision following which blood flow to the foot was assessed for every 5 and 30min. The total time taken per session was 30-45 minutes. The subjects were instructed to practice the nonweight-bearing exercise minimum 5 times every day at home when they were relaxed and at any time of the day. They were also directed to note down their practice time every day in the Daily exercise Practice Calendar was provided by the researcher during the first visit. Finally the pamphlet was distributed. The intervention was repeated with an interval of one week at the surgical OPD on 1st, 2nd, 3rd & 4th visit. Reinforcement of the intervention was given on post test (II & III) i.e. at the end of 5th (II) and 6th (III) visit after the measurement of variables. 5th and 6th visit were one month apart.

Routine care was continued.

Patients were receiving routine care from the surgical OPD such as physician advice, foot care, dietary guidance, follow-up instructions, life style modification and disbursement of medications.

Post tests were scheduled for each patient at the end of 5th and 6th visit. Blood flow assessment was done pre-intervention and post intervention at the end of 5 and 30 min. wound healing assessment at 5th & 6th visit and quality of life at the end of 6th visit. Total days of home practice were assessed on the post test days in the surgical OPD. Reinforcement for non weight-bearing exercise was given during each post test visit after measuring the variables. Apart from the intervention, the study group subjects also received the routine medical care provided in the surgical OPD.

Post test data were collected for blood flow 5th & 6th visit, ulcer healing 5th & 6th visit, and quality of life 6th visit alone. Routine interventions were continued. One session of non weight-bearing exercise was taught to the participants and pamphlets were distributed at 6th visit.

Statistical Analysis

Data were analyzed using the SPSS for windows (version 17). The collected data were grouped and analyzed using descriptive and inferential statistics based on the objectives and hypotheses. Descriptive methods used were frequency, percentage, mean and standard deviation. Inferential statistics such as Chi square, paired, and independent ‘t’ test, Wilcoxon signed Rank test, Mann Witney U test correlation coefficient were used to assess the effect of nonweight bearing exercise on diabetic foot ulcer healing, risk assessment and health related quality of life. RMANOVA was used to determine the differences within groups over a period of time.

3. Results

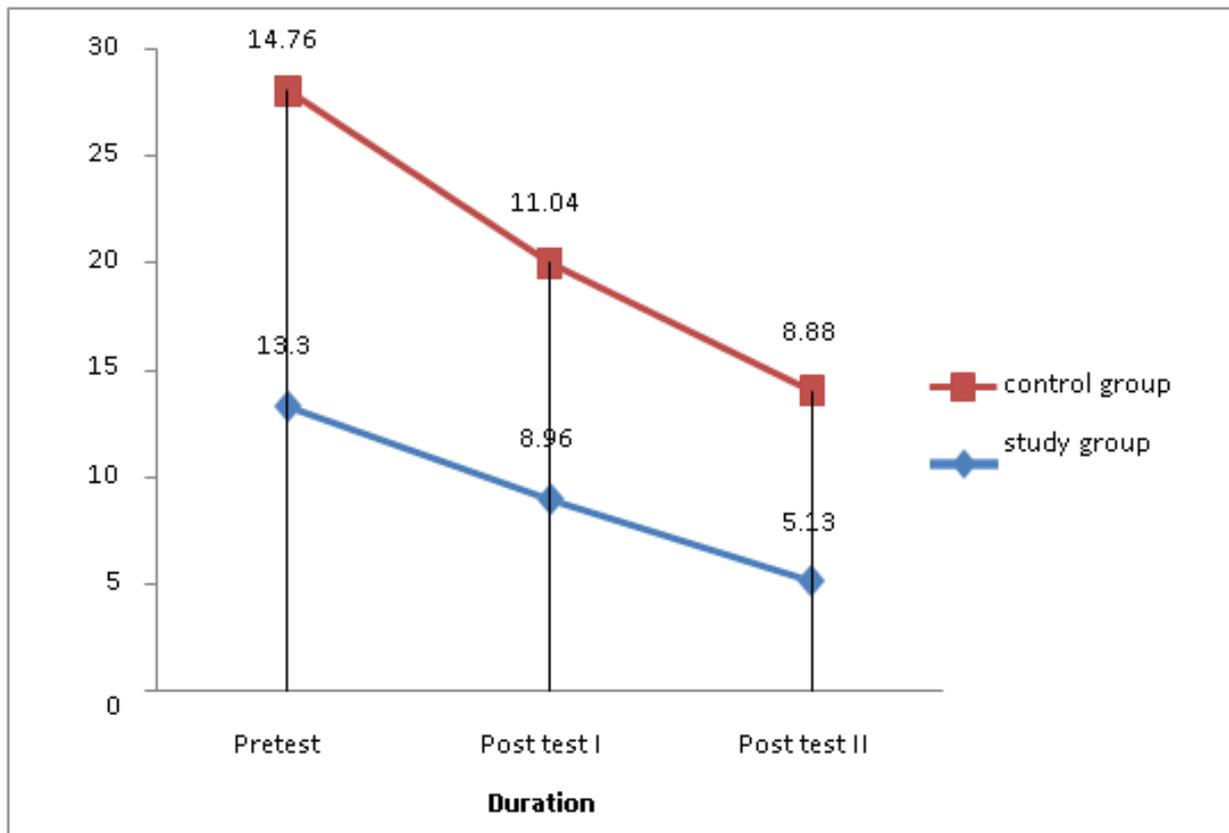


Fig 1. Comparison of pretest and posttest (I,II) mean score of diabetic foot ulcer healing among patients between the study and control groups (N=242).

Table 1. Repeated measures ANOVA of diabetic foot ulcer healing over a period of time within and between the study and control groups (N=242).

Duration	Study group n=121		F & p value	Control group n=121		F & p value	F & p value
	Mean cm2	SD		Mean cm2	SD		
Pretest ^{a,b}	13.30	1.94	2172.83 0.001***	14.76	1.69	1741.86 0.001***	105.24 0.001***
Posttest I ^{c,d}	8.91	2.25		11.04	1.16		
Posttest II ^{e,f}	5.13	2.21		8.88	1.80		

Table 2. Mean score of risk assessment on unaffected foot among patients with diabetic foot ulcer (N=242).

Duration	Study group (n=121)		Control group (n=121)		t & p value
	Mean	SD	Mean	SD	
Pre test	5.90	0.79	6.30	0.80	-4.043 0.0001***
Post test	0.49	0.69	3.12	1.55	-16.762 0.0001***

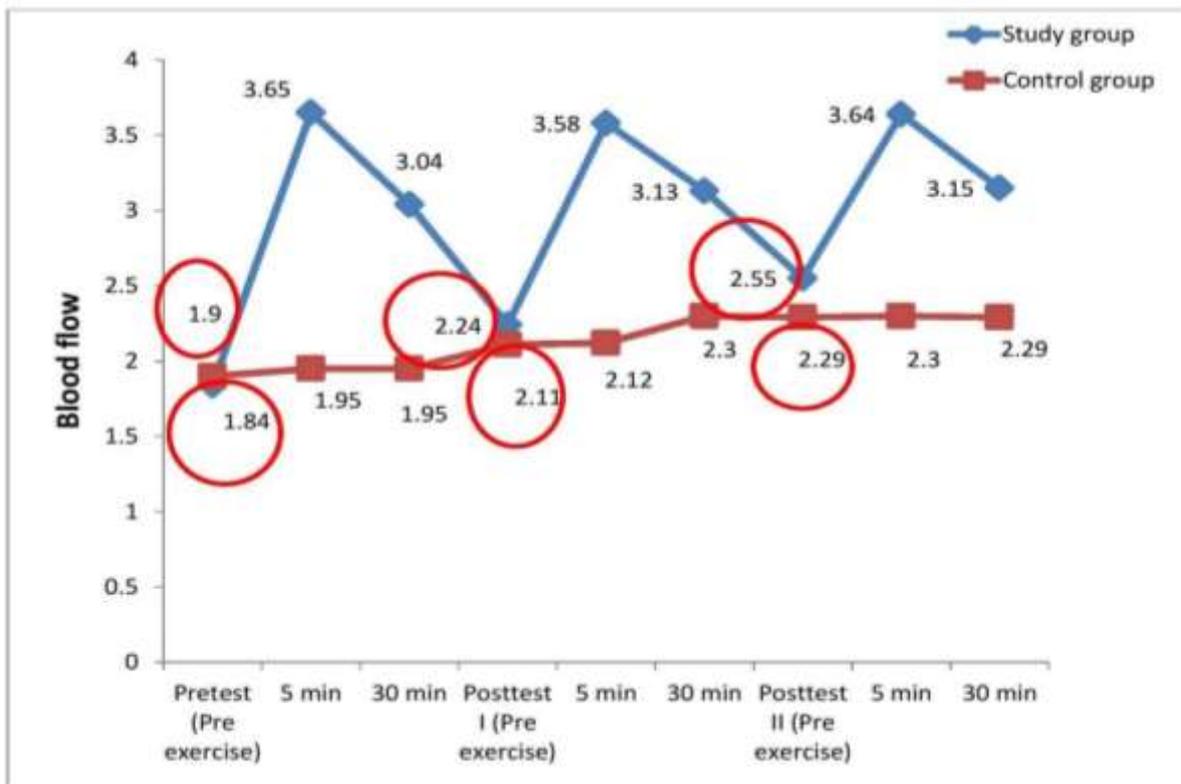


Fig 2. Assessment of blood flow before and after exercise in both study and control group (N=242).

Table 3. Comparison of pretest and posttest HRQOL between study and control groups (N=242).

HRQOL dimension	Duration of Study	Study group		Control group		Mean difference	Z& p value
		Mean	SD	Mean	SD		
Leisure	Pre test	43.67	12.54	43.55	14.58	0.12	0.29 0.769
	Posttest	79.61	7.22	73.00	9.56	6.61	4.02 0.001***
Physical health	Pre test	45.55	13.26	44.66	12.64	0.89	1.47 0.140
	Posttest	83.47	8.24	72.42	7.73	11.04	8.38 0.001***
Daily activities	Pre test	41.77	17.70	42.56	19.11	0.79	0.67 0.500
	Posttest	80.34	8.63	76.70	14.84	3.63	1.59 0.111
Emotional	Pre test	49.08	13.54	52.75	13.78	3.67	1.24 0.213
	Posttest	82.70	6.72	77.37	7.85	5.32	5.57 0.001***
Noncompliance	Pre test	59.40	21.60	47.10	33.68	12.29	3.175 0.001***
	Posttest	89.20	11.93	74.23	15.10	14.97	7.080 0.001***
Family	Pre test	52.76	20.72	56.73	23.76	3.96	1.172 0.241
	Posttest	86.06	8.14	77.95	15.14	8.11	4.331 0.001***
Friends	Pre test	46.07	18.29	49.00	24.62	2.93	1.047 0.295
	Posttest	83.41	8.72	76.82	14.16	6.59	2.586 0.010**
Treatment	Pre test	43.90	8.40	44.47	15.33	0.56	1.304 0.192
	Posttest	80.39	7.95	74.51	9.80	5.88	3.580 0.010**

HRQOL dimension	Duration of Study	Study group		Control group		Mean difference	Z& p value
		Mean	SD	Mean	SD		
Satisfaction	Pre test	40.28	17.49	41.52	13.52	1.23	1.182 0.237
	Posttest	82.69	11.58	76.30	11.39	6.38	3.994 0.001***
Positive attitude	Pre test	29.13	5.79	30.95	9.18	1.81	3.140 0.002**
	Posttest	24.10	8.79	19.56	9.09	4.53	3.197 0.001***
Financial	Pre test	36.37	17.36	38.94	17.31	2.27	0.773 0.440
	Posttest	80.66	11.43	71.63	12.31	9.03	5.938 0.001***

4. Discussion

In this study, the Pressure Ulcer Scale for Healing developed by the National Pressure Ulcer Advisory Panel was employed to assess wound healing, taking into account planimetric measurement, exudate amount, and tissue type. Excluding wounds with ischemia and infection, which often lead to prolonged healing and potential amputation [16], the focus was on superficial and deep wounds penetrating to the capsule or bone, with or without abscess.

The mean wound size in the study group was slightly smaller (13.35 cm²) compared to the control group (14.69 cm²), with minimal variation in size distribution between the groups. Following a one-month interval of nonweight-bearing exercise practice combined with routine care, the study group exhibited a notable reduction in mean ulcer score to 8.96 cm², whereas the control group's score was 11.04 cm². Subsequently, after another month, the study group's mean ulcer score further decreased to 5.13 cm², while the control group's score was 8.88 cm². This reduction was statistically significant ($p < 0.001$), indicating accelerated healing in the study group compared to the control.

Although both groups showed ulcer healing, the study group demonstrated a more substantial reduction in ulcer size, transitioning from 13.35 cm² to 5.13 cm², while the control group's healing progressed slower, from 14.69 cm² to 8.88 cm². The disparity in ulcer healing between the groups ranged from 1.34 cm² to 3.75 cm², emphasizing the effectiveness of nonweight-bearing exercise practice alongside routine care in promoting wound healing.

Overall, the study highlights the significant impact of nonweight-bearing exercise on accelerating wound healing in diabetic foot ulcers, as evidenced by reductions in ulcer size and scores. These findings underscore the importance of incorporating exercise interventions into standard care protocols for diabetic foot ulcer management.

Risk Assessment

The study addresses the high risk of foot ulcer development in diabetic patients, particularly in the contralateral limb or recurrently in the same limb, due to various predisposing factors [17]. Notably, weight-bearing in the contralateral limb can alter foot biomechanics, leading to callus formation and subsequent ulcer development. However, the study acknowledges the challenge of measuring changes

in the contralateral limb feasibility and the need for longer follow-up in future studies to substantiate this information.

Nonweight-bearing exercise was implemented to mitigate risk factors associated with foot ulcers. This exercise regimen aimed to reduce Achilles tendon plantar flexion tension, thereby preventing foot deformities, joint stiffness, and plantar foot pressures, ultimately improving gait quality[18].

The assessment of foot risk utilized the Foot Risk Assessment form developed by the Registered Nurses Association of Ontario. Sensory neuropathy was evaluated using the Semmes-Weinstein monofilament test, with sensory loss at any one site considered indicative of neuropathy[19]. Foot deformities were prevalent among participants, likely attributed to the longer duration of diabetes and sustained hyperglycemia, as supported by previous research findings[20].

Peripheral pulses in the contralateral leg were assessed to evaluate vascular health, with absent pulses observed in few patients, indicating a potential minimization of diabetic foot ulcer risk. Peripheral vascular disease was recognized as a significant contributing factor to ulcer development due to ischemia [21].

Assessment of participants' knowledge and practices regarding foot care revealed poor self-care practices, which are key indicators for ulcer development in the contralateral limb. Despite satisfactory knowledge reported in some studies, actual preventive practices were found to be unsatisfactory, possibly influenced by factors such as illiteracy and low socioeconomic status [22,23].

Pretest and posttest risk assessment scores indicated a significant improvement in the study group compared to the control group, highlighting the effectiveness of the intervention in reducing foot ulcer risk. These findings underscore the importance of comprehensive foot care education and preventive strategies in diabetic patient management.

Blood Flow:

The study emphasizes the critical role of vascular health in wound healing, particularly in diabetic patients, where over sixty percent of wounds are non-healing due to vascular reasons [24]. To assess blood flow, various technologies have been adapted, including Doppler ultrasound, Phase-contrast magnetic resonance imaging, and Photoplethysmography, among others [25]. For this study, the Bi-directional handheld Doppler with LCD (Bidop) was chosen due to its compactness, affordability, and feasibility in monitoring arterial blood flow velocities.

The Pulsatility Index (PI) was utilized for analysis as it provides accurate and stable measurements of clinical significance in evaluating lower extremity arteries [26]. In the study, the popliteal artery was primarily assessed due to dressing covering the plantar aspect of the foot, making other peripheral pulses difficult to identify. Additionally, only single assessments were conducted for the popliteal artery, while the patency of other peripheral pulses was evaluated through manual palpation.

Before the intervention, both groups had similar findings in blood flow measurement, with no significant difference identified in the pulsatility index of the popliteal artery. However, after nonweight-bearing exercise practice by the study group participants, significant improvements were observed in the pulsatility index at one-month and second-month intervals compared to the control group.

Active dorsiflexion and plantar flexion showed an increase in mean velocity in both the popliteal and posterior tibial arteries, indicating the beneficial effects of exercise on blood flow. The study's findings align with previous research demonstrating the impact of ankle position on Doppler measurements, with plantar flexion resulting in increased velocity in the popliteal artery and waveform changes in both popliteal and posterior tibial arteries [27,28].

Overall, the study underscores the importance of nonweight-bearing exercise in improving blood flow and vascular health, thereby contributing to enhanced wound healing in diabetic patients. These findings provide valuable insights into the mechanisms underlying the effectiveness of exercise interventions in diabetic foot ulcer management.

Quality of life

The study sheds light on the challenges faced by diabetic patients with foot ulcers (DFU) in maintaining a good quality of life (QoL) and highlights the significant emotional and financial burdens associated with the condition. Despite advancements in DFU management, patients often lack confidence in their treatment outcomes. An unhealed ulcer not only affects daily activities and social interactions but also increases the risk of complications such as infection and amputation, exacerbating the situation [29].

The Diabetic Foot Ulcer Scale (DFS) was employed to assess the impact of foot ulcers on various domains of QoL, including leisure, physical health, daily activities, emotions, noncompliance, family, friends, treatment, satisfaction, positive attitude, and finance. Both the study and control groups exhibited low QoL scores during the pretest, indicating the substantial negative impact of DFU on patients' lives.

Participants reported that activities such as visiting temples and relatives were greatly affected by the ulcer, alongside physical symptoms like tiredness, discomfort, and mobility issues. Emotional distress, particularly regarding ulcer healing time and the fear of amputation, was prevalent among patients. Additionally, financial burden was a significant concern for patients, further deteriorating their QoL [30,31].

The study found that while there were no statistical differences in various dimensions of QoL between the study and control groups, the noncompliance dimension score was notably higher in the study group. This suggests that noncompliance with treatment, including irregular follow-ups, missed medications, and poor foot care practices, contributed to the development of ulcers and impacted physical health and dependability.

After the intervention, there was a significant improvement in the overall QoL score in the study group compared to the control group, further supported by previous research [32,33]. Patients with healed foot ulcers exhibited higher QoL than those with persistent ulcers, indicating the emotional relief and confidence associated with ulcer healing. Patient education was found to be crucial in improving QoL, as it enhanced adherence to treatment and lifestyle modifications.

The study highlights a correlation between ulcer healing and blood flow, indicating that as blood flow increases, wound size decreases. This finding is supported by previous research, such as the study by [34], which focused on patients with persistent ulcers of at least 1 cm². In this study, the intervention group engaged in nonweight-bearing exercise using a bicycle ergometer, which led to greater reductions in wound size. The researchers observed a significant correlation between ankle brachial index (ABI) and oxygen percentage saturation, further emphasizing the importance of blood flow in wound healing. Based on these findings, the researchers recommended nonweight-bearing exercise as a cornerstone of management for diabetic foot ulcers.

The study demonstrated high adherence to nonweight exercise practices among participants, with 93.4% of the study group engaging in moderately adequate exercise during the 5th visit and 44.6% achieving adequate practice by the 6th visit. These results suggest that the exercise regimen, characterized by its simplicity, clarity, and feasibility, effectively encouraged participants to adhere to the prescribed exercises. Remarkably, none of the patients were previously engaged in exercise, indicating the successful adoption of a new behavior.

There was significant association found between current smoking status and the diabetic foot ulcer healing at $p < 0.01$ in the study group.

5. Limitation

- The duration of the study was limited to three months period, patients could have been followed till the complete healing.
- Though the tool had high reliability for the English and Tamil versions, exposure effect could also have influenced the patients' responses in quality of life.
- The study was limited to non-infected and non-ischemic diabetic foot ulcer.
- The investigator did not have control over the offloading measures and foot wear modifications.

6. Conclusion

The inclusion of nonweight-bearing exercise as part of diabetic foot ulcer management strategies holds promise for improving healing outcomes and reducing the burden of DFU-related complications. Future research and clinical practice should continue to explore the efficacy and implementation of exercise interventions in the holistic care of individuals with diabetic foot ulcers. Fostering patient education and promoting adherence to nonweight-bearing exercise regimens are critical components of successful DFU management. Empowering patients with the knowledge and skills to incorporate regular exercise into their daily routines can enhance self-care practices and contribute to long-term ulcer prevention and management.

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