East African Scholars Journal of Medicine and Surgery
Abbreviated Key Title: EAS J Med Surg
ISSN: 2663-1857 (Print) & ISSN: 2663-7332 (Online)
Published By East African Scholars Publisher, Kenya

Volume-7 | Issue-11 | Nov-2025 | DOI: https://doi.org/10.36349/easjms.2025.v07i11.002

OPEN ACCESS

Original Research Article

Assessment of Foot Deformity and the Associated Factors among Type 2 Diabetes Mellitus Out-patients: The Scenario from a Tertiary Health Care Facility in South-Eastern Nigeria

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Article History
Received: 07.09.2025
Accepted: 03.11.2025
Published: 05.11.2025

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: ***Background*:** Diabetes mellitus foot deformities (FD) comprise all the pathological changes in the foot of a person with diabetes mellitus. The current global burden of FD is worrisome and contributes to the global burden of disability and reduction in the quality of life. ***Objectives*:** This study evaluated the prevalence, spectrum of foot deformity and the associated risk factors in subjects with type 2 DM. ***Materials and Methods*:** This was a descriptive cross-sectional study involving 98 consenting T2DM subjects at Nnamdi Azikiwe University Teaching Hospital, Nnewi, South-eastern Nigeria. Relevant socio-demographic, clinical and Diabetic Neuropathy Symptom (DNS) score data were collected using a structured questionnaire and the DNS questionnaire. Clinical evaluations that included detailed foot, anthropometric, blood pressure measurements, biothesiometry, monofilament testing and lower limb doppler ultrasonography were done. Data was analysed using SPSS version 25. ***Result*:** A total of 98 T2DM subjects were evaluated and comprised 51% and 49% male and female subjects, respectively, with a mean age of 59.61 ± 11.62 years and mean DM duration of 11.11 ± 8.48 years. A total of 62.2% of the subjects had foot deformity, of which 30.6%, 4.1%, 13.3%, 8.2%, 7.1% and 4.1% had prominent metatarsal head, pes cavus, pes planus, claw toe, hammer toe, and mallet toe, while 11.2%, 4.1%, 9.2%, 4.1%, 2.0%, 43.95, 3.1%, 1.0% and 28.6% of the subjects had hallus rigidus, hallus varus, hallus valgus (bunion), bunionette, Charcot foot, muscle atrophy, disarticulation, amputation and limited joint mobility, respectively. Foot deformity showed significant association with the age of the subjects, educational level, DM duration, glycaemic control, global obesity and presence of neuropathy. ***Conclusion*:** The prevalence of FD in T2DM subjects from this study was very high and FD was significantly associated with some modifiable risk factors that included educational level, glycaemic control and global obesity which could be potential targets for therapeutic interventions for foot deformity.

Keywords: Assessment, Associated Factors, Diabetes Mellitus, Foot Deformity, Nigeria.

INTRODUCTION

Diabetes mellitus is a very prevalent metabolic disorder with chronic multi-systemic complications, the musculoskeletal system inclusive. The chronic complications of DM result from vascular and nervous damage. The foot is an integral part of the musculoskeletal system and a complex terminal structure of the lower extremity that comprises several bony structures, muscles, joints, ligaments, tendons and neurovascular bundles [1]. The steadily rising prevalence of diabetes mellitus (DM), more especially type 2 diabetes mellitus (T2DM) has increased the number of the persons living with diabetes that come down with the chronic complications of diabetes mellitus, including vascular and neuropathic sequalae. Pandey *et al*., had earlier found that foot deformity was more in diabetic subjects compared to the non-diabetic population [2]. Diabetes mellitus foot deformities are a component of diabetes mellitus foot syndrome (DFMS) which comprise all the pathological changes in the foot of a

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person with diabetes mellitus. They are among the most prevalent chronic complications of T2DM that result potentially due to diabetic sensorimotor neuropathy and peripheral artery disease and often lead to diabetic foot ulcers (DFUs) and possible lower extremity amputations (LEAs) [3].

The foot is an anatomically complex structure and corresponds to the portion of the lower extremity distal to the ankle. It comprises over 26 individual bones, 30 joints, numerous tendons, ligaments, and muscles [4]. The foot, in combination with the ankle and the long bones of the lower limb, has a total of thirty-three joints [5]. All these structures are responsible for the ability to stand upright, support the weight of the entire body and provide the base for the mechanism of pedal gait and motion. The foot is divided into hind, mid and forefoot. There are number of articulations which facilitate motion of the foot and the articular surfaces of each of the bones are increased by hyaline cartilage [5]. Each joint is invested by a capsule and supported by ligaments. The ankle joint complex is made up of the talocalcaneal (subtalar), tibiotalar (talocrural) and transverse-tarsal (talocaneonavicular) joints [6].

Nerve damage could weaken the intrinsic muscles of the foot, leading to structural changes in the bones of the foot, their joints, and the articulation leading to abnormal foot pressures, abnormal joints mobility, foot deformity, gait abnormalities and trauma [7]. In Germany, more than 50% of all the cases of DMFS results from PAD, which is usually asymptomatic, being masked by a co-existing peripheral neuropathy [3].

Diabetic foot deformity is usually referred to as "foot at risk" of ulceration [8]. They include, but are not limited to claw toes, hammer toes, hallus valgus, hallus varus and prominent metatarsal heads.

The current global burden of diabetic foot disease is worrisome. The life time risk of developing diabetic foot ulceration was between 19% - 34% and approximately 65% of the patients with DFU have a recurrence within 3 - 5 years after healing buttressing the fact that recurrence was common after ulcer healing [9]. The prevalence of Charcot neuroarthropathy, a foot deformity characterized by bone and joint disarticulation in the background of neuropathy was 0.1 – 4% and increased to 35% in patients with peripheral neuropathy [10, 11].

In western Nigeria, the prevalence of DM patients with the foot at risk was 41.5%, while that of DFU was 17.3% [12, 13]. In Southwestern Nigeria the prevalence of DMFU among T2DM subjects was 18.7% [14]. In Northern Nigeria, the prevalence of DFU among T2DM subjects was 14.5% [15]. A multicenter study in Nigeria found that 79.2% of the patients with DFU presented late to the hospital and 10.4% suffered lower extremity amputation [16].

Ababneh *et al*., found that among diabetic patients in Jordan, 17.4%, 16.9%, 14.2%, 0.4%, 3.2%, 2.1% and 1.7% had hallux valgus, claw/hammer toe, limited joint mobility, pes carvus, Charcot foot and amputation, respectively [17].

The economic burden exerted on the health care system by diabetic foot deformity, more especially DFUs and amputations is enormous and is still soaring. This includes direct and indirect costs, with loss of personal earnings and the burden of care givers [18]. Diabetic mellitus foot abnormalities also contribute the global burden of disability and reduction in the quality of life, designating it a considerable public health problem [18].

A search of the existing literature revealed that most of the studies done on foot abnormalities in the diabetic subjects were on DFUs and its feared sequalae, which is disarticulations and amputations. Foot deformity in the setting of DM places the foot at risk of worsening complications and is the prelude to ulceration and amputation. Hence, early diagnosis of the structural and functional diabetic foot deformities and their prompt treatment at the "pre-ulcerative" stage will avert the occurrence of further debilitations, including amputations, reduced quality of life and the attendant morbidity and mortality.

There is a dearth of the studies that evaluated the spectrum of foot deformity in type 2 diabetic subjects globally and more especially in the sub-Saharan Africa. This study aimed at evaluating the prevalence and spectrum of foot deformity and the associated risk factors In subjects with type 2 DM at Nnamdi Azikiwe University Teaching Hospital, Nnewi in South-eastern Nigeria.

MATERIALS AND METHODS

This study was carried out at the diabetes out-patient clinic of Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi, Anambra State, Nigeria. The study population consisted of consenting 98 subjects with type 2 diabetes aged 18 years and above. The study was carried out from May, 2021 to February, 2022.

The inclusion criteria for the study subjects were: all consenting subjects with T2DM aged 18 years and above. The exclusion criteria were: subjects that were less than 18 years of age, had type 1 DM, gestational diabetes mellitus (GDM) or were very sick.

Study Design

This was a cross-sectional, descriptive study. Subjects' recruitment into the study was via simple random sampling technique. All the subjects with T2DM who met the inclusion criteria, had none of the exclusion criteria and gave a formal informed consent to participate in the study were recruited consecutively into the study during clinic consultations. A total of 106 subjects were recruited into the study, 8 subjects had incomplete results

and were dropped, while the 98 subjects had complete data and were analysed.

The study was carried out in two phases and the researcher had two contacts with the subjects on two separate clinic days.

At the first contact, informed consent was obtained, a focused medical history was taken, anthropometric and blood pressure measurements were done. A detailed physical examination of the feet was done to clinically diagnose foot deformities and the subjects were then assisted by the researcher to fill out the Diabetic Neuropathy Symptom (DNS) score questionnaire to screen for diabetic peripheral neuropathy, and the Nottingham Assessment of Functional Footcare (NAFF) questionnaire to assess the subjects' foot care behavior. Next, doppler ultrasonographic assessment of the brachial, and the pedal arteries were done using the pocket Doppler device, to determine the ankle brachial pressure index (ABPI). Biothesiometry was also done to measure the vibration perception threshold (VPT), which was used to objectively determine the presence of diabetic peripheral sensory neuropathy. DNS score > 1 confirmed the presence of neuropathic symptoms and defined DPN [19]. NAFF score above 50 indicated a satisfactory (good) foot care behavior. Scores below 50 suggested poor foot care behavior and that foot care behavior should be further evaluated [20].

Laboratory Procedure

At the second contact with the subjects, 5ml of venous blood was collected from each subject via venipuncture of the cubital vein, following aseptic procedure. This was after they had observed a fast of about 8 - 14 hours based on the instructions they were given during the first meeting. 1 ml of blood for fasting plasma glucose (FBG) was collected in fluoride oxalate bottles and measured by the Trinder glucose oxidase method [21]. 1 ml of blood for glycated haemoglobin (HbA1c) assay was stored in ethylenediaminetetraacetic acid (EDTA) bottle and measured using the boronate affinity chromatography method using the automated CLOVER A1c Analyzer (Infopia, Korea) and CLOVER A1c Self-Test Cartridge [22].

The remaining 3 ml of blood was stored in plain bottle and used for fasting lipid profile assay.

High density lipoprotein (HDL-C) was obtained by a precipitation technique [23].

Total cholesterol level was determined using the kit employing the enzymatic and the 4-hydroxybenzoate/4-aminophenazone systems (BioSystems) [24].

Triglyceride level was determined using a kit employing enzymatic hydrolysis of triglyceride with lipases (Randox) [25]. Low density lipoprotein cholesterol (LDL-C) was measured using a kit employing a precipitation technique [26].

Clinical Procedure

Doppler ultrasonographic assessment of the brachial, dorsalis pedis and posterior tibial arteries were done, using EDAN SONOTRAX Ultrasonic Pocket Doppler version 1.2 (CE 0123) with 8.0 MHz probe and an Accoson mercury Sphygmomanometer [27, 28]. Ankle brachial pressure index (ABPI) was calculated using the formular: ABPI for a leg = Higher pressure obtained from the ankle vessel in that leg / Higher systolic brachial pressure of the arms [29].

Peripheral artery disease (PAD) was taken as ABPI $\leq$ 0.9 [29].

The biothesiometer was used to measure the vibration perception threshold (VPT), which was used for determining the presence of diabetic peripheral neuropathy in the subjects. With the patient lying supine in a couch, testing was done by applying the vibrator of the biothesiometer to the pulp of the big toe of each foot. The vibrator was steadily held, such that, its weight delivered a standard pressure on the vibrator button with the probe balanced vertically on the pulp of the big toe. The subject was instructed to concentrate fully on the procedure and to verbally report the first feeling of the vibration [30, 31]. The amplitude of the vibrator button was set as low as possible at the start of the testing and steadily increased until the subject perceived the vibration. The voltage the biothesiometer displayed at the instant of the vibration was recorded. The process was repeated thrice on the pulp of each of the big toes and the mean value taken as the VPT for each of the lower limbs [30, 31]. Diabetic peripheral neuropathy was defined by a mean vibration perception threshold of > 25 Volts measured with the biothesiometer [30, 31].

A 10g Semmes Weinstein monofilament test was done to assess the perception of touch and to determine if there was loss of protective sensation (LOPS), which also indicated the presence of diabetic peripheral neuropathy [32].

Vibration sensation (pallesthesia) (sensory nerve function) was assessed using a 128 Hz tuning fork and the deep tendon (knee and ankle) reflexes were assessed using a tendon hammer. Absence of vibration perception and reduced or absent knee and ankle reflexes in diabetic subjects, especially the ankle reflexes clinically indicate the presence of diabetic peripheral neuropathy [33].

Diabetic Neuropathy Symptoms (DNS) score is a simple, self-reported questionnaire used for screening for diabetic peripheral neuropathy (DPN). It assesses four (4) symptoms: unsteadiness, pain, pricking sensations (paresthesia) and numbness over the past two

(2) weeks. It has a maximum of 4 points: each symptom is scored 1 point when present and 0 point when absent. DNS score of 1 or higher indicates the presence of DPN in a diabetic patient [19].

The Nottingham Assessment of Functional Footcare (NAFF) questionnaire was designed to measure foot self-care behavior for persons living with diabetes and patients with diabetes mellitus foot syndrome. The NAFF is a quantitative, 29 item self-reported scale. The questionnaire has internal consistency of 0.53, and good test-retest reliability. The researcher asks patients to indicate their responses to items in a Likert scale. The frequency of behavior occurrence is from 0 to 3. A score of above 50 suggests satisfactory or good foot care practices, while a score of 50 or below generally indicates suboptimal foot care habits and the need for further evaluation [20-34].

Semmes Weinstein 10 g monofilament (SWM) is a low cost, bed side screening tool for detecting loss of protective sensation (LOPS) in diabetic patients with DPN. Semmes Weinstein 10 g monofilament evaluation (SWME) is done with the patient lying supine on a couch, the monofilament is applied perpendicularly first to a site other than the foot for the patients to get accustomed to how the SWM feels on touching their skin. Then, the patients are instructed to close their eyes and say "yes" when they feel the touch at their feet. The monofilament is held until it buckles, indicating that the correct force (10 g) was applied and if the patient could not feel the monofilament at one or more sites, it suggested LOPS, a risk factor for foot ulceration and amputation. The SWME is performed at 10 sites on each foot: the plantar surfaces of the first, third and fifth digits; the plantar surfaces of the first, third and fifth metatarsal heads; the plantar surface of the heel, the dorsal medial side of the mid-foot; and the dorsal surface of the foot between the base of the first and second toes [32, 35].

Weight and height were measured using Stadiometer (RGZ-120), waist circumference, measured with a measuring tape and blood pressure measured using Accoson mercury Sphygmomanometer in accordance with the WHO STEPS instruments [29].

Definition of Terms and Criteria

Hypertension was defined as systolic BP ≥ 140 mmHg and or diastolic BP ≥ 90 mmHg, measured on at least 2 separate occasions or if a patient is already on anti-hypertensive medications [36].

Diabetes mellitus was defined by fasting plasma glucose of ≥ 7.0 mmol/l (126 mg/dl) measured on at least 2 separate occasions [37]. Type 1 DM was defined as subjects with DM who are dependent on insulin for survival and are at risk for ketoacidosis [37].

Type 2 DM was defined as patients with DM on diet therapy either alone or in combination with oral glucose lowering agent(s) for glycaemic control [37].

Dyslipidaemia was taken as HDL-C <1.04 mmol/L(males) or < 1.3 mmol/L (females) or TG ≥ 1.7 mmol/L or LDL-C ≥ 2.6 mmol/L or total cholesterol (TC) ≥ 5.2 mmol/L or if the patient is on lipid lowering agents [38].

Young age was taken as 18-44 years, middle age as 45-64 years and old age as 65 years and above [39]. Poor glycaemic control was taken as $HbA_{1C} \geq 7.0\%$ [37].

Global obesity was defined by body mass index (BMI) >30 (kg/M^2) [37]. Central obesity was defined by waist to hip ratio (WHR) > 0.9 [37].

Diabetic peripheral neuropathy (DPN) was defined by a vibration perception threshold (VPT) > 25 Volts measured with the biothesiometer [30].

Peripheral artery disease (PAD) was defined by an ankle brachial pressure index (ABPI) value of ≤ 0.9, while > 1.4 defined non compressibility of the arteries (calcification of the arteries) [27, 28].

Foot Deformities:

Prominent metatarsal head was defined as any inspected or palpable plantar prominences of the metatarsal heads of the foot [40].

Hammer toes was defined as extension at the MTP joint, Flexion at the proximal interphalangeal (PIP) joint and hyperextension at the distal interphalangeal (DIP) joint [41].

Claw toe was defined as hyperextension of the MTP joint with flexion at the PIP joint and DIP joint [41]. Charcot foot was defined as non-infectious destruction of bone and joint including loss of foot arches (Rocker bottom deformity) [42].

Pes cavus was defined as an abnormally high medial longitudinal arch, which extended between the first metatarsal head and the calcaneus [43].

Limited joint mobility was defined as stiffness or restriction of the range of motion at the joint which was assessed by evaluating the range of motion of the ankle joints, subtalar joints, metatarsal joints, and interphalangeal joints through their normal ranges of motion, and determining whether there was any pain or restriction of the range of motion [44].

Bunionette was defined as adduction deformity of the fifth metatarsal joint, causing the 5^{th} metatarsal to move outward, making it prominent [45].

Hallux valgus (bunion) was defined as an abduction deformity of the great (big) toe and an adduction deformity of the first metatarsal, with the big toe (hallux) deviating towards the second toe [46].

Hallux rigidus was defined by a limitation of movement: flexion and extension (stiffening) at the first metatarsophalangeal (MTP) joint, causing a stiff big toe [47, 48].

Hallux varus was defined as adduction deformity (medial deviation) of the great toe at the first MTP joint with medial deviation of the hallux in relation to the first MTP joint [49].

Mallet toe was defined as flexion deformity at the distal interphalangeal (DIP) joint of the toe where the tip of the toe bends downwards away from the rest of the toes [50].

Pes planus was defined as the absence of the arches of the foot making it flat. Acquired pes planus occurs most commonly due to posterior tibial tendon dysfunction [51].

Amputation was reported as any resection of any part of the limb. It was divided into groups: major amputation (ankle disarticulation, transfemoral amputation, or transtibial amputation), and minor amputation (a toe or transmetatarsal amputation) [52].

Muscle atrophy was defined as the loss of the mass of the skeletal muscles at the foot [53].

Statistical Analysis

Data collected was entered into spreadsheet using Microsoft Office Excel, and then analysed using Statistical Package for Social Sciences (SPSS) version 25. Results of categorical variables were presented in tables as frequencies and percentages. The mean values and standard deviation for the continuous variables were calculated. Chi-square test or Fisher's exact test was used to determine the association between foot deformity and the categorical variables. The level of significance for all tests was set at $p < 0.05$.

RESULTS

A total of 98 subjects were evaluated in the study and they comprised 51% males and 49% females with a mean age of 59.61 ± 11.62 years. The majority of the subjects (40.8% and 88.8%) had tertiary education and had never smoked (details in Table1).

Table 1: Socio-demographic characteristics of the subjects

Variable	Frequency (n)	Percentage (%)
Age (years)		
Young age	9	9.2
Middle age	53	54.1
Old age	36	36.7
Mean = 59.61 ± 11.62		
Sex		
Male	50	51.0
Female	48	49.0
Educational level		
No formal	3	3.1
Primary	36	36.7
Secondary	19	19.4
Tertiary	40	40.8
Ever smoked cigarette		
Yes	11	11.2
No	87	88.8

2. Mean Values of Clinical Variables

The mean duration of diabetes was 11.11 ± 8.48 years and the mean HbA1c level, Ankle-Brachial Pressure Index (ABPI), Vibration Perception Threshold (VPT), Diabetic Neuropathy Symptom (DNS), and Nottingham Assessment of Functional Footcare (NAFF) scores were 8.4±2.34 %, 1.20± 0.30, 29.11± 16.53 (Volts), 1.48± 1.29 and 44.56± 8.53, respectively (details in table 2).

Table 2: Mean values of clinical variables

Variable	Minimum	Maximum	Mean	SD
Duration of DM (years)	0.50	38.00	11.11	8.48
HbA1c (%)	4.50	15.60	8.44	2.34
Mean ABPI	0.65	2.70	1.20	0.30
Mean VPT (Volts)	0.40	62.00	29.11	16.53

Variable	Minimum	Maximum	Mean	SD
DNS score	0	4.00	1.48	1.29
NAFF score	30.11	66.79	44.56	8.53

DM = Diabetes Mellitus; HbA1c = Glycated haemoglobin; ABPI = Ankle brachial pressure index; VPT = Vibration perception threshold; DNS = Diabetic neuropathy symptom; NAFF = Nottingham assessment of functional footcare

3. Clinical Characteristics of the Subjects

The majority (67.3%) of the subjects had long durations of diabetes and the minority (21.4%) exercised regularly. Similarly, about 51.0% of the subjects had good long term glycaemic control, while 50.0% and 85.4% of the male and female subjects had obesity, respectively. Lastly, about half of the subjects had diabetic peripheral neuropathy (DPN), determined by biothesiometry, while 19.4%, 49.0%, 43.9%, 28.6% and 74.5% of the subjects had peripheral artery disease (PAD), loss of protective sensation (LOPS), loss of vibration sense (determined using tuning fork), absent or reduced reflexes (ankle and knee) and poor foot care practices, respectively (details in table 3).

Table 3: Clinical characteristics of the subjects

Variable	Frequency (n)	Percentage (%)
Duration of diabetes		
Short duration	32	32.7
Long duration	66	67.3
Exercise		
Yes	21	21.4
No	77	78.6
Global obesity		
Yes	35	35.7
No	63	64.3
Abdominal obesity (Males)		
Yes	25	50.0
No	25	50.0
Abdominal obesity (Females)		
Yes	41	85.4
No	7	14.6
Glycaemic control		
Good	48	51.0
Poor	50	49.0
PAD		
Absent	79	80.6
Present	19	19.4
PAD grading		
Mild	5	5.1
Moderate	12	12.2
Severe	2	2.0
Neuropathy		
Absent	49	50.0
Present	49	50.0
LOPS		
Absent	50	51.0
Present	48	49.0
Vibration sense (using tuning fork)		
Absent	43	43.9
Present	55	56.1
Deep tendon reflexes		
Absent/Reduced	28	28.6
Normal	70	71.4
NAFF score		
Satisfactory foot care practices	25	25.5
Suboptimal foot care practices	73	74.5

PAD = Peripheral artery disease; LOPS = Loss of protective sensation; NAFF = NAFF = Nottingham assessment of functional footcare

4. Prevalence of Foot Deformities in the Subjects

A total of 62.2% of the subjects had foot deformity, of which 30.6%, 4.1%, 13.3%, 8.2%, 7.1% and 4.1% had prominent metatarsal head, pes cavus, pes planus, claw toe, hammer toe, and mallet toe, respectively, while 11.2%, 4.1%, 9.2%, 4.1%, 2.0%, 43.95, 3.1%, 1.0% and 28.6% of the subjects had hallus rigidus, hallus varus, hallus valgus (bunion), bunionette, Charcot foot, muscle wasting (atrophy), disarticulation, amputation and limited joint mobility, respectively (details in table 4).

Table 4: Prevalence of foot deformities in the subjects

Variable	Frequency (n)	Percentage (%)
Prominent metatarsal head		
Absent	68	69.4
Present	30	30.6
Pes cavus		
Absent	94	95.9
Present	4	4.1
Pes planus		
Absent	85	86.7
Present	13	13.3
Claw toe		
Absent	90	91.8
Present	8	8.2
Hammer toe		
Absent	91	92.9
Present	7	7.1
Mallet toe		
Absent	94	95.9
Present	4	4.1
Hallus rigidus		
Absent	87	88.8
Present	11	11.2
Hallus varus		
Absent	94	95.9
Present	4	4.1
Hallus valgus (bunion)		
Absent	89	90.8
Present	9	9.2
Bunionette		
Absent	94	95.9
Present	4	4.1
Charcot foot		
Absent	96	98.0
Present	2	2.0
Muscle atrophy		
Absent	55	56.1
Present	43	43.9
Amputation (minor)		
Absent	95	96.9
Present	3	3.1
Amputation (major)		
Absent	97	99.0
Present	1	1.0
Joint mobility		
Limited	28	28.6
Unlimited	70	71.4
Foot deformity		
Absent	37	37.8
Present	61	62.2

5. Association between Foot Deformity and Socio-Demographic Variables

Foot deformity showed significant association with the age of the subjects, educational level and duration of diabetes. Foot deformity was more in the elderly and middle-aged, compared to the young subjects. Equally, foot deformity was more in subjects with no formal education and in subjects with primary education compared to those with secondary and tertiary education. Lastly, subjects who has a long duration of diabetes had higher prevalence of foot deformity compared to those with short duration of diabetes.

Foot deformity showed no significant association with gender, smoking, exercise, the site of work, foot care knowledge, foot care practices and DNS score (details in table 5).

Table 5: Association between foot deformity and socio-demographic variables

Variable	Foot deformity *n* (%)		X^2	p-value
	Absent	Present		
Age				
Young age	5 (55.6)	4 (44.4)	8.349	0.015*
Middle age	25 (47.2)	28 (52.8)		
Old age	7 (19.4)	29 (80.6)		
Sex				
Male	20 (40.0)	30 (60.0)	0.219	0.640
Female	17 (35.4)	31 (64.6)		
Level of education				
No formal	2 (66.7)	1 (33.3)	8.318	0.040*
Primary	9 (25.0)	27 (75.0)		
Secondary	5 (26.3)	14 (73.7)		
Tertiary	21 (52.5)	19 (47.5)		
Ever smoked cigarette				
Yes	3 (27.3)	8 (72.7)	0.579	0.447
No	34 (39.1)	53 (60.9)		
Exercise				
Yes	10 (47.6)	11 (52.4)	1.107	0.293
No	27 (35.1)	50 (64.9)		
DM duration				
Short	17 (53.1)	15 (46.9)	4.776	0.029*
Long	20 (30.3)	46 (69.7)		
Site of work				
Indoor	25 (40.3)	37 (59.7)	0.473	0.491
Outdoor	12 (33.3)	24 (66.7)		
Foot care knowledge				
Yes	28 (35.9)	50 (64.1)	0.561	0.454
No	9 (45.0)	11 (55.0)		
DNS score				
0	14 (51.9)	13 (48.1)	4.560	0.336
1	12 (40.0)	18 (60.0)		
2	5 (29.4)	12 (70.6)		
3	4 (26.7)	11 (73.3)		
4	2 (22.2)	7 (77.8)		
NAFF score				
Satisfactory foot care practices	9 (36.0)	16 (64.0)	0.044	0.834
Suboptimal foot care habits	28 (38.4)	45 (61.6)		

DM = Diabetes mellitus; DNS = Diabetes neuropathy symptom; NAFF = Nottingham assessment of functional footcare

6. Association between Foot Deformity and Clinical/Laboratory Variables

Foot deformity had significant association with glycaemic control, global obesity, presence of neuropathy: increased vibration perception threshold, loss of protective sensation, loss of vibration sensation and absent/reduced deep tendon reflexes. Subjects with poor glycaemic control, global obesity, neuropathy, loss of protective sensations, loss of vibration sensation, as well as subjects with absent or reduced deep tendon reflexes had higher prevalence of foot deformity compared to those with converse conditions. There was no significant association between foot deformity and dyslipidaemia, blood pressure, peripheral artery disease, anti-diabetic- and lipid-lowering drugs use (details in table 6).

Table 6: Association between foot deformity and clinical/laboratory variables

Variable	Foot deformity *n* (%)		X^2	p-value
	Absent	Present		
Glycaemic control				
Good	24 (50.0)	24 (50.0)	6.002	0.014*
Poor	13 (26.0)	37 (74.0)		
Dyslipidaemia				
Present	35 (40.2)	52 (59.8)	2.020	0.155
Absent	2 (18.2)	9 (81.8)		
Treatment for diabetes				
OADs	30 (41.7)	42 (58.3)	1.774	0.412
Insulin	1 (25.0)	3 (75.0)		
Both	6 (27.3)	16 (72.7)		
Abdominal obesity				
Yes	27 (40.9)	39 (59.1)	0.856	0.355
No	10 (31.3)	22 (68.8)		
Global obesity				
Yes	20 (57.1)	15 (42.9)	8.708	0.003*
No	17 (27.0)	46 (73.0)		
SBP control				
Good	30 (43.5)	39 (56.5)	3.250	0.071
Poor	7 (24.1)	22 (75.9)		
DBP control				
Good	29 (39.2)	45 (60.8)	0.264	0.607
Poor	8 (33.3)	16 (66.7)		
Anti-hypertensive drug(s) use				
Yes	20 (37.7)	33 (62.3)	0.000	0.997
No	17 (37.8)	28 (62.2)		
Lipid-lowering drug(s) use				
Yes	23 (39.7)	35 (60.3)	0.218	0.640
No	14 (35.0)	26 (65.0)		
PAD				
Present	6 (31.6)	13 (68.4)	0.383	0.536
Absent	31 (39.2)	48 (60.8)		
Vascular calcification				
Present	11 (29.7)	26 (70.3)	1.629	0.202
Absent	26 (42.6)	35 (57.4)		
Neuropathy (Increased VPT)				
Present	8 (16.3)	41 (83.7)	19.148	0.000*
Absent	29 (59.2)	20 (40.8)		
LOPS				
Present	7 (14.6)	41 (85.4)	21.495	0.000*
Absent	30 (60.0)	20 (40.0)		
Vibration sense				
Present	30 (54.5)	25 (45.5)	15.037	0.000*
Absent	7 (16.3)	36 (83.7)		
Deep tendon reflexes				
Present	33 (47.1)	37 (52.9)	9.188	0.002*
Absent	4 (14.3)	24 (85.7)		

OAD = Anti diabetic drug(s); SPB = Systolic blood pressure; DBP = Diastolic blood pressure; PAD = Peripheral artery disease; LOPS = Loss of protective sensation

DISCUSSION

A total of 98 T2DM subjects had complete data and were analysed in this study. The mean age of the subjects was 59.61 ± 11.62 years and the majority of the participants (51%) were male while 49% were female subjects. Similarly, the majority (40.8% & 88.8%) of the subjects had tertiary education and had never smoked, respectively. Also, the majority ofsubjects had poor glycaemic control, the mean HbA1c was 8.44 ± 2.34%.

Cigarette smoking is a risk factor both macro and microvascular complications of diabetes mellitus [54]. Equally, poor glycaemic control is a significant risk

factor for the development and progression of diabetes-related complications [55, 56].

The overall prevalence rate of foot deformity among the subjects was 62.2%. This high prevalence could be largely explained by the facts that up to 67.3% and 78.6% of the subjects studied had long duration of DM and never had regular exercise and both were risk factors for developing foot deformity in diabetic subjects [8,58]. Similarly, the high mean HbA1c, VPT and DNS scores (8.44 ± 2.34%, 29,11 ± 16.53 Volts & 1.48 ± 1.29, respectively), that reflected a poor long term glycaemic control, and the presence of diabetic peripheral neuropathy (DPN), respectively could also explain the high prevalence rate of foot deformity in the subjects. Poor glycaemic control and DPN were found to be risk factors for the development of foot deformities in DM subjects [8,56].

Finally, 50% and 85.4% of the male and female subjects had abdominal (central) obesity, respectively while 38.7%, 19.4% and 78.5% of the subjects had global obesity, PAD and suboptimal foot care practices and all were shown to be associated with the development of foot deformity in previous studies [59-61]. Adebabay *et al*., found that the overall prevalence of foot deformity in diabetic patients in Ethiopia was 33.4% and this contrastingly, is lower than that found by this study. Unlike the index study, they evaluated larger population of diabetic subjects, but a lesser spectrum of specific foot deformities [8]. Walters *et al.*, equally, found that the prevalence rate of foot deformity in their diabetic cohort in East Dorset, UK was 44.5% [62]. Their study was done over three decades ago and their sample size was 1077 DM subjects. Apparently, the prevalence rate of diabetic foot deformity varied based on the spectrum of specific foot deformities that was evaluated and the peculiarities of the population studied, including the sample size.

Prevalence of the Different Foot Deformities in the Subjects

The most prevalent foot abnormality found by this study was muscle atrophy (43.9%), followed by prominent metatarsal head (30.6%), pes planus (13.3%), hallux rigidus (11.2%), hallux valgus (9.2%), claw toe (8.2%), hammer toe (7.1%), pes carvus (4.1%), mallet toe (4.1%), hallux varus (4.1%), bunionette (4.1%), minor amputation (3.1%), Charcot foot (2.0%), and major amputation (1.0%), respectively. The index study additionally found that the prevalence rate of DPN and PAD was 50% and 19.4%, respectively. The high prevalence rate of peripheral neuropathy and peripheral artery disease among the subjects could account for the high prevalence rate of DM foot deformities found by this study. Mekonnem *et al*., found the prevalence rates of 7%, 8.5%, 9%, 12% and 44.9% for pes cavus, hallux valgus, calluses, claw/hammer toe and foot ulcer, respectively in their diabetic subjects [63]. Comparable to this study, Mekonnem *et al*., also found a prevalence rate of PAD of 18.4%, but a lower prevalence rate of DPN (20.4%) among their DM subjects [63]. Additionally, the index study found that 25.5% of the subjects practiced optimal foot care practices and this is higher than the 15.8% recorded by Mekonnem *et al*., [63].

Lastly, Ababneh *et al*., in Jordan found that the commonest foot abnormality in their diabetic subjects was hallux valgus (17.4%) [65]. The prevalence rates of most the other foot abnormalities they found were comparable to those of the index study: Charcot foot deformity (2.1%), pes cavus (3.2%), limited joint mobility (9.2%), claw /hammer toe (16.0%), prominent metatarsal head (14.2%) and amputation (1.7%) versus 9.2%, 2.0%, 4.1%, 28.6%, 8.2%, 7.1%, 30.6% and 4.1% for hallux valgus, Charcot foot, pes cavus, limited joint mobility, claw toe, hammer toe, prominent metatarsal head and amputation found by the et and the index study, respectively [17].

Association between foot Deformity and Socio-Demographic Risk Factors

This study found significant association between diabetic foot deformity and the age of the subjects: elderly subjects had more foot deformity compared with young and middle-aged subjects. Ababneh *et al.*, equally found that elderly subjects were more prone to developing diabetic foot deformity [17]. The prevalence of neuropathy, foot deformity and PAD, as well as the risk of amputation were found to increase with increasing age [64]. This study also found significant association between foot deformity and the duration of DM and the educational status of the subjects. Foot deformity was more prevalent among the subjects who had no formal education and those with primary education, compared to those that attained higher levels of education. Equally, subjects with longer duration of DM had higher prevalence of foot deformity and similar findings were reported by some other studies [8-63]. Education generally, and foot care education specifically reduces the risk of foot deformity in DM subjects [65]. Compared to this study, some other researchers disparately found significant association between foot deformity in diabetic subjects and gender. Hallux valgus and diabetic foot ulcer (DFU) were more prevalent in female subjects compared to their male counterparts [13-17].

The index study did not find significant association between foot deformity and smoking and exercise. This may likely be due to the fact that the percentage of the subjects that smoked cigarette or had regular exercise was very small. Differently, some other studies found significant association between foot deformity in DM subjects and cigarette smoking, exercise, site of work, DNS score and foot care practice [2-58].

Association between Foot Deformity and Clinical/Laboratory variables in the Subjects

This study found that foot deformity had significant association with glycaemic control, global obesity, DPN: diagnosed with biothesiometer (VPN), tuning fork and tendon hammer (reflexes). Poor glycaemic control, global obesity, and DPN were reported as risk factors for the development of foot deformity in diabetic subjects. Similar findings were equally made by some other scholars [8,56].

Contrastingly, Halawa *et al.*, did not find significant association between plantar pressure, which is a marker of LOPS and by extension, DPN and the age of their diabetic subjects, duration of DM, global obesity and glycaemic control [66].

Lastly, this study did not find significant association between foot deformity and blood pressure, dyslipidaemia, PAD, treatment for DM, anti-hypertensive medication(s) use, and lipid-lowering medication(s) use. Agreeable to the index study, Halawa *et al*., did not find significant association between foot deformity in DM subjects and glycaemic control. Contrastingly, they did not find significant association between foot deformity and the age of the subjects, duration of DM and global obesity [66]. Finally, unlike this study, Luo *et al*., found that diabetic subjects with hallux valgus deformity had significantly less smoking habit, but that they paradoxically had good glycaemic control (lower HbA1c) [67].

Strengths and Limitations

This study evaluated a broader spectrum of DM-associated foot deformities and the risk factors for them compared to most other published literatures on this very important topic done in sub-Saharan Africa.

Notably also, this study was done in a specialist diabetes clinic in a tertiary health facility and the finding may not reflect the true prevalence of foot deformity in type 2 DM subjects in the rural communities or the primary health care setting.

CONCLUSION

The prevalence rate of foot deformity in subjects with type 2 DM recorded in this study was very high and was significantly associated with risk factors that included increasing age, longer duration of DM, lower educational status, poor glycaemic control, global obesity, and the presence of neuropathy in the subjects. Most of these risk factors for DM-associated foot deformity are potentially reversible if detected and corrected very early in the course of treatment of diabetes. This would go a long way to reducing the occurrence and retarding the progression of foot deformity in subjects with type 2 diabetes. Concerted efforts should be made by both the governmental agencies and health care physicians in giving diabetes education, especially foot care education to diabetic patients. A multi-disciplinary approach to the management of DM and DM foot deformity must be generally adopted by our hospitals, especially the specialist hospitals and the attending physicians should endeavor to screen the foot of their DM patients regularly and offer timely treatment to the subjects found to have foot deformity.

Acknowledgement: The authors acknowledge all the subjects that participated in the study.

Author's Contributions: CME – conception, design of the research and manuscript writing; AME – design, literature search/review, editing of manuscript; HEI – critical review of manuscript; HCN – manuscript writing, editing and critical review. The authors read and approved the final manuscripts.

Funding: No funding was received by the authors.

Conflict of Interest: None declared.

Ethical Approval: Ethical approval was obtained from the ethics committee of Nnamdi Azikiwe University Teaching Hospital, Nnewi with identification number: NAUTH/CS/66/VOL.13/VER 3/92/2020/067.

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Cite This Article: Chidiebele Malachy Ezeude, Afoma Marypaula Ezeude, Henry Emeka Ikeabbah, Harriet Chinwe Nwadimkpa (2025). Assessment of Foot Deformity and the Associated Factors among Type 2 Diabetes Mellitus Out-patients: The Scenario from a Tertiary Health Care Facility in South-Eastern Nigeria. *East African Scholars J Med Surg*, *7*(11), 325-338.