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RESEARCH ARTICLE

Prevalence and Associates of Foot Deformities among Patients with Diabetes in Jordan

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Abstract: ***Objectives*:** To determine the prevalence of, and factors associated with, people with foot deformities, among patients with diabetes in Jordan.

***Methods*:** A cross-sectional study was conducted on 1000 diabetic participants recruited from the National Center for Diabetes, Endocrinology, and Genetics in Jordan. Participants had their feet clinically examined to detect the following foot deformity outcomes: Hallux valgus, claw/hammer toe, prominent metatarsal heads, limited joint mobility, pes cavus, Charcot foot, and amputations. Sociodemographic and health variables were also collected from participants' interviews, medical records, or clinical examination. Logistic regression was used to analyse associations between variables and each foot deformity outcome.

***Results*:** Of the 1000 diabetic patients: Hallux valgus was found in 17.4%, claw\hammer toe in 16%, prominent metatarsal head in 14.2%, limited joint mobility in 9.4%, pes cavus in 3.2%, Charcot foot in 2.1%, and amputations in 1.7%. Hallux valgus was associated with gender (p=0.012), age (p<0.01) and shoe choices (p=0.031); claw\hammer toe was associated with age (p=0.04), retinopathy (p<0.001), sensory and painful neuropathy (p<0.001); limited joint mobility was associated with age only (p=0.001); Charcot foot was associated with glycemic control (p=0.016), hypertension (p<0.000), sensory neuropathy (p<0.001), and painful neuropathy (p<0.001); and, amputations were associated with duration of diabetes (p<0.043), sensory neuropathy (p=0.001), and painful neuropathy (p=0.001).

***Conclusion*:** Prevalence of different foot deformities in Jordan variedbetween 1.7% - 17.4%. Sociodemographic factors such as age, gender and shoes choices or presence of diabetes-related microvascular complications (neuropathy and retinopathy) or hypertension were independently associated with foot deformities among the Jordanian diabetic population.

Keywords: Diabetes complications, diabetic foot, prevalence, foot deformities, etiology, Jordan.

1. INTRODUCTION

Jordan is a developing country that has had a noticeable rise in the prevalence of Diabetes Mellites (DM) in recent decades [1]. The associated diabetes-related complications that affect the lower limbs were also highly reported [2, 3]. For instance, the prevalence of diabetic foot ulcers (DFUs) vary between 4 to 5.3% [2-4], and the prevalence of the related amputations is around 1.7% [3].

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Foot deformities among diabetic patients have been identified as a causal pathway for developing DFUs in those that have developed diabetes-related peripheral neuropathy [5-7]. The peak plantar pressure has been shown to be high in the presence of foot deformities [8]. For example, foot deformity such as hallux valgus increases this pressure under the medial forefoot [9, 10]. Likewise, a systematic review of 15 studies found that restriction of the ankle joint range in dorsal flexion because of diabetes led to increasing plantar pressure and development of plantar forefoot ulcers [11]. The associated high plantar pressure with foot deformities and the subsequent development of callus in the presence of peripheral sensory neuropathy [6, 8] may lead to subcutaneous hemorrhage and if not treated lead subsequently to diabetic foot ulceration [12].

Foot deformity is an essential component of diabetic foot syndrome [13]. Both type 1 and type 2 DM lead to microvascular complications such as neuropathy [14]. Motor neuropathy, which is the involvement of motor nerves especially in advanced cases of neuropathy, can cause muscle weakness such as weakness of foot muscles [15]. As a consequence, several foot deformities may develop [16]. However, the evidence to support this association is not clear. A review of the literature that included 17 studies did not find a significant association between different foot deformities and factors such as motor nerve function or intrinsic foot muscle atrophy which suggests a lack of understanding of the etiology of foot deformities [16]. Due to this limited recognition of the etiology or the outcomes of foot deformities, more investigation in this field is needed [13]. Thus, a part of this study was designed in an attempt to fill this gap in knowledge and provide more understanding of how these factors may influence in DFUs development.

In Jordan, data on foot deformities among diabetic patients are scarce. Other than a previous study that has reported a prevalence of 34% of overall foot deformities [3], there is no data that estimates the prevalence of different types of foot deformities and their associated factors among diabetic population. Therefore, this study aimed to determine the prevalence of different morphological foot deformities and their associated factors among diabetic patients in Jordan.

2. METHODS

2.1. Study, Design, Setting, and Population

This was a cross-sectional study. It was performed at the national center for diabetes, endocrinology, and genetics (NCDEG) which is the biggest referral diabetes center in Jordan. A sample of 1000 diabetic patients (type1 or type 2) was selected. The sample size was calculated to estimate each foot deformity. The sample size to estimate a prevalence of 50% with a margin of error of 5% and the level of significance of 0.05 at a power of 80% was almost 780 persons. A prevalence of 50% was used because it yielded the largest sample size. The sample size was increased to 1000. The selection of participants was systematic. Every second patient was recruited during their regular visits at the diabetes clinics at the NCDEG where the quality of diabetes care usually demands one visit every 2-3 months. Diabetes was defined as a self-reported physician diagnosis [17]. Diabetes patients below 20 years of age were excluded.

2.2. Data Collection Procedures

Ethical approval was obtained from the ethics office at the NCDEG. The data was collected during the period from October 2008 till January 2009. A structural interview questionnaire was designed to collect the data through interviewing participants, investigating medical records, and examining participants' feet. Participants were aware of the purpose of this study by providing them a written information form including consent. The researcher (A.A) and another qualified researcher at NCDEG were the only persons who conducted the interviews with participants. They also performed clinical foot screening and medical files reviewing. The researchers had the adequate skills and knowledge to assess the main outcomes of this research as they received their podiatry training including foot screening at the national institute for diabetes, endocrinology, and genetics [18]. This was during their graduate high diploma course.

2.3. Variables Collected

The collected variables including definitions and supporting citations are presented in Table **1**. This table has two main groups which are the sociodemographic variables and the health variables. Both sociodemographic and health information variables were taken verbally from participants or through medical records. The researchers also performed a physical examination of participants' feet, including a neurological assessment to assess sensory neuropathy (Table **1**). In addition, clinical inspection to assess footwear was performed by the researchers during the clinical examination to identify the patient's shoe type. Participants were asked about the type of footwear they mostly used in their daily life (> 12 h/day) [19].

Table **2** displays the definitions and the supporting citations of the study's main outcomes variables which were foot deformities. The morphological changes of participants' feet were inspected by the researchers to detect the presence of foot deformities according to these definitions.

2.4. Statistical Analysis

Statistical analysis was carried out using Statistical Package for Social Sciences IBM SPSS version 15. Chi-square test was used to determine the associations between foot deformities and other variables. Multiple logistic regression was used to assess the independent associations between foot deformities with other variables. A separate logistic regression model was used for each foot deform outcome. Forward Selection (Likelihood Ratio) was used to specify how independent variables were entered into the analysis. Multicollinearity between independent variables was tested and considered in the selection of variables. A P-value <0.05 was considered statistically significant.

3. RESULTS

Table **3** displays the baseline characteristics of the 1000 participants, including 482 (48.2%) were males and 518 (51.8%) were females. The mean age of participants was 58.4 years (SD = ± 11.4). In terms of smoking habits, most participants (69%) were non-smokers. Most participants (72.6%) were unemployed. Most footwear used by participants were shoes (54.5%) while 26.5% of participants wore sandals and 13.7% wore high heel shoes. Boots and therapeutic footwear were only worn by (1.8%, 0.35%) of participants retrospectively.

Table 1. Definitions of study variables.

Item	Definition
Sociodemographics	
Age	Age in whole years at the time of data collection
Gender	Male or female
Total family income	The monthly income of the family in Jordanian Dinar (JD)
Occupation	Employed or unemployed
Health Information	
Type of DM	Type 1 or type 2 as reported in medical files
Duration of DM	Duration in years as reported in medical files
Glycosylated hemoglobin (HBA1C)	It was analyzed by using a high-performance liquid chromatography (HPLC) method (Bio-Rad) and performed at NCDEG during participants' regular visits. Glycaemic control was judged depending on the average of three HbA1c readings, one at the examination day, and two previous reading obtained from the medical record
DM treatment	Diet, oral, insulin, or (oral & insulin) as reported in medical files
Body mass index (BMI)	Height and weight were measured for each patient during diabetes regular visits. BMI was calculated using the following formula: BMI= Weight (kg)/ [Height (m)] 2 World Health Organisation (WHO) criteria for adults were used to classify BMI as follows [20]: Normal: BMI <25 kg/m^2 Overweight: BMI = 25-29.9 kg/m^2 Obese: BMI $>$ 30 kg/m^2
Hypertension (HTN)	Participants were considered hypertensive if they took antihypertensive drugs, or it was defined as a self-reported physician diagnosis
Retinopathy	It was defined as self-reported ophthalmologist diagnosis in the patients' files
Smoking	According to WHO guidelines for controlling and monitoring the tobacco epidemic [21]. Participants were asked about their smoking habits which were defined as the following: Past smoker: who had smoked > 100 cigarettes in his life. Current smoker: regular smoking of at least one cigarette per day for at least one month Non-smoker: who never smoked in his\her life
Sensory neuropathy (loss of protective sensation)	It was evaluated by using a 10-g Nylon Semmes-Weinstein monofilament by testing the 3 recommended plantar sites (great toe, third, and fifth metatarsals). This procedure was applied according to the guidelines of the international consensus of the diabetic foot. If participants answered two out of the three applications correctly, this indicated the presence of a protective sensation and absence of it on two wrong answers out of three applications [22]
Painful neuropathy	It was evaluated by asking participants for any signs of paraesthesia, itching, tingling, pain or burning sensation [23, 24]
Footwear	Therapeutic footwear was defined if the shoes meet the following properties [25]: The outsole should be flexible The insole should be custom made The heel of the shoe should be capable for shock absorption and to avoid weight being thrown forward on to metatarsal heads Enough flexibility of the tongue Other footwear was defined as the following [26]: Sandals: are open types of footwear. They can be made of rope, rubber, leather, wood Shoes: are footwear less than boot and it is shaped to foot and the area below the ankle Boots: are types of footwear which cover at least the foot and usually the ankle, and sometimes extends up to the knee or even the hip High heel shoes: are shoes which raise the heel of the wearer's foot significantly higher than the toes. When both, the heel and the toes are raised, as in a platform shoe, it is generally not considered to be a high-heel

Table 2. Definition of foot deformities.

Foot Deformity	Definition
Hallux valgus	A deformity of the great toe by abduction valgus and pronation associated with bone prominence on the inner edge for the metatarsal (bunion) [27].
Prominent metatarsal heads	It was defined as any inspected or palpable plantar prominences of the metatarsal heads of the foot [28].
Claw\ hammer toes	The plantar flexion the distal and middle interphalangeal joint in comparison with proximal phalanx is called hammer toe while claw toe was defined as the dorsal flexion of the metatarsophalangeal joint associated with hammer toe [29].
Charcot Foot	Non-infectious destruction of bone and joint including loss of foot arches (Rocker bottom deformity) [30].
Pes Cavus	An abnormally high medial longitudinal arch, which extends between the first metatarsal head and the calcaneus [31].
Limited joint mobility	It was defined as stiffness or restriction of range of motion of the joint which was assessed by evaluating the range of motion of the ankle, subtalar joint, metatarsal joints, and interphalangeal joints through their normal ranges of motion, and determining whether there is any pain or restriction of the range of motion [32].
Amputation	It was reported as any resection of any part of the limb (big toe, another toe (s), midfoot, ankle, below the knee, or above the knee).

Table 3. Sociodemographic characteristics of the study population.

Variable	Frequency (*n*)	Percentage (%)
Gender		
Male	482	48.2%
Female	518	51.8%
Age Groups /Years Mean ± SD = 58.4 ± 11.4		
≤50	207	20.7%
51-60	334	33.4%
>60	459	45.9%
Smoking		
Non	690	69%
Past	146	14.6%
Current	162	16.2%
Total Family Income (JD)		
≤500	653	65.3%
>500	345	34.5%
Occupation		
Employed	274	24.4%
Unemployed	726	72.6%
Shoe Type		
Therapeutic footwear	35	0.35%
Sandals	265	26.5%
Shoes	545	54.5%
Boots	18	1.8%
High heel shoes	137	13.7%

Table **4** shows the clinical and anthropometric characteristics of the study population. The mean duration of diabetes was approximately 9 years and 57.7% of participants had HbA1c more than 7 mmol/l. Type 1 diabetes was only present in 1.3% of participants. Regarding BMI, 57.2% of participants were obese. Also, 62.7% of participants were treated by diet and oral anti glycemic agents.

The prevalence of participants with each individual foot deformity is presented in Table **5**. The deformity with the highest prevalence in participants in the population studies was hallux valgus (17.4%) and with the lowest prevalence was amputations (1.7%).

Participant characteristics and bi-variant analysis (Chi-square analyses) for each foot deformity outcome with identified associated factors are presented in Supplementary Tables **S1**-**S7**. After conducting multivariant logistic regression, the prevalence of each foot deformity was associated with several sociodemographic and clinical variables (Table **6**).

Table 4. Clinical and anthropometric characteristics of the study population.

Variable	Frequency (*n*)	Prevalence N (%)
Duration of DM/Years Mean ± SD = 9 ±7.6		
≤5	428	42.8%
>5	572	57.2%
HbA1c (mmol/l)		
≤7	423	42.3%
>7	577	57.7%
DM Type		
Type 1	13	1.3%
Type 2	987	98.7%
BMI		
Normal	91	9.1%
Overweight	335	33.5%
Obese	572	57.2%
DM Treatment		
Diet + Oral	627	62.7%
Insulin ± oral	369	36.9%
Retinopathy		
Yes	156	15.6%
No	840	84%
HTN		
Yes	649	64.9%
No	351	35.1%
Sensory Neuropathy		
Yes	174	17.4%
No	826	82.6%
Painful Neuropathy		
Yes	118	11.8%
No	882	88.2%

Table 5. Prevalence of participants with each foot deformity outcome in the study population.

Rank	Foot Deformity	N	Prevalence (%)
1	Hallux valgus	174	17.4%
2	Claw/hammer toe deformity	160	16%
3	Prominent metatarsal head	142	14.2%
4	Limited joint mobility	94	9.4%
5	High medial arch (Pes cavus)	32	3.2%
6	Charcot's deformity (Rocker Bottom)	21	2.1%
7	Amputations	17	1.7%

Table 6. The adjusted odds ratio for the prevalence of the studied foot deformities.

Hallux Valgus Deformity		
Variable	**OR (95%CI)**	**p-value**
Gender		
Male	0.6 (0.4-0.9)	0.012
Female	1	
Age		
≤50	1	
51-60	1.7 (0.9-3.1)	0.046
>60	3.7 (2.2-6.9)	<0.001
Shoe Type		
Others	1	
High heel shoes	3 (1-9.6)	0.031
Claw\Hammer Toe Deformity		
Variable	OR (95%CI)	p-value
Age		
≤50	1	
51-60	2.3 (1.3-4.2)	0.005
>60	2.4 (1.3-4.4)	0.004
Retinopathy		
Yes	1.6 (1 -2.6)	<0.001
No	1	
Painful Neuropathy		
Yes	3 (1.9-4.8)	<0.001
No	1	
Sensory Neuropathy		
Yes	4 (2.7-6)	<0.001
No	1	

(Table 6) Contd…

Limited Joint Mobility		
Variable	**OR (95%CI)**	**p-value**
Age		
≤50	1	
51-60	1.5 (0.7-3)	0.248
>60	3.3 (1.6-6.8)	0.001
Charcot Deformity		
Variable	OR (95%CI)	p-value
HbA1c		
≤7	1	
>7	6 (1.4-27)	0.016
HTN		
Yes	4.8 (1.1-21.2)	<0.001
No	1	
Sensory Neuropathy		
Yes	16.7 (5.4-51.9)	<0.001
No	1	
Painful Neuropathy		
Yes	5 (2-12.5)	<0.001
No	1	
Amputations		
Variable	OR (95%CI)	p-value
Duration of DM		
≤5	1	
>5	7.1 (0.8-56)	0.043
Sensory neuropathy		
Yes	10.4 (3.5-31.6)	<0.001
No	1	
Painful Neuropathy		
Yes	17 (4.6-62)	<0.001
No	1	

3.1. Hallux Valgus

Hallux valgus was present in 17.4% of participants. Hallux valgus had bi-variant associations with female sex, above 60 years age and high heel shoes (All p<0.001) (Supplementary Table **S1**). In the adjusted multivariate model (OR; 95% CI), hallux valgus deformity was associated with male sex (0.6; 0.4-0.9; p=0.012), age above 60 years (3.7; 2.2-6.9; p<0.001), and high heel shoes (3; 1-9.6; p=0.031).

3.2. Claw/Hammer Toe Deformity

Claw/hammer toe was present in 16% of participants. Claw/hammer toe had bi-variant associations with BMI, retinopathy, sensory and painful neuropathy (All p<0.002) (Supplementary Table **S2**). In the adjusted multivariate model (OR; 95% CI), claw/hammer toe was associated with age above 60 years (2.4; 1.3-4.4, p=0.004), retinopathy (1.6; 1-2.6; p<0.001), painful neuropathy (3; 1.9-4.8; p<0.001) and sensory neuropathy (4; 2.7-6; p<0.001).

3.3. Prominent Metatarsal Head

The prominent metatarsal head was present in 14.2% of participants. The prominent metatarsal head had bi-variant associations with past smokers, duration of DM >5 years, HbA1c >7, Insulin ± oral treatment, retinopathy, sensory and painful neuropathy (All $p<0.002$) (Supplementary Table **S3**). In the adjusted multivariate model, no significant associations were found between prominent metatarsal head deformity and the study variables.

3.4. Limited Joint Mobility

Limited joint mobility was present in 9.4% of participants. Limited joint mobility had bi-variant associations with age above 60 years, occupation (Unemployed) and shoe type (Sandals) (All $p<0.001$) (Supplementary Table **S4**). In the adjusted multivariate model (OR; 95% CI), limited joint mobility was associated with only age above 60 years (3.3; 1.6-6.8; $p<0.001$).

3.5. High Medial Arch (Pes Cavus)

Pes cavus was present in 3.2% of participants. Pes cavus had bi-variant associations with Age (51-60 years), past smokers, family income < 500 JD, HbA1c >7 mmol/l and overweight BMI (All $p<0.05$) (Supplementary Table **S5**). In the adjusted multivariate model, no significant associations were found between pes cavus deformity and the study variables.

3.6. Charcot Deformity (Rocker Bottom)

Charcot deformity was present in 2.1% of participants. Charcot deformity had bi-variant associations with shoe type (shoes), duration of DM >5 years, HbA1c >7 mmol/l, HTN, sensory and painful neuropathy (All $p<0.01$) (Supplementary Table **S6**). In the adjusted multivariate model (OR; 95% CI), Charcot deformity was associated with HbA1c (6; 1.4-27; $p<0.01$), HTN (4.8; 1.1-21.2; $p<0.001$), painful neuropathy (5; 2-12.5%; $p<0.001$), and sensory neuropathy (16.7; 5.4-51.9; $p<0.001$).

3.7. Amputations

Amputations were present in 1.7% of participants. Amputations had bi-variant associations with shoe type (Therapeutic footwear), duration of DM >5 years, retinopathy, HTN, sensory and painful neuropathy (All $p<0.02$) (Supplementary Table **S7**). In the adjusted multivariate model (OR; 95% CI), amputations were associated with duration of DM >5 years (7.1; 0.8-56; $p=0.043$), sensory neuropathy (10.4; 3.5-31.6; $p<0.001$), and painful neuropathy (17; 4.6-62; $p<0.001$)

4. DISCUSSION

This is the largest study to investigate the prevalence of different foot deformities among diabetic patients in Jordan. Within this population, the most common structural foot deformities identified were hallux valgus (17.4%), claw\hammer toe (16%), and prominent metatarsal head (14.2%). Other foot deformities such as limited joint mobility (9.4%), pes cavus (3.2%), and Charcot foot (2.1%) were less common among diabetic patients.

4.1. Hallux Valgus

This was the most prevalent deformity identified (17. 4%). This figure is lower than what was reported in previous studies which ranged between 23.9% - 49.4% [7, 33, 34]. Methods of measurement such as self-reporting or clinical examination can lead to this variation [27]. For instance, one study identified hallux valgus deformity by radiographic assessment of foot structure which might enable earlier detection of this deformity [33].

After adjusting for the associated sociodemographic and clinical variables, this deformity was not related to diabetes or its complications such as neuropathy. Of note, neuropathy was not a significant risk factor for developing hallux valgus in a previous study [35]. However, we found that hallux valgus was mainly associated with sociodemographic factors such as age or gender. For example, women had 2 times the odds of having hallux valgus in comparison with men. In addition, we found that patients who wore high heel shoes had 3 times more odds of having hallux valgus compared to other groups. This result may explain why hallux valgus was more prevalent in females as most people in Jordan who wear high heel shoes are female. The results of this study aligned with the results of a meta-analysis of 78 papers that investigated the etiology of hallux valgus deformity and also identified that age and gender were independent factors associated with the prevalence of hallux deformity [27].

4.2. Claw\Hammer Toe Deformity

This deformity was found in 16% of the overall population. In contrast, the prevalence of claw\hammer toe was higher in other populations and ranged between 32-49% [7, 33, 34, 36]. As mentioned above, we believe that the assessment procedure may have led to this variation. For instance, Smith *et al.* [33] identified claw \hammer deformities according to radiographic changes of bone structure and this might enable detection of this deformity in early stages. In comparison, our measurement was based on clinical inspection which could be the reason for this difference of claw\hammer toe prevalence. This suggests that differences in prevalence of these foot deformities may be due to the different definitions used to identify claw/hammer toe deformities, as the methods of assessment are not established or standardized, and as such lead to a large variation in outcomes, especially in cases of mild claw/hammer toe deformities [13].

The study results showed that claw\hammer toes deformity was significantly associated with factors such as age, and the presence of diabetes-related complications, including retinopathy and neuropathy. These results confirm the common hypothesis that diabetes may cause atrophy of the small intrinsic muscles in the foot which lead to foot deformities [37, 38]. However, one descriptive study investigated claw toe deformities by Magnetic Resonance Imaging (MRI) and its relation to muscle atrophy and showed no relationship between the diabetes-related atrophy of intrinsic muscles and claw toe deformity [39]. Furthermore, a literature review of the etiology of foot deformities in diabetic populations did not find evidence that correlates muscle weakness that results from motor neuropathy and developing foot deformities such as claw\hammer toe [16]. Therefore, this data suggests that the etiology of the claw\hammer toe is still not clear.

4.3. Limited Joint Mobility

This deformity was only found in 9.4% of the overall population and was only associated with age. Participants above 60 years old age had around 3 times the odds of having limited joint mobility in comparison with other age groups. Despite a previous study [15] finding a strong relationship between motor neuropathy, muscle strength, and foot deformity progression, our findings did not support this. It is also in contrast with the common belief that the range of motion of many joints may be decreased in patients with diabetes [40] as no associations were found between limited joint mobility and variables such as duration of diabetes, HbA1C readings, or presence of diabetes complications such as neuropathy. However, Martinez *et al.* [35] had similar findings to ours as reporting no significant relationship between diabetic neuropathy and limited joint mobility. Corbalan *et al.* [41] also did not find that the presence of limited joint mobility was associated with different neurological examinations. This may instead be explained by other mechanisms for limited joint mobility such as glycosylation of collagen in joint capsules [37]. Thus, this highlights the complexity of the etiology of foot deformities among diabetic patients.

4.4. Charcot Deformity

Of the overall diabetic population here, Charcot deformity was found in 2.1%. This number was not consistent with previous findings from Jordan [42] reporting the incidence of Charcot's foot to be only 0.19% of diabetic patients [42]. However, our findings are in line with Smith *et al.* [33] which found 1.4% of diabetics had Charcot deformity. Interestingly, there seems to be variation in the prevalence of Charcot's foot in different populations. Indians, for example, had a slightly higher prevalence of Charcot's foot in comparison with our result with this deformity present in 3.6% of Indian diabetic populations [36]. Also, there was a significant difference of Charcot foot between non-Hispanic whites and Mexican American (11.7/1,000 *vs*. 6.4/1,000; P = 0.0001) [43]. A narrative review estimated the prevalence of Charcot's foot between 0.08% - 13%. This variation may be related to hidden Charcot disease as up to 25% of diagnoses can be missed [44]. This confirms the need for a regular musculoskeletal assessment of the foot which is a neglected aspect of care in many health care settings [45]. In addition, the variation in the prevalence of Charcot deformity may be also due to the variation between races [43].

As expected, our study showed that Charcot deformity had a significant association with the duration of diabetes and the presence of diabetes complications including retinopathy and neuropathy. Higher HbA1c findings were associated with the presence of Charcot foot (OR 6, 95% CI = 1.4 - 27). In addition, our results showed that patients who had sensory neuropathy were more likely to have Charcot foot (16 times). Also, patients who had painful neuropathy were 5 times more likely to have Charcot deformity. The same factors including age, HbA1c, and presence sensory neuropathy were also found in a previous study from Jordan [42]. These results from Jordan are consistent with earlier literature that neuropathy is considered the main predisposing factor for the initiation and deterioration of a Charcot foot deformity [46-48].

4.5. Amputations

Amputations were present in 1.7% of our population studied. This number is consistent with a recent result from Jordan (1.7%) [2]. However, in a relatively older study from the same country [4], the prevalence of amputation was higher. Bader *et al.* [4] reported a 5% of overall prevalence of amputations. The comparison of the outcomes of these studies might indicate a significant decline in the prevalence of amputations among diabetic patients in Jordan. Similarly, different studies in developed countries [49-53] showed the same decline where many of these studies attribute this decrease to the development of podiatric services. The same explanation may be a factor in our findings. Podiatry care was significantly developed at the NCDEG in the last few years. There is a special diabetic foot clinic with special equipment that provides standard podiatry services. Health education and foot screening are regularly performed for all patients attending this center. Also, the diabetic foot clinic has specialist podiatric nurses who collaborate with a multidisciplinary team from other specialties with adequate skills and special training [18].

The presence of amputations among the population of this study was mainly associated with the duration of DM. This confirms that the length of time someone has diabetes is responsible for increasing risks of amputations among diabetic patients in comparison with the normal population [52]. We also found that amputations were associated with diabetes-related complications such as neuropathy. Otte *et al.* [54] found the same association as amputations were significantly associated with nephropathy. However, race can be another risk factor for developing amputations. A prospective study showed that Mexican Americans had a significantly higher incidence of amputations in comparison with non-Hispanic whites [43]. Factors such as race, quality of care, duration of diabetes or race might lead to the variation in the incidence of amputations among diabetic patients [55].

From the previous studies, it is clear that the prevalence of foot deformities in the diabetic population is variable, and this may be related to two main reasons. Firstly, the measurement methods may have an impact on this variation as no standard measurement of the changes in musculoskeletal foot structure exists in people with diabetes [13]. Foot deformities are usually identified according to subjective clinical inspection by the researchers [2, 56, 57]. This includes inspecting any changes in the physical appearance of the foot which sometimes can lead to a bias in outcomes. Secondly, the variation in the heterogeneity of populations could be responsible for these different prevalence outcomes of foot deformities as well. For instance, the studied diabetic populations with higher age might have a higher prevalence of foot deformities. In contrast, populations who had poor diabetes care might have a higher mortality rate which resulted in less observation of foot deformities.

5. STRENGTH AND LIMITATIONS

This study has provided important new information regarding the prevalence of different foot deformities in Jordan. It appears to be one of the largest sample sizes (n=1000) to investigate foot deformities in people with diabetes in Jordan and potentially worldwide. Despite the study population being recruited from one setting (NCDEG) which may not represent the overall population in Jordan, this setting is the biggest referral diabetes center in Jordan and receives patients from most parts of Jordan and as such may be more representative of the Jordanian diabetic population than first thought. In alignment with the large sample size, the statistical power to detect associated factors of these deformities is perhaps also more robust than most other similar studies performed to date in this field.

However, this study was associated with a number of obvious limitations. Firstly, this study was cross-sectional which was not able to establish the causal pathway of foot deformities. Secondly, some other study variables such as employment categories could have been more specifically defined, such as employment status and medical comorbidities. However, we note most study variable definitions adhered with that of the international reporting standards for diabetic foot studies [17]. Thirdly, the assessment of foot deformities relied on the clinical examination of the researchers involved. Recent developments in assessment methods of foot structures including plain radiography, ultrasonography, computed tomography, and MRI may have provided more reliable outcomes [13]. Lastly, we have investigated the prevalence and associates of specific individual foot deformity which provides very useful knowledge on these particular deformities. However, we note people with diabetic foot disease can have multiple of these individual foot deformities at once and they are sometimes associated with each other. Unfortunately, we did not collect data on those who had at least one foot deformity or multiple foot deformities, and we are therefore unable to analyse the overall prevalence and associates of those with one or multiple foot deformities. However, we recommend this to be investigated in future similar studies.

6. RECOMMENDATIONS

As this study has found a relatively high prevalence of some foot deformities among the Jordanian diabetic population, it is recommended that more attention should be paid by health care providers in diabetes clinics to screen for these foot deformities. The early detection of foot deformities may help to potentially prevent DFUs and amputations by implementing interventions aimed at reducing the high plantar pressures brought on by these deformities using such as therapeutic footwear and some surgical procedures. In addition, due to the significant relationship between foot deformities such as claw\hammer toes, limited joint mobility, Charcot foot or amputations, and diabetes-related microvascular complications, we encourage clinicians to consider further examination of diabetic patients' feet if they have an uncontrolled or long duration of diabetes especially with complications such as neuropathy or retinopathy. All these diabetes-related consequences may be a clinical marker of these foot deformities. Furthermore, as this study was cross-sectional, further prospective longitudinal or case-control studies are needed to establish cause-and-effect relationships between foot structural changes and diabetes.

CONCLUSION

Several foot deformities have been found to be highly prevalent among the diabetic population in Jordan. Deformities such as claw\hammer toe, Charcot foot, and amputations were associated with variables related to diabetes and its complications. On the other hand, deformities such as hallux valgus, prominent metatarsal head, or pes cavus were not associated with diabetes. Factors such as age, gender or shoe choices were identified as factors independently associated with hallux valgus deformity for instance. This reflects the variance and complexity of the etiology of different foot deformities among the Jordanian diabetic population.

LIST OF ABBREVIATIONS

BMI	=	Body Mass Index
CKD	=	Chronic Kidney Disease
DFUs	=	Diabetic Foot Ulcers
DM	=	Diabetes Mellites
HBA1C	=	Glycosylated Hemoglobin
HTN	=	Hypertension
JD	=	Jordanian Dinar
MRI	=	Magnetic Resonance Imaging
NCDEG	=	National Center for Diabetes, Endocrinology, and Genetics (NCDEG)
PAD	=	Peripheral Arterial Disease
WHO	=	World Health Organization

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the ethics office at the NCDEG.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Participants were aware of the purpose of this study by providing them a written information form including consent.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's web site along with the published article.

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