The diabetic foot: Cavoid or not?

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Article points

1. Patients with diabetic peripheral neuropathy may develop a pronated foot.
2. Biomechanical assessment is fundamental in patients with neuropathy due to increased risk of shear and pressure under the hallux during pronation.
3. Foot shape in patients with diabetic peripheral neuropathy must be observed in both weight-bearing and nonweight-bearing positions.

Key words

- Cavoid foot
- Foot type
- Peripheral neuropathy

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Diabetic peripheral neuropathy has been found to lead to a cavoid-type foot with a high arch and prominent metatarsal heads developing in some cases. In this study, it was discovered that patients with advanced peripheral neuropathy may develop a severely pronated foot type, which may result in increased risk of shear and pressure under the hallux (Nubé et al, 2006). This emphasises the importance of biomechanical assessment in patients with diabetic peripheral neuropathy. Furthermore, this study highlights that when treating patients with diabetic peripheral neuropathy, clinicians must assess patients in weight-bearing and nonweight-bearing positions to aid in decision-making regarding footwear and treatment.

It is commonly accepted that diabetic peripheral neuropathy may lead to weakness and atrophy of the intrinsic foot muscles, causing hammer/claw toes (Cavanagh et al, 2001; Caselli et al, 2002), with prominent metatarsal heads resulting in a high-arched, cavoid foot type (Giacomozzi et al, 2002). It is still unclear whether neuropathy is responsible for the development of the cavoid-type foot and associated deformities (Bus et al, 2002; VanSchie et al, 2004).

This study was undertaken to investigate the foot type of patients with diabetic peripheral neuropathy, compared with a nondiabetic control group. Preliminary results suggest there was a higher number of participants with pronated feet than with cavoid-type feet. This highlights the need for further research into the effects of diabetic neuropathy on the biomechanics of the foot.

Background

Diabetic foot disease is a major complication of diabetes with potentially devastating consequences, such as ulceration and infection, which may lead to hospitalisation, amputation, and premature death (Dinh and Veves, 2005). Diabetic neuropathy is an important factor in foot ulceration, together with limited joint mobility, altered foot pressure, poor glycaemic control, and vascular insufficiency (Caputo et al, 1994; McNeely et al, 1995; Reiber et al, 1999).

It is thought that diabetic neuropathy not only leads to the insensate foot, without the protection of pain, but also to structural changes in the foot, resulting in a characteristic high-arched, cavoid-type foot with bony prominences (Lippmann et al, 1976; Coughlin, 1984; Habershaw and Donovan, 1984; Cavanagh et al, 2001), susceptible to increased pressure and shear forces (Payne et al, 2002). Diabetic neuropathy increases the risk of foot ulceration by 12.1 times (Lavery et al, 1998).

The theory that diabetic neuropathy results in a cavoid-type foot with prominent metatarsal heads and clawed toes has been commonly accepted (Caselli et al, 2002). However, no prevalence data on foot structure abnormalities in people with or without diabetes are available (Bus, 2008). Recent imaging research has questioned the association between neuropathy and foot deformity (Bus et al, 2002). Moreover, structural foot deformities and arch profile are not commonly reported in the literature using standardised methods, making any comparison of data difficult.

Aim

The aim of this controlled study was to compare the distribution of foot type in patients with diabetic peripheral neuropathy with a control group, using the Foot Posture Index (FPI)-6.

Methods

The study population was selected from patients who attended the diabetic foot clinic located within the only national hospital in Malta, where health care is provided free to all patients at the point of delivery. People with diabetes are referred to this clinic from all over the island and the study was undertaken after obtaining ethical approval from the relevant committees.

The first 30 participants who satisfied the inclusion criteria for Group 1 (*Box 1*) were included, while the first 60 individuals available to take part in the study, who satisfied the inclusion criteria were included in Group 2 (control).

Neuropathy

The presence of neuropathy in Group 1 was assessed using the Neuropathy Symptom Score (NSS) as used by Pham et al (2000). The NSS includes a series of questions leading to a composite score; an NSS of ≥3 is indicative of neuropathy. In addition, the Neuropathy Disability Score (NDS) was used to determine the severity of neuropathy (Boulton, 2005). This involves a series of assessments, including Neurotip™ (Owen Mumford, Oxford) discrimination, vibration perception, and tendon reflex examination, which also lead to the creation of a composite score; an NDS ≥6 is indicative of moderate to severe neuropathy.

Foot type

The participants in both groups were assessed for foot type using the FPI-6 developed by Redmond et al (2006), which was found to have good internal construct validity and intra-class correlation coefficient of 0.62–0.91. The FPI-6 is a criterion-based, observational scoring system of six weight-bearing clinical measures providing a validated quantification of postural variation in three major anatomical segments of the foot (rearfoot, midfoot, forefoot) in the three cardinal body planes (Keenan et al, 2007). The aggregated score leads to classification of foot types, ranging from severely pronated to severely supinated feet.

Results

Data were collected over a period of 2 months. Data from three participants in Group 1 were discarded due to lack of consistency when answering the questions for the neuropathy symptom and neuropathy disability scores. Therefore, Group 1 consisted of a total of 27 participants (17 men, 10 women) with a mean age of 62.2 years. Group 2 consisted of 60 participants (23 men, 37 women) with a mean age of 64.5 years.

All the participants in Group 1 were diagnosed as having type 2 diabetes with a duration from time of diagnosis ranging from 1 to 30 years (mean duration, 15.6 years). Neuropathy scores ranged from 5.5 to 7.5 in the NSS and 5.43 to 6.67 in the NDS in Group 1 (*Table 1*).

Almost half (48.1%; 13/27) of the participants in the diabetic neuropathic group had pronated feet, while 29.6% (8/27) had supinated feet. The distribution of foot type across the groups were compared (*Figure 1*). There was a higher percentage of severely pronated feet (22.2%) in the Group 1, compared with the control group (8.3%). The percentage of participants with severely supinated feet did not differ greatly between the two groups (Group 1, 7.4%; Group 2, 6.7%). Participants with severely pronated feet also achieved the highest combined NDS and NSS scores, while the lowest combined neuropathy scores were achieved by participants with severely supinated feet.

Discussion

The results observed in this study illustrate there was a higher prevalence of severely pronated feet (FPI-6 >10+) found in people with diabetic neuropathy (22.2%), compared with controls (8.33%). This finding questions the theory that people with diabetic neuropathy typically develop a cavoid foot type, suggesting the possibilty of the development of a pronated foot and possibly an acquired flat foot deformity, commonly due to posterior tibial tendon dysfunction (PTTD) (Myerson and Corrigan, 1996; Augustin et al, 2003) in this group of patients.

This is supported by Holmes and Mann (1992) who found that 60% of patients with PTTD had associated obesity, diabetes, and hypertension, which may contribute to degenerative changes in the PTTD. Degenerative tears in the posterior tibial tendon were most often found to be initiated posterior and distal to the medial malleolus (Squires and Jeng, 2006). This supports the theory of the possibility of PTTD dysfunction in diabetic neuropathy since Andersen

Box 1. Inclusion and exclusion criteria

Inclusion criteria

Group 1

- Individuals with diabetes and diabetic peripheral sensory neuropathy (insensitive to 10-g monofilament)
- Aged 45–75 years

Group 2

- Healthy individuals aged 45–75 years

Exclusion criteria

- Individuals with any condition that may affect: (a) Peripheral sensation (e.g. poliomyelitis, Parkinson's disease, stroke, Charcot, congenital neuropathy, spina bifida), or; (b) Foot shape (e.g. rheumatoid arthritis, talipes, or major foot deformity resulting from injury or surgery)

"Diabetic neuropathy has often been associated with a cavoid-type foot, [but] this study suggests that people with advanced peripheral neuropathy may also develop a severely pronated foot type."

et al (1997) found a distal-to-proximal gradient of muscle atrophy in diabetic patients with neuropathy, suggesting that the changes would be even greater in foot muscles.

Despite the attention given in past years to cavoid-type neuropathic foot with prominent metatarsal heads, the results of this study suggest that some people with diabetic neuropathy may also have a pronated foot type. In fact, participants who had the highest neuropathy scores had severely pronated feet.

Although these observations were not expected, the fact that peripheral neuropathy does not necessarily result in a cavoid, supinated foot type is evident in other medical conditions with associated peripheral neuropathy, such as spina bifida, cerebral palsy (Genaze, 2000), and leprosy.

These findings have important implications for practice, with diabetes and pronated feet more susceptible to hallux ulceration than patients with other foot types (Nubé et al, 2006). Similarly, diabetic neuropathy and flat foot deformity have been previously associated with increased risk of ulceration by Ledoux et al (2005) who observed a non-significant trend between ulcer occurrence ($p=0.09$) and the presence of hallux valgus (HAV), which was significantly correlated ($p=0.003$) with pes planus (commonly known as flat foot) foot type.

Interestingly, it was observed during data collection that several participants classified as having pronated feet (FPI ≥+5) when weight bearing, had high longitudinal arches with prominent metatarsal heads and clawed toes when nonweight bearing. This highlights the importance of assessing the patient in both weight-bearing and nonweight-bearing positions.

This finding may explain accepted theory that diabetic neuropathy results in a cavoid-type foot, since the assessment of structural foot deformity was not standardised for weight/nonweight bearing in previous studies (Bus, 2008).

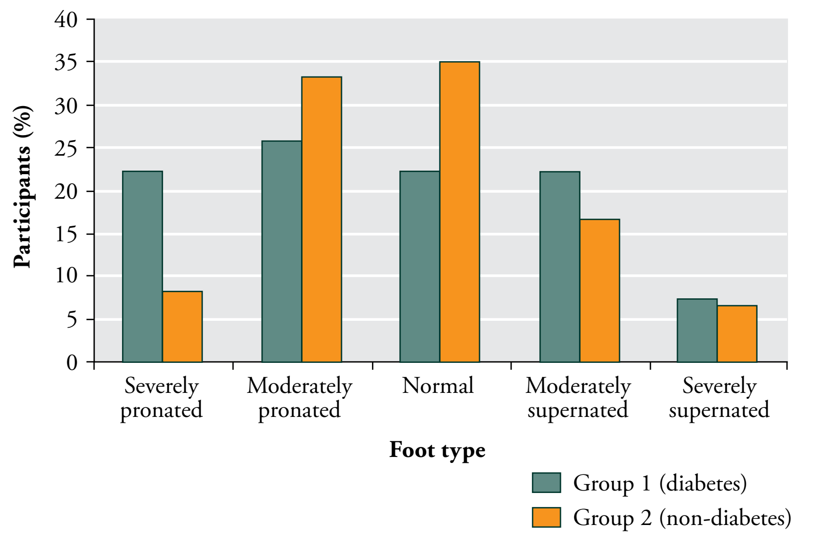

Figure 1. Foot types in Groups 1 and 2.

Conclusion

Diabetic neuropathy has often been associated with a cavoid-type foot with a high arch and prominent metatarsal heads. This study suggests that people with advanced peripheral neuropathy may also develop a severely pronated foot type, which may result in increased risk of shear and pressure under the hallux (Nubé et al, 2006), highlighting the importance of biomechanical assessment in patients with diabetic peripheral neuropathy.

Clinicians must assess people with diabetic peripheral neuropathy in both weight-bearing and nonweight-bearing positions as this may have important implications on the footwear and orthotic treatments selected. More comprehensive studies are required to explore this further together with the consideration of posterior tendon dysfunction in diabetic neuropathic patients.

Due to the relatively small number of participants involved, this study is considered to be a pilot, providing evidence for the need of further research related to foot type in diabetic neuropathy. The lack of random sampling in this study limits generalisation of the results. Further research should ideally utilise random sampling with more than one researcher for data collection, enabling inter- and intra-rater reliability testing of the neuropathy and FPI scores. ■

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Table 1. Foot type, neuropathy scores, and foot postures for Group 1

	Severely supinated	Moderately supinated	Normal	Moderately pronated	Severely pronated
Foot type (*n*)	2	6	6	7	6
NSS (mean)	5.5	7	7.5	6.43	7.5
NDS (mean)	5.5	5.83	6	5.43	6.67
FPI (mean)	–6.5	–2.3	2.83	8	10.67

FPI, Foot Position Index (Redmond et al, 2006); NDS, Neuropathy Disability Score (Boulton, 2005); NSS, Neuropathy Symptom Score (Pham et al, 2000).

Abbott C, Carrington AL, Ashe H et al (2002) The North-West Diabetes Foot Care Study: incidence of, and risk factors for, new diabetic foot ulceration in a community-based cohort. *Diabet Med* **19**: 377–84

Andersen H, Gadeberg PC, Brock B, Jakobsen J (1997) Muscular atrophy in diabetic neuropathy: a stereological magnetic resonance imaging study. *Diabetologia* **40**: 1062–9

Augustin JF, Lin SS, Berberian WS, Johnson JE (2003) Non-operative treatment of adult acquired flatfoot with the Arizona brace. *Foot Ankle Clin* **8**: 491–502

Boulton AJM (1998) Lowering the risk of neuropathy, foot ulcers and amputations. *Diabetes Medicine* (Suppl 4): S57–S59

Boulton AJM (2005) Management of diabetic peripheral neuropathy. *Clinical Diabetes* **23**: 9–15

Bus SA, Yang QX, Wang JH et al (2002) Intrinsic muscle atrophy and toe deformity in the diabetic neuropathic foot. *Diabetes Care* **25**: 1444–50

Bus SA (2008) Foot structure and footwear prescription in Diabetes Mellitus. *Diabetes Metab Res Rev* **24**(Suppl 1) S90–S95

Caputo GM, Cavanagh PR, Ulbrecht JS et al (1994) Assessment and management of foot disease in patients with diabetes. *N Eng J Med* **331**: 854–60

Caselli A, Armstrong DG, Pham H et al (2002) The forefoot-to-rearfoot plantar pressure ratio is increased in severe diabetic neuropathy and can predict foot ulceration. *Diabetes Care* **25**: 1066–71

Cavanagh PR, Ulbrecht JS, Caputo GM (2001) The biomechanics of the diabetic foot in diabetes mellitus. In: Levin and O'Neal's The Diabetic Foot. 6th edition. Bowker JH, Pfeifer MA (eds) St Louis, MO, Mosby 125–96

Coughlin MJ (1984) Mallet toes, hammer toes, claw toes, and corns: causes and treatment of lesser-toe deformities. *Postgrad Med* **75**: 191–8

Dinh TL, Veves A (2005) A Review of the Mechanisms implicated in the pathogenesis of the diabetic foot. *Lower Extremity Wounds* **4**: 154–9

Genaze RR (2000) Pronation. The othotist's view. *Clin Podiatr Med Surg* **17**: 481–503

Giacomozzi C, Caselli A, Macellari V et al (2002) Walking strategy in diabetic patients without peripheral neuropathy. *Diabetes Care* **25**: 1451–7

Habershaw G, Donovan JC (1984) Biomechanical considerations of the diabetic foot. In: *Management of Diabetic Foot Problems*. Kozak GP, Hoar CS, Rowbotham JL et al (eds). Philadelphia, WB Saunders 32–44

Holmes GB, Mann RA (1992) Possible aetiological factors associated with rupture of the posterior tibial tendon. Foot & Ankle **13**: 70–9

Keenan A, Redmond AC, Horton M et al (2007) The Foot Posture Index: Rasch Analysis of a Novel Foot-Specific Outcome Measure. *Arch Phys Med Rehabil* **88**: 88–93

Lavery LA, Armstrong DG, Vela SA et al (1998) Practical criteria for screening patients at high risk for diabetic foot ulceration. *Arch Intern Med* **158**: 157–62

Ledoux WR, Shofer JB, Smith DG et al (2005) Relationship between foot type, foot deformity and ulcer occurrence in the high-risk diabetic foot. *Journal of Rehabilitation Research & Development* **42**: 665–72

Lippmann HI, Perotto A, Farrar R (1976) The neuropathic foot of the diabetic. *Bull NY Acad Med* **52**: 1159–78

McNeely MJ, Boyko EJ, Ahroni JH et al (1995) The independent contributions of diabetic neuropathy and vasculopathy in foot ulceration: how great are the risks? *Diabetes Care* **18**: 216–9

Myerson MS, Corrigan J (1996) Treatment of posterior tibial dysfunction with flexor digitorum longus tendon transfer and calcaneal osteotomy. *Orthopedics* **19**: 383–8

Nubé VL, Molyneaux L, Yue DK (2006) Biomechanical risk factors associated with neuropathic ulceration of the hallux in people with diabetes mellitus. *J Am Podiatr Med Assoc* **96**: 189–97

Payne C, Turner D, Miller K (2002) Determinants of plantar pressures in the diabetic foot. *J Diabetes Complications* **16**: 277–83

Pham H, Armstrong DG, Harvey C et al (2000) Screening techniques to identify people at high risk for diabetic foot ulceration: a prospective multicenter trial. Diabetes Care **23**: 606–11

Redmond AC, Crosbie J, Ouvrier RA (2006) Development and validation of a novel rating system for scoring standing foot posture: the Foot Posture Index. *Clin Biomech* **21**: 89–98

Redmond AC, Crane YZ, Menz HB (2008) Normative Values for Foot Posture Index. *J Foot Ankle Res* **1**: 6

Reiber GE, Vileikyte L, Boyko EJ et al (1999) Causal pathways for incident lower-extremity ulcers in patients with diabetes from two settings. *Diabetes Care* **22**: 157–62

Squires NA, Jeng CL (2006) Posterior tibial tendon dysfunction. *Operative Techniques in Orthopaedics* **16**: 44–52

Van Schie CHM, Vermigli C, Carrington AL, Boulton A (2004) Muscle weakness and foot deformities in diabetes. *Diabetes Care* **27**: 1668–73