

DISTAL FAT PAD DISPLACEMENT AND ELEVATED PLANTAR PRESSURE IN DIABETIC NEUROPATHIC PATIENTS WITH TOE DEFORMITY

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INTRODUCTION

Elevated dynamic plantar pressure is as a major risk factor for plantar ulceration in diabetic feet with loss of protective sensation (Veves, 1992). Through the distal migration of the sub-metatarsal head (MTH) fat pad cushion, hyperextension (claw toe) deformity of the metatarsal phalangeal (MTP) joint has been suggested to play an important role in explaining these increased pressure levels (Ellenberg, 1968). However, objective quantitative evidence for such an association does not exist. Therefore, the aim was to assess the relationship between MTP joint hyperextension deformity, sub-MTH fat pad status and dynamic plantar pressure in diabetic neuropathic feet.

METHODS

Thirteen diabetic subjects (eight males) with peripheral sensory neuropathy and MTP joint hyperextension and 13 age and gender matched diabetic controls with neuropathy but no toe deformity were examined (Table 1). In 9 subject pairs the second ray and in 4 pairs the third ray of the foot was examined.

Table 1. Subject specific data (mean (SD))

Variable	Deformity	Controls
Age (yrs.)	56.3 (8.6)	57.2 (6.5)
BMI (kg/m ²)	27.2 (2.9)	26.4 (4.1)
DM ¹ duration (yrs.)	32.8 (12.0)	31.1 (12.8)
VPT ² (Volts)	33.5 (12.2)	36.2 (10.6)
MTP joint angle (α)	-57 (12)	-31 (6)

¹ Diabetes mellitus, ²vibration perception threshold (>25 = indicator for neuropathy)

A 1.5 Tesla magnetic resonance imager (Siemens, Germany) was used to acquire high-resolution (512x512 pixels) T1-weighted spin-echo sagittal plane images of the metatarsal region of the foot. From these images the MTP joint extension angle was measured (Figure 1) in order to distinguish between deformed and normally aligned toes. Additionally, sub-MTH and sub-phalangeal fat pad thickness was measured.



Figure 1: Assessment of MTP joint extension angle (α) and fat pad thickness in the forefoot.

Dynamic plantar pressures were measured at 70 Hz using an EMED-NT pressure platform (Novelgmbh, Germany). Five trials per subject using a ‘two-step’ gait approach were collected. From an anatomically referenced regional division of the foot (Figure 2), peak pressure (PP), force-time integral (FTI), and contact area (CA) were calculated.

All outcomes were analyzed statistically using independent t-tests (SPSS, p<0.05).

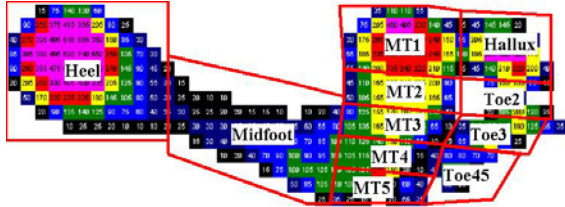


Figure 2: Schematic example of the division of the foot in 11 regions for pressure analysis.

RESULTS

Sub-MTH fat pad was significantly thinner and sub-phalangeal fat pad was significantly thicker in the subjects with toe deformity when compared to the controls (Table 2). The thickness ratio was substantially lower in the deformed feet reflecting distal fat pad displacement. Peak pressure at the MT region of interest (ROI) was significantly higher in the patients with deformity whereas PP at the toe ROI was not different between the groups. The toe-loading ratio, which is a ratio of FTI in the toes and in the MTs was significantly lower in the group with toe deformity. MT PP was significantly correlated with degree of toe deformity (α) ($r=-0.76$), sub-MTH pad thickness ($r=-0.59$) and thickness ratio ($r=-0.60$) ($p<0.005$).

Table 2: Results (mean (SD))

Variable	Deformity	Controls
Pad thickness (mm)		
Sub-MTH	2.7 (1.5)	6.3 (1.8) ^b
Sub-phalangeal	10.9 (2.4)	8.9 (1.4) ^a
Thickness ratio	0.26 (0.16)	0.70 (0.16) ^b
PP MT (kPa)	627 (236)	374 (111) ^b
PP toe (kPa)	110 (74)	145 (68)
Toe-loading ratio	0.036 (0.017)	0.072 (0.030) ^b
CA toes (cm ²)	8.1 (1.9)	12.1 (1.5) ^b

^a $p<0.05$; ^b $p<0.005$

DISCUSSION

The results clearly show a distal migration of the sub-MTH fat pads when deformity of the MTP joint is present, which can be explained by the fact that the fat pads are physically connected to the proximal

phalanges via flexor tendons and plantar ligaments (Bojsen-Moller, 1979). As a result of this migration, the fat pad lost its function as principal shock absorber of the MTHs, which was demonstrated by the significantly increased metatarsal peak pressures in the subjects with deformity. Within these interrelationships, the degree of MTP joint deformity was a strong independent contributor to elevated plantar pressure explaining 58% of its variance.

Due to the characteristic ‘cocked-up’ position of the clawed toe, the contact area of the toes during load bearing was reduced (Table 2); the toes had become less functional and as a result the MTHs bore an increased amount of weight as evidenced by a significant reduction in the toe-loading ratio in the patients with deformity. These findings confirm suggestions made by Boulton et al. (1987). Thus, while the fat tissue migrates *distally* in the foot, the load ‘migrates’ *proximally* in the foot. For diabetic patients who have lost protective sensation this is of major importance because it increases the risk for ulceration of the plantar surface of the foot. Therefore, these patients should be prescribed with adequate pressure-relieving footwear.

In conclusion, this study confirms the long held belief that MTP joint hyperextension deformity leads to a distal displacement of the sub-MTH fat pad cushion and to elevated dynamic plantar pressures in diabetic patients with neuropathy.

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