



Association of limited joint mobility and high plantar pressure in diabetic foot ulceration in Asian Indians

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Abstract

Aim: To investigate the association of limited joint mobility (LJM) and plantar foot pressure in Asian Indian diabetic subjects. **Subjects and methods:** The LJM and plantar pressure were measured in 345 consecutive subjects attending the foot clinic. The study groups were: Control—non-diabetic controls ($n = 50$), DM—diabetic patients without neuropathy ($n = 100$), DM+N—diabetic neuropaths ($n = 110$) and DM+NU—diabetic neuropaths with past history of foot ulceration ($n = 85$). Joint mobility was assessed using a goniometer. Plantar pressure was measured using the RS-Scan platform system. All subjects were able to walk comfortably unaided at their own pace. Data obtained on the metatarsal heads were used for analysis. Neuropathy status was assessed using the biothesiometer. **Results:** The diabetic patients had higher prevalence of LJM and higher plantar pressure than control subjects ($P < 0.0001$). Among the diabetic patients, those with neuropathy and history of plantar ulceration had higher LJM and plantar pressure compared to non-neuropaths ($P < 0.001$). **Conclusions:** Both LJM and high plantar pressure appear to be important determinants of foot ulceration in susceptible neuropathic South Indian diabetic patients.

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Keywords: Diabetic neuropathy; Limited joint mobility; Foot pressure; Foot ulceration

1. Introduction

This study investigate the association of limited joint mobility (LJM) and plantar foot pressure with diabetic foot ulceration in Asian Indian diabetic subjects, as there are no reports in native Indian diabetic subjects. Foot ulceration is a major

chronic complication of diabetes. Several studies in the UK have reported that foot ulceration is less among the Asian Indian migrants [1–3]. However diabetic foot infection is a common cause for hospital admission among diabetic patients in India. This could be attributed to several socio cultural practices such as barefoot walking, inadequate facilities for diabetes care, poor education and poor socio economic conditions [4]. Recurrence of foot infection is also common among Indian Type 2 diabetic subjects, for which both peripheral neuropathy and peripheral vascular

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disease are important determinants [5]. LJM contributes to the abnormal mechanics in the diabetic foot. Diabetic subjects often have limitations in the range of motion of feet that are rigid, firm and dry. An important factor in the development of ulceration of the insensitive, neuropathic foot is the presence of abnormal pressure at the site of ulceration [6]. LJM and plantar pressures have been reported to be higher in European patients than in Asian patients [2,3].

2. Subjects and methods

The LJM and plantar foot pressure were measured in 345 subjects; (M/F: 218/127), 295 consecutive South Indian diabetic patients and 50 age-matched controls. They were seen at the M.V. Hospital for Diabetes, a speciality clinic attended by diabetic patients of all socio economic strata. Consecutive diabetic subjects seen during a period of 6 months (from March 2001 to September 2001) with or without neuropathy, including those with a past history of plantar ulceration were included. Patients with active ulceration were excluded from the study. Control subjects were selected from the non-diabetic relatives of the patients. The response rate among the selected control subjects was 80.6% (50/62). All control subjects also were tested with a standard OGTT. Age, body weight and duration of diabetes were recorded. The control subjects and patients gave informed consent for the study.

The study groups were: non diabetic control subjects (Control) ($n = 50$), subjects with diabetes (DM) ($n = 100$), subjects with diabetes and neuropathy (DM+N) ($n = 110$), diabetic neuropaths with history of plantar ulcer (DM+NU) ($n = 85$). During the study 23 cases with active foot infection were withdrawn. Neuropathy was diagnosed by Biothesiometer [7]. Patients included in DM+N and DM+NU had severe grades of neuropathy (VPT > 25 V). Joint mobility in the foot was assessed at two sites, in the subtalar joint and in the hallux [8,9]. Subtalar joint mobility was assessed because of its critical role in normal biomechanics of the foot [8]. With the patient supine and the subtalar joint in the neutral position, a vertical line was marked on the

patient's skin from the heel to the midcalf and the maximum range of calcaneal inversion and eversion were measured with goniometer. Range of motion at the metatarsophalangeal joint was measured as follows. With the patient supine and the joint in neutral position, a line was drawn on the medial aspect of the foot from the tip of the hallux to the heel, and maximal range of dorsiflexion and plantar flexion were determined. The mean of three readings made on each foot was calculated and reported as the mean range of motion at each site. These two sites were selected because of their pivotal role in the biomechanics of normal gait patterns. Clinical examinations of joints were performed routinely by the same observer. History of plantar ulceration was obtained by interview and review of case records of each patient.

The plantar pressure measurement was done using international protocol guidelines as detailed below [10]. The mean dynamic foot pressures were measured in patients walking barefoot, using the RS Scan (RS Scan, Belgium) platform system. Data obtained from the metatarsal heads only were used as the 'peak pressure'. All pressures were recorded as N/cm^2 and then converted to kPa. Any plantar callosities were removed prior to the foot pressure measurement ($n = 5$). The sensor is calibrated using a single limb support model. Based on the subject's body weight, a value based on the force generated in the single limb support is calculated. Once calibrated, the various testing parameters are performed. All subjects were able to walk comfortably unaided at their usual pace. The patients walked without shoes over the platform, and the maximum plantar peak pressure for the entire foot was obtained. Six dynamic footprints, three from each foot were recorded.

3. Statistical comparisons

Group comparisons were by One-way ANOVA using the Turkey-HSD procedure. Multiple linear regression analysis was performed to identify variables (age, body weight and duration of diabetes) associated with joint mobility.

4. Results

The clinical characteristics of the study groups are shown in Table 1. As gender differences were absent, data for the total group is presented. Intragroup differences were absent for body weight and duration of diabetes. Mean age of DM+N was higher when compared with other groups ($P < 0.001$).

Joint mobility was significantly reduced in all diabetic groups when compared with the control subjects ($P < 0.0001$). Among the diabetic groups, DM+N and DM+NU had significantly lesser joint mobility compared with the DM group ($P < 0.001$) (Table 2). Neuropaths with and without history of plantar ulceration had higher pressure than the DM group ($P < 0.001$).

Maximum pressure loading was under the first metatarsal in 45% of those with previous ulceration, in 37% of neuropaths, in 20% of non-neuropaths and in 16% of controls. It was also noted that in 53% of patients with a history of previous ulceration, the highest pressure was at the site of the previous ulceration.

Age had an inverse association with the joint mobility (Table 3). However, only the group with neuropathy had higher age compared to other groups. Joint mobility was restricted to a higher degree by the presence of neuropathy and foot ulcer, irrespective of the age group. Table 3 shows the results of multiple linear regression analyses, with each of the joint mobility functions as the dependent variables. The control group was used as the reference while testing the association of other study groups with the dependent variable.

Multiple linear regression analysis showed that duration of diabetes was not significantly asso-

ciated with the joint mobility. The degree of joint mobility was more restricted in the presence of neuropathy and foot ulceration. The analysis showed that mobility functions were inversely associated with diabetes ($DM+NU > DM+N > DM$).

5. Discussion

The subtalar joint and the joints of the foot play a crucial role in normal function during walking. In this study, we have evaluated the extent of joint mobility in diabetic subjects with and without neuropathy. We found that diabetic patients with neuropathic foot ulceration had significantly less joint mobility and higher plantar pressures than those with neuropathy only and also those without neuropathy. In a study from the UK, foot ulcers were 2.1 times more prevalent in Caucasians vs Asian diabetic patients (132/2400 vs 11/400 $P < 0.05$) [2]. In our study we found that diabetic patients with a history of neuropathic plantar ulceration had lesser joint mobility and higher plantar pressures than those without ulceration and neuropathy. Several studies have shown that limitation of joint mobility of the foot and the ankle caused abnormally high plantar foot pressures [11]. In a study by Van Schie and Boulton [3], Caucasian patients with diabetic neuropathy had a mean plantar pressure of 1150 kPa, the non-diabetic controls subjects had a mean of 658 kPa. The corresponding values in our study were 744.4 and 312.4, respectively. This probably means that compared to Caucasians, Asians have lower plantar pressures. However among Asians, those with diabetic neuropathy with and without plantar

Table 1
Characteristics of patients in study groups

	Control	DM	DM+N	DM+NU
Number of subjects	50	100	110	85
Age (years)	50.1 (5.6)	52.3 (5.6)	54.3 (5.1)*	51.8 (5.9)
Weight (kg)	68.1 (9.5)	68.5 (10.5)	68.4 (10.3)	69.2 (9.6)
Duration of diabetes (years)	–	9.6 (6.5)	11.6 (6.3)	10.7 (6.0)

Values are mean (SD).

* $P < 0.001$ vs Control, DM and DM+NU.

Table 2
Comparison of the joint mobility and pressure measurements

Parameters	Control	DM	DM+N	DM+NU
Number of subjects	50	100	110	85
Inversion (°)	34.2 (4.8)	30.2 (4.4)*	22.7 (5.2)***	19.7 (4.0)***
Eversion (°)	21.1 (3.3)	17.8 (4.2)*	11.6 (5.3)***	9.1 (4.3)***
Flexion (°)	58.2 (6.6)	47.5 (10.5)*	33.4 (11.9)***	28.1 (9.6)***
Extension (°)	33.1 (6.6)	25.5 (10.3)*	19.9 (9.2)***	16.4 (9.2)***
Pressure (kPa)	312.4 (116.9)	471.3 (242.3)*	616.5 (161.6)***	744.4 (151.6)***

Values are mean (SD).

* $P < 0.0001$ vs control.

** $P < 0.001$ vs DM.

*** $P < 0.001$ vs all other groups.

Table 3
Results of multiple linear regression analysis showing parameters associated with joint mobility and foot pressure

Dependent variable	Inversion		Eversion		Flexion		Extension		Pressure	
	β	P	β	P	β	P	β	P	β	P
Age (years)	-0.25	<0.001	-0.16	0.0002	-0.46	<0.001	-0.35	0.0001	-4.12	0.022
Weight (kg)	-0.09	0.0001	-0.07	0.004	-0.16	0.004	-0.12	0.02	-0.76	0.43
Duration (years)	-0.01	0.79	-0.07	0.08	-0.07	0.4	-0.07	0.38	2.9	0.09
DM	-3.3	0.0001	-2.2	0.009	-8.9	<0.001	-6.06	0.0006	140.4	0.0001
DM+N	-10.3	<0.001	-7.98	<0.001	-22.0	<0.001	-10.9	<0.001	287.9	0.001
DM+NU	-13.9	<0.001	-10.9	<0.001	-0.46	<0.001	-0.35	0.0001	409.1	<0.001
R^2 (%)	62.7		53		56.1		31.5		40	

ulceration had higher pressures than those without neuropathy. Decreased sensation and LJM of dorsiflexion and subtalar joint motion have been reported in patients with diabetes mellitus and foot ulceration. Muller et al. believed that the limited dorsiflexion and subtalar motion restricted the foot's ability to absorb shock and transverse rotation, therefore increasing the risk of plantar ulceration in the insensate foot. They concluded that less than 5° of dorsiflexion or 30° of subtalar motion should be treated with mobility exercises and protective footwear [12]. Other studies have suggested that high foot pressures alone do not cause foot ulceration, since patients with rheumatoid arthritis who had abnormally high foot pressures but no neuropathy did not develop foot ulceration, unlike diabetic patients with neuropathy and high plantar foot pressures who are prone to develop foot ulcers [13].

In conclusion, South Indian diabetic patients had LJM which was decreased further if neuropathy and history of plantar ulceration coexisted. LJM and increased plantar pressure appear to be important determinants of foot ulceration irrespective of the duration of diabetes in South Indian diabetic patients.

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