

Studies of Experimental Hosiery in Diabetic Neuropathic Patients with High Foot Pressures

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High plantar pressures and painless trauma are associated with the development of foot ulcers in diabetic patients. Padded hosiery has been reported to reduce plantar pressures in patients at risk of ulceration. Using the optical pedobarograph we have studied 10 patients who regularly wore experimental padded hosiery for 6 months. The hosiery continued to provide substantial and significant reduction in peak forefoot pressures at 3 months (mean reduction 15.5 %, $p < 0.01$) and 6 months (17.6 %, $p < 0.01$), although the level of reduction was less than that seen at baseline (31.3 %, $p < 0.05$). In addition, commercially available hosiery designed as sportswear has been tested, and compared with experimental hosiery. Although these socks (with high or medium density padding) provided significant pressure reduction versus barefoot (mean 17.4 % and 10.4 %, $p < 0.01$), this was not as great as that seen with experimental hosiery (27 %, $p < 0.05$). Thus the use of socks designed to reduce pressure stress on diabetic neuropathic feet is effective, and continues to be so for a considerable period of time. Commercially available sports socks may also have a place in the management of the diabetic insensitive foot.

KEY WORDS Diabetic foot Foot ulcers Foot pressure Footwear

Introduction

Foot ulceration in neuropathic diabetic patients is thought to be largely preventable.¹ Vigilance for painless trauma, and the protection of the high-risk foot from extrinsic stresses such as raised forefoot pressure² are the main aims of management. The former can be dealt with by effective patient education, and the latter by the use of shock absorbent insoles³ and specially designed shoes.⁴ However the shoes necessary for optimal protection are often not ideal cosmetically, as the need for extra depth and sometimes rocker soles can make these heavy and unacceptable to the patient.

Most people wear some sort of hosiery, and an American hosiery company has produced patented padded hosiery designed to reduce the stresses on athletes' feet while they participate in sporting activities. These have been shown to reduce blistering in runners when compared with conventional hosiery,⁵ and to result in a reduction in forefoot pressures in diabetic patients during walking in contrast to when patients wore their own socks.⁶

We have now carried out longitudinal studies involving the regular wearing of experimental hosiery for 6 months in order to ascertain whether the pressure reduction persists, and compared the experimental hosiery with currently available sports socks from the same manufacturer.

Patients and Methods

Ten patients with Type 1 or Type 2 diabetes, clinical neuropathy (symptoms plus diminished vibration perception and/or absent ankle reflexes),⁷ and high dynamic plantar pressure ($\geq 10 \text{ kg cm}^{-2}$)⁸ were recruited for the longitudinal study. Vibration perception threshold was measured with a Biothesiometer.⁷ The mean age of the patients in this part of the study was 51.3 (range 27–65) years. Six had Type 2 diabetes. Mean vibration perception threshold was 35.1 (13–51) (age related normal < 25). Six patients had a history of foot ulceration.

Each was issued with three pairs of the experimental socks (Thorneberg Hosiery, Statesville, NC, USA), with variable thickness of padding over different parts of the foot (approximate composition 85 % acrylic, 15 % nylon). Patients were asked to keep a diary of the use of the socks, and the number of times they were washed. The socks were indelibly marked to ensure that repeat tests were performed with the same pair on each occasion. Dynamic recordings of foot pressures were carried out with the optical pedobarograph⁸ at baseline, 3 months and 6 months. Pedobarography has previously been shown to be repeatable and reliable in multiple studies of individuals over 1 week, with individual coefficients of variability of 7–14 %.⁹ Three footsteps were recorded on each side barefoot and with the experimental socks. Analysis was made of the peak forefoot area and of the first and fifth metatarsal heads (mean of three footsteps on each occasion). Comparisons were made using the Wilcoxon matched pairs signed

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rank test with the Amstat statistical package for Amstrad computers (SC Coleman, Ashby-de-la-Zouch, UK).

For the comparative studies, a further 16 patients with high dynamic plantar pressures were studied. Mean age was 55.8 (33–70) years, ten had Type 2 diabetes, and mean vibration perception threshold was 38.5 (13–51). The recording techniques were as described above. Patients wore experimental socks and currently available socks for different sports from the same manufacturer (UK importers: Ardblair sports importers, Blairgowrie, UK), which had either 'high density' or 'medium density' padding under the metatarsal area, although less padding over the instep and dorsum of the foot than the experimental hosiery. Statistical analysis was as described above.

Results

Diaries showed that the socks were washed and worn regularly in rotation, each pair for approximately equal periods (approximately 30 and 60 days at the respective assessments). Socks were washed every 2 days on average (range 1–5). The follow-up studies showed that the experimental socks maintained the pressure-reducing effect (mean 15.5 %) at the area of maximum pressure for 3 months ($p < 0.01$), although the effect was significantly less than when they were new (31.3 %, $p < 0.05$). At 6 months the socks continued to provide significant reduction of plantar pressure compared with barefoot measurements, at a similar level (17.6 %) to that found at 3 months (Table 1). All patients in the prospective study found the socks to be acceptable, and elected to continue wearing them after the study period. No patient developed a foot ulcer during the study.

The comparative studies demonstrated that both medium and high density forefoot padding (sportswear hosiery) reduced plantar pressure significantly (mean 10.4 % and 17.4 %, respectively, $p < 0.01$), Table 2, though the effect was less with medium density than high density padding ($p < 0.05$). High density padding was not quite as effective in pressure reduction as the experimental socks.

Discussion

Despite increasing interest in diabetic foot problems this decade,¹⁰ diabetes remains one of the main causes of non-traumatic amputation in the Western world.¹¹ Strategies to prevent ulceration and amputation include identification and education of at-risk patients² and protection of high-risk feet. Traditionally, this latter option has been addressed by provision of specialist shoes with protective insoles,^{12,13} but certain insole materials have a short life and bottom out under the high pressures usually present under the metatarsal heads.¹² We reported recently that hosiery has the potential to protect feet from high pressures, demonstrating the ability to reduce plantar pressure in high-risk patients.⁶ In this study we have confirmed that these pressure-relieving properties can be maintained for a period of 6 months, although not surprisingly the degree of pressure reduction is significantly less after several months than at baseline. In addition, socks have potential advantages over insoles, in that they protect the lateral and dorsal surfaces of the foot which can ulcerate if subjected to pressure from ill-fitting shoes. It has recently been shown that the use of specially designed hosiery reduces blistering in athletes during marathons,⁵ which probably reflects an ability to reduce shear forces, though no good technology currently exists for measuring these.

In the second part of this study we have compared currently available socks with experimental hosiery. Tennis and running socks which have high density padding under the metatarsal heads provide the best protection, significantly better than walking or golf socks which have medium density padding. Moreover the tennis and running socks provide good protection for the lateral and dorsal aspects of the forefoot. Thus these are probably the optimum type of sock currently available from this manufacturer's range.

The combination of socks and sensible depth shoes (or, if needed, off-the-shelf extra depth shoes) may be of great value at a very low cost when compared with the provision of customized shoes and insoles. In this context, however, it should be noted that sports socks are generally

Table 1. Peak forefoot pressure measurements in diabetic patients with peripheral neuropathy taking part in the follow-up study

	Barefoot (kg cm ⁻²)			With experimental socks (kg cm ⁻²)		
	Highest	1st MH	5th MH	Highest	1st MH	5th MH
Baseline	15.90(4.38)	8.71(4.01)	8.45(5.34)	10.48(3.33) ^b	6.58(3.67) ^a	5.48(3.57) ^a
3-month follow-up	15.20(4.05)	8.20(3.72)	7.78(5.08)	12.81(3.92) ^{bc}	6.50(3.50) ^a	6.53(4.61)
6-month follow-up	15.78(5.66)	9.63(5.33)	8.69(6.04)	12.28(5.12) ^{bc}	8.28(5.06)	6.80(3.98)

Mean (SD).

MH, metatarsal head.

^a $p < 0.05$, ^b $p < 0.01$ versus barefoot; ^c $p < 0.05$ versus baseline studies.

Table 2. Pressure measurements in diabetic patients with peripheral neuropathy taking part in the comparative studies

	Peak pressure (kg cm ⁻²)		
	Highest forefoot area	1st Metatarsal	5th Metatarsal
Barefoot	13.24(3.44)	7.31(4.91)	8.30(4.77)
Experimental socks	9.13(2.89) ^c	6.28(3.46)	6.00(3.63) ^b
High density padding	10.37(2.82) ^{c,d}	6.26(3.98)	6.52(3.92) ^a
Medium density padding	11.14(3.84) ^{b,e}	6.74(3.97)	6.57(4.91) ^a

Mean (SD).

^a*p* < 0.05, ^b*p* < 0.01, ^c*p* < 0.001 versus barefoot; ^d*p* < 0.05, ^e*p* < 0.01 versus experimental socks.

thicker than conventional socks, and shoe fitting should be carried out using the type of hosiery intended for use with the shoes. Although, as with any sort of padding, the socks will 'bottom-out' with time, they still appear to provide some pressure relief, so that long-term use is not likely to be detrimental when compared with the use of conventional socks which do not provide pressure reduction.^{6,9} Socks have additional advantages over the use of insoles alone; the potential effect on shear forces discussed above applies to all surfaces of the foot, while insoles deal only with forces acting on the sole.

In this study we have measured pressures only at the sock/floor interface, but recent studies using insole materials and in-shoe measurements³ have shown similar results to those obtained by optical pedobarography.¹⁴ Thus these measurements are likely to reflect changes of pressure at the sole of the foot.

In conclusion we have demonstrated the potential of special hosiery to contribute to the care of the diabetic foot. While development of fibre technology and padding distribution continues, the currently available high density socks are probably the best choice for the protection of the insensitive foot.

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