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Changes in load bearing in the rheumatoid foot

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SUMMARY A study of peak force exerted under areas of the foot was made in 27 patients with rheumatoid disease and in 30 normal persons. Patients were found to exert considerably less force under their toes and under the first metatarsal head and more force under the 3 outer metatarsal heads. It was possible to correlate these changes with increasing clinical and radiological severity.

In normal walking the centre of gravity of loading begins in the proximal part of the heel, passes over the medial side of the midfoot on to the second metatarsal head, and ends at the lateral border of the great toe (Fig. 1). Although the highest loads are exerted on the heel, it is the forefoot that is involved for the greater part of the foot contact time (Dhanendran and Hutton, in preparation). The variations in the load distribution under the normal foot are now established, and since the foot is a common site of pain and deformity in rheumatoid arthritis, we decided to try to correlate the changes in loading with clinical and radiological disease.

Barrett (1976) in a qualitative study found that there was high pressure under the second and third metatarsal heads in rheumatoid arthritis. We have tried to quantify the force distribution under the feet of patients and controls of similar age and weight. We hope that the results presented here will aid in the treatment of these patients.

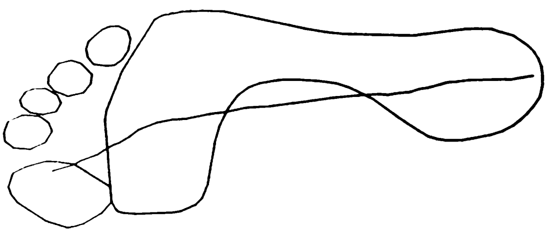

Fig. 1 *A computer printout showing the line representing the centre of gravity of loading under a normal foot*

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Patients and controls

Twenty-seven patients with established rheumatoid disease volunteered for the study. All but 3 were seropositive. There were 16 women and 11 men aged between 19 and 70 years, with a mean age of 50·7 years and a mean weight of 69·2 kg. At the time of the study no patient had undergone foot surgery. Patients with symptoms or signs in the knees, hips, and back were excluded. The 54 feet were divided into 3 groups:

Group 1 included 17 left and 16 right feet which radiologically had no rheumatoid erosions in the metatarsophalangeal (MTP) joints. All but 4 patients had admitted to metatarsalgia at some time. There were 5 feet with a hallux valgus deformity of 30° or more.

Group 2 included 8 left and 8 right feet which showed marked erosive changes in the MTP joints. Some patients had marked callus formation but pain was denied by the owners of 11 feet. Four feet showed a hallux valgus deformity of 30° or more.

Group 3 included 2 left and 3 right feet all with marked erosive changes involving both the MTP and the subtalar joints, and clinically there was MTP subluxation and a valgus hindfoot. The 2 left feet were reported to be painless. There was only 1 foot with a hallux valgus deformity of 30° or more.

Thirty normal volunteers, 15 men and 15 women between the ages of 36 and 64 years (mean age 50·9 years) and with a mean body weight of 60·9 kg, formed the control group.

Method

A number of previous studies of load distribution under the foot have been made, but they have been only qualitative or semiquantitative (Beely, 1882; Morton, 1935; Harris and Beath, 1947; Arcan and Brull, 1976). Pressure transducers fitted into the shoe have also been used (Bauman and Brand, 1963; Collis and Jayson, 1972) and allow measurement over several steps, but their disadvantages include trailing wires, their presence in the shoe, and the fact that their positioning is critical.

We therefore decided to use another system (Dhanendran *et al.*, 1978). Briefly 128 load cells are arranged in a 16 by 8 matrix which is built into a walkway 8 metres long (Fig. 2). Each load cell is made of a ring mounted with 4 strain gauges and works on the proving ring principle. Each of the load cells has a load bearing surface 15 mm by 15 mm and the total load sensitive area thus amounts to 25 cm by 12 cm. The signals from the load cells are fed through an interface to a PDP11/40 minicomputer, which records and displays the measurements.

Subjects were asked to walk barefoot along the walkway at their normal walking speed, and at least 4 recordings were made for each foot. Fig. 3 shows the peak force experienced by each load cell under the foot of 1 of our control subjects. For analysis the foot was divided into 8 areas (Fig. 4). The peak force for each area was calculated from the information shown in Fig. 3. and expressed as a percentage of the subject's body weight. The average of 4 runs was taken.

Results

The peak forces for the subjects are compared with those for the 3 groups of patients in Table 1. A breakdown of peak forces for the 5 feet in group 3 is given in Table 2.

The load under the big toe is reduced in group 1 and significantly reduced in groups 2 and 3. All 3 groups show a significant reduction in loading under

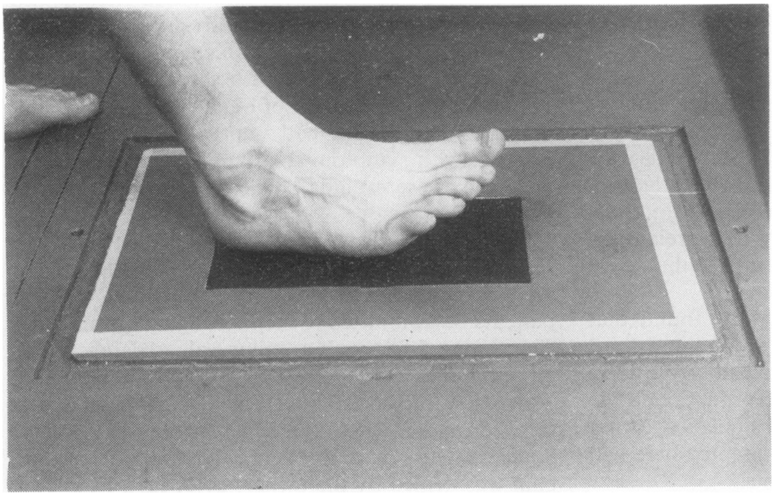

Fig. 2 *The walkway with a foot striking the load cells*

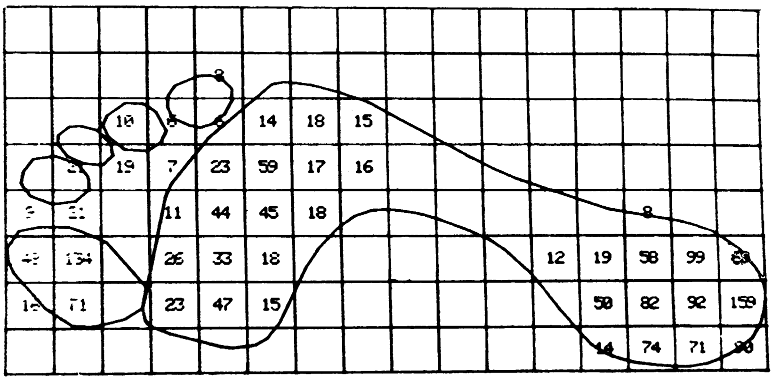

Fig. 3 *A computer printout showing the peak forces (in Newtons) exerted on each load cell. The foot outline is shown in correct register.*

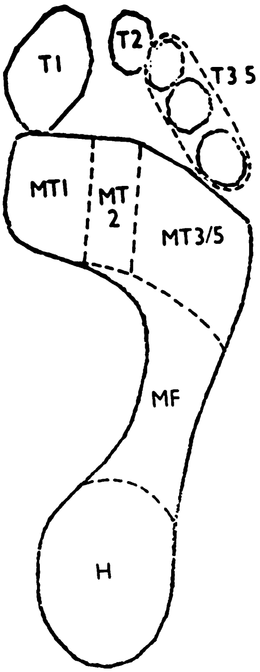

Fig. 4 *The 8 areas used for analysing the foot*

the 3 outer toes. The peak loads under the first and second metatarsal heads do not show a significant change from normal except in group 3, where there is considerably less load under the first metatarsal head. More force is exerted under the lateral 3 metatarsal heads, though the increases are not significant. There is no significant change in loading under the midfoot and heel in any group. None of the groups showed a significant change from normal in their speed of walking.

Table 3 shows the callosities under the forefoot for the patients studied. There were more callosities under the medial side.

Table 3 *The position of the callosities on the feet of the patients*

		Callosities							
		Medial				Lateral			
Group	No. of feet	T1	T2	MT1	MT2	T3/5	MT3	MT4	MT5
1	33	6	0	13	13	0	10	5	4
2	16	1	0	5	5	0	3	2	2
3	5	0	0	1	3	0	4	0	2
		Total	47			Total	32		

Discussion

In rheumatoid arthritis there may be limitation of movement in the phalangeal joints accompanied by muscular weakness and by flexion of the proximal interphalangeal joints leading to elevation of the proximal phalanx. This is reflected in our results by the significant reduction in toe loading for all 3 groups. Further, this seems to be related to the clinical and radiological severity of the arthritis.

The elevation of the first interphalangeal joint also produces the 'windlass' mechanism (Hicks, 1954), which raises the longitudinal arch, thus favouring the midfoot. Our results show a small reduction in midfoot loading in all groups.

It has been suggested that the presence of painful callosities under the metatarsal heads is lessened by hyperactivity of flexor digitorum longus, which transfers the load forward to the tips of the digits (Morton, 1935). Our work shows a shift of loading away from the medial side of the forefoot to the

Table 1 Mean values of peak forces expressed as a percentage of body weight for the controls and for the three groups of patients. Asterisks denote the level of significance (* =5%, ** =1%, Mann-Whitney test) at which the mean differs from the mean for the normals

		T1	T2	T3/5	MT1	MT2	MT3/5	MF	H
Normals	Mean	18·0	3·2	4·8	24·4	23·7	37·6	12·8	70·4
Group 1	Mean	15·5	1·4**	2·6**	26·0	22·4	38·9	10·8	67·3
Group 2	Mean	15·2*	0·5**	1·1**	24·7	23·6	39·5	11·8	72·6
Group 3	Mean	6·8**	0·0**	0·5**	17·5*	21·5	44·6	8·9	74·7

Table 2 *Details of the feet in group 3 with the peak forces expressed as a percentage of body weight*

	Side	Sex	Age	T1	T2	T3/5	MT1	MT2	MT3/5	MF	H
Patient 1	Right	M	52	3·3	0·0	0·0	16·5	25·9	72·4	8·4	86·9
Patient 2	Left	F	63	0·9	0·0	0·0	25·3	23·6	60·5	4·9	82·9
Patient 3	Right	F	43	1·4	0·0	0·0	0·2	1·2	9·2	5·5	80·0
Patient 4	Left	F	69	15·2	0·0	2·7	16·3	27·1	46·7	13·2	60·4
Patient 4	Right	F	69	13·2	0·0	0·0	29·0	29·6	34·4	12·3	63·1

lateral side, with more callosities under the medial side. However, there is no evidence of increased loading on the toes.

The lateral shift in loading at the metatarsal heads is not satisfactorily explained by the presence of pain, as some of our patients denied feeling it. There are 2 possible explanations. First, erosive changes at the midtarsal joint do not allow effective pronation during foot contact; thus extra loads are placed on to the lateral side of the foot. Secondly, the reduced loading carried by the toes, the great toe in particular, throws load back on to the lateral metatarsals. The shift in loading to the lateral 3 metatarsals may be the cause of pain at these sites, since the dorsiflexion of the proximal phalanges pulls the plantar fat pads under the metatarsal heads forward, leaving them vulnerable. Whatever the explanation for the increased load under the lateral metatarsal heads, it seems likely to us that an attempt to redirect the loading back on to the structurally stronger medial side of the forefoot may be of benefit to the patient. Robertson personal communication in a separate pilot study has shown that it is possible to do this to some extent by using rigid insoles.

In normal walking about 20% of body weight acts on the great toe at kick-off: this figure is higher for subjects younger than those in our control group (Dhanandran and Hutton, in preparation). This is counteracted by tension in the toe flexor tendons, which react with the force on the great toe to produce a resultant force approaching body weight to act on the first metatarsophalangeal joint (Stokes *et al.*, in press). This high force may be a further reason for the reduction in great toe loading seen in patients with rheumatoid disease.

More research is needed into whether insoles (rigid or not) really modify the pattern of loading in the foot and whether insoles designed to alter the pattern to one approaching the normal are actually beneficial to the patient's comfort and gait. A further study into whether the use of such insoles might in the long term influence the development of mechanical problems in the knee, as some rheumatologists and orthopaedic surgeons believe, might produce useful results.

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