

Relation between heel position and the distribution of forefoot plantar pressures and skin callosities in rheumatoid arthritis

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Abstract

Objective—To investigate the relation between the position of the rearfoot and the distribution of forefoot plantar pressures and skin callosities in rheumatoid arthritis.

Methods—Plantar pressures and callosity patterns were measured in 102 rheumatoid arthritis patients (120 feet with normal heel alignment and 84 feet with valgus heel alignment measured by goniometry) and in 42 (84 feet) age matched healthy adults. Peak pressures (kPa) were measured across the metatarsal heads in-shoe using an FScan system and the distribution of plantar callosities was visually mapped for each foot.

Results—Peak pressures were significantly greater at all but the first metatarsal head in the rheumatoid normal heel alignment and healthy adult groups than in the rheumatoid valgus heel group. The feet of both the rheumatoid normal heel group and the healthy adult group behaved the same, the highest peak pressures registering on the central metatarsal heads. However, only in the rheumatoid group were plantar callosities found at these sites. In the rheumatoid valgus heel group, lateral metatarsal heads were frequently non-weightbearing, producing gross loading patterns with a dominant medial distribution. Peak pressures were shifted to the medial forefoot accompanied by a higher prevalence of callosities. The results, however, failed to establish clearly an association between peak pressures and callus formation.

Conclusions—In rheumatoid arthritis there is an important interrelation between the rearfoot position and forefoot pressure sites.

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The metatarso-phalangeal joints are commonly involved in rheumatoid arthritis. First symptoms frequently appear at this site and remain persistent through the course of the disease. Recognisable radiological pathology of these joints has been identified in up to 86% of patients.¹ Persistent synovitis can cause painful symptoms, often described by patients as walking on pebbles, marbles, or glass. A general widening of the forefoot is accompanied by hallux valgus and hammer and claw toe

deformities with subluxation or dislocation at the metatarso-phalangeal joints.¹⁻⁶

Weightbearing and ambulatory activities of daily living place high physical demands on the forefoot of rheumatoid arthritis patients. Weightbearing and gait functions are normally performed in an enclosed shoe so abnormally high pressures may be generated at the interface of the shoe and deformed bony prominence. Skin callosities and bursae can develop at the metatarso-phalangeal joints as a protective response but eventually these serve further to increase local pressures and exacerbate symptoms. Some patients, particularly those receiving oral corticosteroid treatment and more rarely those with peripheral neuropathy or vasculitis, are at risk of ulceration.¹⁻⁶ Many patients suffer from distressing and disabling symptoms which require various conservative and surgical treatments calling on the services of physicians, therapists, and surgeons.

Foot pressure studies in rheumatoid arthritis consistently show raised peak pressures across the metatarsal heads in comparisons with normal values.⁷⁻¹² In normal feet, peak pressures are highest over the second and third metatarsal heads, with a gradual fall off medially and laterally.¹³ In rheumatoid arthritis, previous studies have shown considerable variation of both pressure and force distribution with normal central and atypical medial and lateral patterns described.^{10 12 14 15} These raised pressures and abnormal distribution patterns have been attributed to either gross pathological changes in the forefoot, or to gait modification as a pain avoidance strategy. While these factors are important, little attention has been given to the role of the rearfoot on the transfer of load forward to the forefoot during the stance phase of gait.^{16 17} In rheumatoid arthritis a dominant feature of the rearfoot is valgus heel deformity, which is found in up to 30% of patients, while varus heel deformity occurs in less than 2% of patients.¹ If normal rearfoot mechanics are necessary to transfer pressure to the forefoot in a central distribution pattern then dysfunction may alter this pattern, with detrimental effects.

Pressure studies offer the most objective means of detecting raised and redistributed pressures in the forefoot. However, if raised pressures are associated with the development of secondary skin lesions, then simple observational mapping of lesion patterns may give a clue to the underlying mechanical function of

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the forefoot. The aim of this study was therefore to explore the relation between the heel position and the pattern of pressure lesions and peak pressures in the forefoot in rheumatoid arthritis.

Methods

PATIENTS

Plantar pressure measurements and lesion patterns were recorded for 102 consecutive rheumatoid arthritis patients attending a rheumatology outpatient clinic. Patients fulfilled the American Rheumatism Association 1987 revised criteria for rheumatoid arthritis.¹⁸ Measurements were also taken from 42 healthy sex and age matched adults with no history of organic disease likely to affect foot posture or gait, and who on examination had no significant foot pathology. The age (years), body mass (kg), disease duration (years), and disability scores, using the Stanford Health Assessment Questionnaire (HAQ), were recorded for each patient. Ethics approval was granted for the project and all patients gave their informed consent.

HEEL ALIGNMENT MEASUREMENT

The heel position was measured by one observer using a standard weight bearing technique employed by therapists.¹⁹ Here the position of the heel relative to the ground—the relaxed standing foot posture (RSFP)—is measured from a heel bisection line using a small goniometer. An everted position of the calcaneus relative to the ground of 5 degrees or greater was used as the diagnostic criteria for valgus heel deformity. Using this procedure rheumatoid arthritis patients had 120 feet with normal heel alignment and 84 feet with valgus heel alignment, while all the healthy adults had heel alignments within normal limits.

LESION ASSESSMENT

Each foot was visually inspected for pressure lesions across the metatarsal heads. Each lesion was palpated to determine its relation to the underlying metatarsal head. Four patients with skin ulceration were not included because of the potential for pressure attenuation from ulcer dressings. In the healthy adult group subjects with forefoot plantar callosities were excluded from the study.

PEAK PRESSURE MEASUREMENT

Plantar pressures were recorded in-shoe using the F-Scan system (Tekscan). This system uses a thin insole constructed from a matrix of 960 force sensing resistors sandwiched between two stable polymer outer layers. The size of each sensor is 0.5 mm, small enough to identify and measure pressures at metatarsal heads. The sensors have been found to lose accuracy with prolonged use but this was controlled in this study by replacing all sensors after 50 steps.²⁰ Sensors were placed inside the shoe and connected to a portable PC by a small processing box secured at the ankle and trailing cables secured on the waist of the subject.

A standard range of footwear was used in conjunction with the pressure sensors because:

Table 1 Demographic and disease characteristics of the study groups

	Healthy adults (n=42)	RANH (n=60)	RAVH (n=42)
Sex ratio (F:M)	31:11	44:16	32:10
Age, years (range)	61 (43-82)	63.5 (27-85)	63 (41-79)
Disease duration, years (range)	—	7 (1-40)	15 (1-50)
Body mass (kg)	68 (50-112)	67 (42-108)	63 (47-93)
HAQ disability score (0-3)	—	1 (0-2.875)	1.562 (0.125-2.75)
RSFP, degrees (range)	0 Neutral (3 valgus; 4 varus)	0 Neutral (4 valgus; 2 varus)	8 Valgus (25 valgus; 5 valgus)

RANH, rheumatoid arthritis normal heel alignment group; RAVH, rheumatoid arthritis valgus heel group; RSFP, relaxed standing foot posture.

(1) shoe sole construction is known to influence ground reaction forces and peak pressures during gait^{21,22}; (2) medial heel counter stiffness can influence rearfoot pronation during gait.²³

All subjects were given a warm-up period to acclimatise to the foot wear. Sensors were cut to fit the shoes and calibrated using body mass as the applied force. Subjects were then requested to walk along an open corridor and pressures were recorded when patients had reached normal walking speed. Given the range of physical disability present among the rheumatoid arthritis patients, no attempt was made to standardise walking speed and for all subjects a minimum of five left and right steps were recorded. The system software was used to generate gross pressure patterns and peak pressures for individual metatarsal heads. Peak pressures were taken from the third step to be recorded.

STATISTICAL ANALYSES

The results for the demographic and disease characteristics and lesion distribution patterns were presented as ratio values, median scores, and percentage values. The peak pressure data tended to yield positively skewed distributions. These data are summarised using medians (range), with Mann-Whitney U and Kruskal-Wallis tests used for between group analyses. P values < 0.05 were considered statistically significant. Data were analysed using Statview SE for Apple Macintosh PC.

Results

DEMOGRAPHIC AND CLINICAL DETAILS

The demographic and clinical details of the patients are summarised in table 1. The sex ratio, body mass, and age values were similar

Table 2 Distribution of callosities across the metatarsal heads for rheumatoid arthritis patients (%)

Group	Metatarsal head				
	1	2	3	4	5
Valgus heel (No of lesions = 64)	33	23	23	9	11
Normal heel (No of lesions = 114)	11	33	32	19	18

Table 3 Median (range) peak pressures at the metatarsal heads for study groups

Group	Metatarsal head peak pressure (kPa)				
	1	2	3	4	5
Valgus heel (n = 84 feet)	225.5 (0-887)	208.5 (0-811)	183 (0-834)	118.5 (0-739)	67 (0-339)
Normal heel (n=120 feet)	221.5 (0-1250)	290.5 (0-1150)	306 (0-1160)	200 (0-800)	140 (0-852)
Healthy adult (n=84 feet)	246 (53-631)	290 (104-867)	296 (115-642)	206 (62-431)	122 (31-308)
P value ^a	NS	0.001	0.001	0.001	0.001
P value ^b	NS	0.01	0.001	0.001	0.01

^a Kruskal-Wallis test.

^b Repeated Kruskal-Wallis test after removal of zero pressure values.

Table 4 Metatarsal head (MH) loading patterns for rheumatoid arthritis study groups

Metatarsal head loading pattern	Valgus heel (n=84 feet)	Normal heel (n=120 feet)
MH 1-5	54	113
MH 1-4	8	2
MH 1-3	5	2
MH 1-2	4	0
MH 1 only	6	0
No loading	5	0
MH 2-5	1	0
MH 3-5	0	2
MH 4-5	1	1
MH 5 only	0	0

for the three study groups. Patients with valgus heel deformity had rheumatoid arthritis for approximately twice as long as the non-valgus heel patients and were more physically disabled. The RSFP heel position for the healthy adult and rheumatoid arthritis normal heel group were similar, the median value in both cases being 0 degrees neutral compared with the valgus heel group with a median heel position of 8 degrees valgus.

CALLOSITY LESION PATTERNS

The lesion distribution patterns was determined by a percentage breakdown for each metatarsal head from the total number of lesions per foot-type (table 2). Lesions were distributed more medially (1 > 2 = 3 > 4 < 5) in the valgus heel group, in comparison with a central pattern (1 < 2 > 3 > 4 > 5) found in the normal heel group.

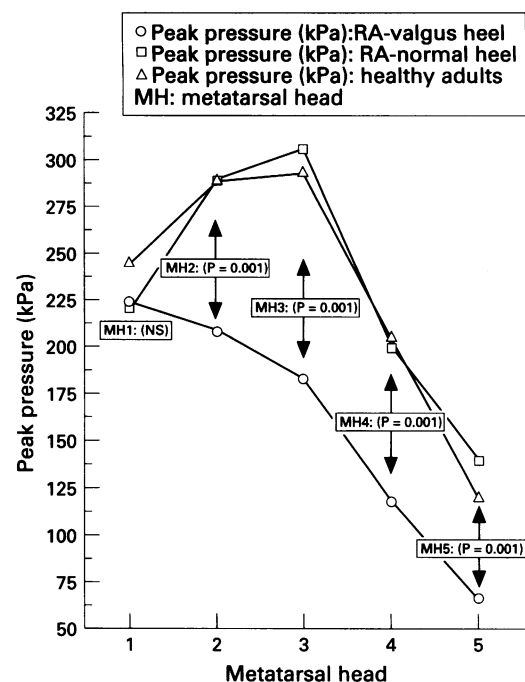
PEAK PRESSURES

The results established two patterns of peak pressure distribution across the metatarsal heads (table 3, figure). In the healthy adult group and the rheumatoid normal heel group, the highest peak pressures were found over the central metatarsal heads, while in the rheumatoid valgus heel group, peak pressures followed a medial to lateral distribution in order of magnitude. No statistically significant differences

Table 5 Median peak pressures at the metatarsal heads for rheumatoid arthritis patient groups in relation to the absence or presence of a plantar lesion

Group	Lesion	Metatarsal head				
		1	2	3	4	5
Valgus heel	Present	258	399	277	170	71
	Absent	220	148	172	112	62
	P value ^a	NS	< 0.05	NS	NS	NS
Normal heel	Present	274	285	240	266	206
	Absent	212	272	273	198	133
	P value ^a	NS	< 0.05	< 0.05	NS	< 0.05

^a Mann-Whitney U test.



Peak pressures (kPa) across the metatarsal heads in the various study groups.

were seen in the peak pressures in the healthy control group or the rheumatoid normal heel group. Statistically significant differences were detected in peak pressures between the latter two groups and the rheumatoid arthritis valgus heel group at all except the first metatarsal head.

The gross loading patterns in table 4 show 27% of rheumatoid arthritis valgus heel feet have a medially dominant distribution pattern where one or more of the lateral metatarsal heads are non-weightbearing. The forefoot of five subjects were fully non-weightbearing in this group. Only a few feet in the rheumatoid normal heel group showed a dominant medial or lateral pattern.

To evaluate the relation between peak pressure and the occurrence of a plantar lesion, peak pressures were compared from each metatarsal head where lesions were present or absent (table 5). In both study groups and at all metatarsal heads, peak pressures were higher where lesions were present. In the valgus heel group only the second metatarsal head had a significantly higher peak pressure, this being 2.5 times greater in the presence of a lesion. In the normal heel group statistically significant differences were seen at the second, third, and fifth metatarsal heads.

Discussion

The rheumatoid arthritis forefoot is vulnerable to raised peak pressures, which can be distributed across the forefoot in a range of patterns. The aetiology has been inherently associated with the pathological changes normally seen in the forefoot of rheumatoid arthritis patients.⁷⁻¹²

We hypothesised, however, that rearfoot function may be an important mechanism contributing to the distribution and magnitude of peak pressures in rheumatoid forefoot. The results of our study support an interrelation between the two foot segments, with both the

gross loading patterns, peak pressure distributions, and callosity distributions favouring a medial to lateral pattern in the rheumatoid valgus heel group. This contrasts with findings from the normal heel rheumatoid group, who had normal central patterns compared to a healthy adult population.

Valgus heel is a progressive deformity caused by excessive pronation at the subtalar joint, and in rheumatoid arthritis this component of motion can be both three times greater than normal and last up to 100% of the stance phase of gait.¹⁷⁻²⁴ Three factors have been identified as being potentially important in the aetiology of the condition: (1) recurrent synovitis in the subtalar joint, (2) weakness and laxity in supporting soft tissues, and (3) unchecked progression of early stance phase pronation.²⁻³

The principal feature of the dysfunction is excessive and prolonged pronation, which imparts mobility to the mid-tarsal joint of the foot. While this may be necessary to cushion the impact forces to supportive structures as the foot initially bears weight, later, towards propulsion, the foot fails to become rigid and provides a less than effective lever for push off.²⁴ This may be further compounded in rheumatoid arthritis in the long term, as joints become stiff in the presence of recurrent synovitis.

Valgus heel deformity is thought to redistribute load medially to the forefoot, altering the normal central pressure distribution pattern. The timing of the gait sequence within the foot makes this mechanism plausible although it is possible that the opposite effect may be equally important. Inflammatory pathology in the forefoot may alter patterns of muscular activity, perhaps through a modified pain avoidance gait, which could simultaneously bring about atypical forefoot pressure patterns and irreversible rearfoot changes. It is often difficult to determine the precise aetiology in individual patients; in our study, while an interrelation has been shown, a lack of adequate control in the study design prevents us from establishing any causal link.

In comparison with other studies we failed to show significantly raised forefoot pressures in the rheumatoid groups above normal healthy adult values. Furthermore, valgus heel rheumatoid patients showed significantly lower peak pressures at all but the first metatarsal head. While the highest peak pressures were recorded in rheumatoid arthritis subjects, on an individual basis zero pressure values were also found, indicating non-weightbearing metatarsal heads. Reanalysis of the data removing zero values failed to influence this unusual finding significantly. One possible explanation may be the modified gait patterns shown by these patients as part of their overall physical disability. Although not formally measured, the gait observed was slow with reduced single limb support times and increased double limb support times. These factors contribute to reduce vertical ground reaction forces and peak pressures during the stance phase period. In the rheumatoid arthritis normal heel group the median peak

pressures were the same as in the normal healthy adult group, while in the valgus heel group— who had longer disease duration and were more severely disabled—the median peak pressures at all but the first metatarsal head were significantly reduced. At this one site the mechanical redistribution of pressure medially from the rearfoot dysfunction may have served to raise the peak pressure to normal levels.

In the rheumatoid arthritis valgus heel group three patients (five feet) presented with no evidence of forefoot loading. Two patients (four feet) presented with severe bilateral rigid valgus heel deformity, midfoot collapse, and dorsiflexed, abducted, and non-weightbearing forefeet. One patient reported severe unilateral forefoot pain with active avoidance of forefoot contact. It is thus possible for more complex pressure loading patterns to be generated as a product of rearfoot dysfunction and forefoot symptoms.

We found a direct relation between the distribution of peak pressures and callosities, suggesting that one can predict the other. However, the precise nature of the relation is unclear as peak pressures were higher at all sites where lesions were present but only reached statistical significance in four out of 10 instances. This would suggest that while pressure has a major role in the causation of skin lesions other factors may be equally important. In rheumatoid arthritis this could include the time during which a metatarsal head experiences abnormally high pressures, the patient's inability to vary the gait pattern and hence the frequency of loading at vulnerable sites, and local factors such as skin tissue viability.

In conclusion, both local bony and soft tissue pathology and rearfoot mechanical factors must be considered when interpreting forefoot pressures and pressure lesion patterns in the rheumatoid arthritis foot. Valgus heel deformity is related to a shift in peak pressures and pressure lesions from a normal central pattern to a medial forefoot pattern. Peak pressures may not always be raised relative to normal values, and any physical disability which modifies the gait should be considered. The findings of the study may have important clinical implications, particularly where conservative mechanical treatment is indicated. By ignoring mechanical events in the rearfoot the opportunity could be missed to use functional foot orthoses, considered to be potentially more effective than simple insoles. These devices are popular among podiatrists because they are reported to re-establish normal motion in the rearfoot, reducing the harmful effect of pronation on the forefoot. A longitudinal study is under way in our department to evaluate this hypothesis.

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