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Forefoot joint damage, pain and disability in rheumatoid arthritis patients with foot complaints: the role of plantar pressure and gait characteristics

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***Objective*. To assess (i) the relationship between forefoot joint damage and foot function (expressed as gait and pressure parameters), (ii) the relationship between foot function and pain, and (iii) the relationship between foot function and disability in patients with foot complaints secondary to rheumatoid arthritis (RA).**

***Methods*. Sixty-two patients with RA-related foot complaints were included. Measurements of joint damage, gait characteristics, plantar pressure, pain and disability were obtained. Data were analysed using descriptive and correlational techniques.**

***Results*. Joint damage on radiographs of the forefoot correlated significantly with forefoot pressure ($r = 0.296$, $P = 0.020$). Further investigation of the metatarsophalangeal joints (MTPs) showed joint damage to correlate significantly with peak pressure and pressure–time integral (PTI) of MTP1 and MTP4. A significant correlation between PTI under the forefoot and barefoot pain was found ($r = 0.290$, $P = 0.022$). Gait parameters (total contact time and the duration of heel loading) and disability, measured with the Foot Function Index, were significantly correlated ($r = 0.315$, $P = 0.013$ and $r = 0.266$, $P = 0.037$, respectively).**

***Conclusion*. Forefoot joint damage in the rheumatoid foot is related to increased pressure under the forefoot, especially pressure under the first and fourth MTP joints. High forefoot pressure is associated with pain during barefoot walking. A prolonged stance phase and delayed heel lift are related to disability in daily activities.**

KEY WORDS: Foot, Rheumatoid arthritis, Forefoot joint damage, Gait, Plantar pressure, Pain, Disability, Relationships.

Foot complaints are a major problem in patients with rheumatoid arthritis (RA). Approximately 90% of patients complain of painful feet at some time during the course of their disease [1, 2]. The presence of foot complaints, both in the early and in the chronic stage of RA, has been shown to severely affect patients' daily activities, especially ambulation and other weight-bearing tasks [3]. Despite the number of patients reporting foot complaints and the consequences for daily activities, the rheumatoid foot has so far received little attention in scientific research.

In the present study, a model describing the assumed relationships between pathology, impairments and disability in the rheumatoid foot was used (Fig. 1). The model might be useful in clinical diagnosis and decision-making regarding the rheumatoid foot. Inflammation of joints and soft tissues, even when vigorously treated, can severely disrupt foot structure by causing joint damage and structural deformities [2]. Common foot structure deformities in RA patients are subluxation of the metatarsophalangeal joints (MTPs), toe deformities and valgus alignment of the rearfoot. Changes in foot structure may be associated with impaired foot function during weight-bearing. Furthermore, impaired foot function, expressed as alterations in gait and pressure, may relate to pain and disability during daily activities [4, 5].

In recent years, a limited number of studies have been performed aimed at identifying relationships between foot function on the one hand and foot structure, pain and disability on the other. To assess foot function, plantar pressure measurements have been used, yielding gait characteristics and pressure distribution patterns. Patients with RA showed modified gait patterns: the duration of the stance phase and double support phase is increased and the moment of heel lift is delayed [6]. Additionally, pressure, especially under the forefoot, is elevated [7–10]. Evidence linking radiological erosion scores and increased plantar pressure was found [11]. Foot deformities have been shown to relate to changed pressure distribution patterns and increased peak pressure [12 , 13]. Also, relationships between increased forefoot pressure and pain in RA have been reported [9, 14]. Furthermore, gait characteristics were found to relate to disability in daily activities [15, 16]. The relationship between pressure and disability has not been investigated, to our knowledge.

Knowledge about relationships between foot impairments and disability, especially regarding the role of plantar pressure and gait characteristics, is limited. Thus, there is a need for replication and extension of research on these relationships. The purpose of the present study was to assess: (i) the relationship between forefoot joint damage and foot function (expressed as gait and pressure parameters); (ii) the relationship between foot function and pain; and (iii) the relationship between foot function and disability in patients with foot complaints secondary to RA.

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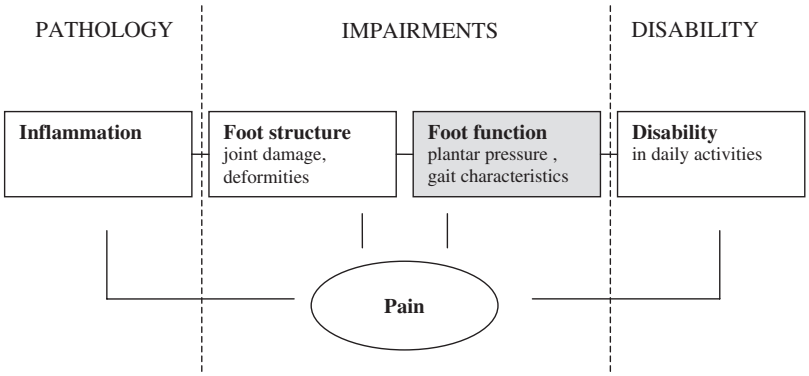

FIG. 1. Model of RA-related foot impairments and disability.

Materials and methods

Patient selection

Sixty-two patients at an out-patient clinic for rehabilitation and rheumatology (Jan van Breemen Institute) in the Netherlands served as the study population. The following inclusion criteria were used: (i) RA diagnosed by a rheumatologist (according to ACR criteria [17]); (ii) referred to a podiatrist or a rehabilitation physician for RA-related foot complaints; (iii) older than 18 yr; and (iv) informed consent of the patient. Exclusion criteria were: (i) inability to walk independently; (ii) inability to complete questionnaires (because of language or cognitive problems); and (iii) ambulation problems due to non-RA-related causes. The medical ethics committee of the Slotervaart Hospital in Amsterdam approved this study and written informed consent was obtained from each subject.

Measures

Joint damage. A trained rheumatologist scored the radiographs of the feet using the Sharp/van der Heijde method [18]. The 10 MTP and two interphalangeal joints of the big toes were scored for erosions and joint space narrowing. The erosion score per joint site can range from 0 to 5, where 0 is no erosion and 10 is severe erosions on both sites of the joint. Joint space narrowing is combined with a score for (sub)luxation and scored from 0 to 4, where 0 is normal and 4 is a bony ankylosis or complete subluxation. The maximum erosion score for all joints in both feet is 120. The maximum score for joint space narrowing in all joints of both feet is 48. The total score is the sum of erosions and joint space narrowing in all joints of both feet.

Foot function. To obtain pressure and gait parameters, plantar pressure measurements were performed using an EMED®-nt system (Novel Electronics, Novel, Munich, Germany; 4 sensors per cm^2, sample frequency 50 Hz). The platform was mounted in the middle of a walkway of 5 m. The two-step method of collecting plantar pressure measurements was used [19]. This method requires the patient to stand (barefoot) two steps away from the pressure platform and, at a self-selected pace, step onto the platform and continue walking for at least three steps. The measurements started after instruction of the patient and familiarization with the procedure. Data from both feet were collected. Three correct measurements per foot were recorded. A measurement was rejected when the whole foot failed to be placed on the platform or when the patient was out of balance according to the tester or to the patient. All patients started walking with their right foot.

Disability in daily activities. Disability was assessed using the physical functioning (PF) subscale of the Foot Function Index (FFI) and the WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index), and a 10-m walking test.

The FFI [20] measures pain and mobility limitation as the impact of foot problems. The scale consists of 23 items divided into three subscales: pain (nine items), physical functioning (nine items) and limitation (five items). The items are rated on a five-point scale. To calculate the subscale scores and the total score, the item scores are summed, divided by the maximum possible sum of the item scores and then multiplied by 100. The scores range from 0 to 100; the higher the score the more pain, disability and limitation, respectively.

The Dutch WOMAC [21] originally measured pain, joint stiffness and physical functioning as the impact of osteoarthritis in hips and knees. For the present study, the impact of arthritis in the hips, knees, ankles and feet was measured by changing the instruction of the questionnaire. The WOMAC consists of 24 items divided into three subscales: pain, joint stiffness and physical functioning. The scores range from 0 to 100; the higher the score, the more pain, stiffness and disability respectively.

For the 10-m walking test, the patient was instructed to walk 10 m at a normal, comfortable walking speed. Time to walk this distance was recorded.

Pain. Pain in the feet during activities was measured by the pain subscale of the FFI. As pressure measurements were performed barefoot, pain during barefoot standing and walking was measured by selecting and summing two items of the FFI pain scale (items 3 and 4).

Additional measures. Disease activity was expressed as a composite index consisting of a swollen and painful joint count out of 44 joints, erythrocyte sedimentation rate (mm/h) and a visual analogue scale for general health [22]. A trained nurse performed the measurements and calculated the disease activity score (DAS-44). Other data recorded were sex, age, body mass index (weight/$height^2$), disease duration, medication and location of foot complaints in the last week.

Data and statistical analyses

Pressure and gait data were analysed with Novel-Ortho® and Novel-Win® software. A division mask (Novel mask) divided the foot into 10 anatomically referenced regions: heel, midfoot, first to fifth MTP joints, hallux, second toe, and other toes. For each region, the peak pressure (PP) and pressure–time integral (PTI) was calculated. The PP was determined as the highest pressure measured by a single sensor in a region. The PTI of a region was defined as the integral of pressure over time measured in the single

sensor within that region showing the PP. Pressure data for the forefoot were used in further analyses, as this region is known to play an important role in foot pathology in RA patients. The maximum PP and maximum PTI under the forefoot and the PP and PTI for each MTP were calculated. Also, gait parameters, i.e. the total contact time and the duration of heel loading (expressed as percentage of total contact time), were determined. The processed data were transferred to SPSS (version 12.0). Data for the most affected foot, according to the patient, were used for further analysis.

As the score for joint damage and the PF subscales of the FFI and WOMAC were not normally distributed, Spearman correlation coefficients were calculated to analyse relationships between these variables. To analyse relationships between other variables, Pearson correlations were determined. Two-sided testing and a significance level of $P < 0.05$ were used for all analyses.

Results

Descriptive data

Characteristics of patients are shown in Table 1. Sixty-two patients participated: 47 women and 15 men, with a mean age of 55.7 yr. Eighty-nine per cent of the patients reported forefoot complaints in the last week. The median PF score of the FFI and WOMAC was 19.1 and 17.3%, respectively. Mean peak pressures and mean PTIs in different regions of the foot are shown in Table 2.

Relationships between joint damage and foot function

Table 3 shows the correlations between joint damage, expressed as the Sharp/van der Heijde score, and foot function. Joint damage in the forefoot and hallux was significantly correlated with the maximum PTI measured under the forefoot ($r = 0.296$, $P = 0.020$). Further analyses of the regions in the forefoot showed the Sharp/van der Heijde score to correlate significantly with the PTI of MTP1 and MTP4 ($r = 0.328$, $P = 0.010$ and $r = 0.290$, $P = 0.037$, respectively). Also, the Sharp/van der Heijde score was significantly correlated with PP of the MTP1 and MTP4 regions ($r = 0.319$, $P = 0.012$ and $r = 0.268$, $P = 0.037$, respectively). No significant correlations between joint damage and gait parameters were found.

Relationships between foot function and pain

The correlations between foot function measures and pain are shown in Table 4. The maximum PTI under the forefoot was significantly correlated with pain when standing or walking barefoot ($r = 0.290$, $P = 0.022$). Further analyses on the PTI under the forefoot showed the PTI of MTP4 to correlate significantly with barefoot pain ($r = 0.301$, $P = 0.017$). No significant correlations between gait parameters and pain were found.

Relationships between foot function and disability

Gait parameters, i.e. total contact time and duration of heel loading, were significantly correlated with all disability measures (Table 5). Pressure parameters, i.e. maximum PP under the forefoot and maximum PTI under the forefoot, were not significantly correlated with disability.

Secondary analyses

The DAS-44 was significantly correlated with FFI PF and WOMAC PF ($r = 0.492$, $P = 0.000$ and $r = 0.604$, $P = 0.000$, respectively). DAS-44 and FFI pain were significantly correlated ($r = 0.383$, $P = 0.002$). FFI-pain was related to FFI-PF and WOMAC-PF ($r = 0.787$, $P = 0.000$ and $r = 0.619$, $P = 0.000$, respectively).

Table 1. Characteristics of patients ($n = 62$)

Age (yr)[a]	55.7 (13.11)
Sex (M/F)	15/47
Body mass index (kg/m^2)[a]	26.4 (3.7)
Time since RA diagnosed (months)[b]	96.0 (36.0–144.0)
Medication	
NSAIDs	50%
DMARDs	84%
Biologicals	13%
DAS-44[a]	2.4 (1.0)
Sharp/van der Heijde score[b]	8.0 (1.5–24.5)
Forefoot complaints	89%
PP forefoot (N/cm^2)[a]	63.2 (25.0)
PTI forefoot (N/cm^2)*s	21.4 (8.7)
Total contact time (ms)[a]	852.1 (153.6)
Heel lift (% total contact time)[a]	59.7 (9.1)
FFI total score (% of total score)[b]	23.0 (11.3–45.1)
FFI PF	19.1 (8.0–45.1)
FFI pain	28.6 (18.2–41.7)
FFI pain barefoot (sum)[b]	2 (1.0–4.0)
WOMAC total (% of total score)[b]	19.0 (8.0–43.6)
WOMAC PF	17.3 (5.7–46.7)
WOMAC pain	20.0 (8.8–41.3)
Walking test (s)[a]	8.3 (1.8)

Data are [a]mean (S.D.), [b]median (interquartile range), percentage or number.

Table 2. Mean (S.D.) values for PP (N/cm^2) and PTI (N/cm^2)*s in different foot regions

	PP	PTI
Heel	29.4 (8.8)	8.4 (2.5)
Midfoot	12.0 (5.7)	4.3 (2.4)
MTP1	40.2 (24.5)	14.3 (9.3)
MTP2	49.0 (27.5)	16.0 (7.7)
MTP3	44.2 (19.0)	15.6 (5.6)
MTP4	30.3 (16.2)	12.0 (6.5)
MTP5	25.9 (19.1)	9.9 (7.5)
Hallux	47.1 (32.9)	13.9 (11.0)
Second toe	16.6 (10.7)	4.8 (3.6)
Other toes	13.9 (9.0)	4.2 (3.0)

Table 3. Correlations between joint damage and foot function

	Sharp/van der Heijde score	*P*-value
PP forefoot	0.211	0.103
PTI forefoot	0.296	0.020
Total contact time	0.161	0.215
Heel lift	0.239	0.064

Table 4. Correlations between foot function and pain

	FFI pain	*P*-value	FFI pain barefoot	*P*-value
PP forefoot	−0.002	0.990	0.127	0.326
PTI forefoot	0.159	0.216	0.290	0.022
Total contact time	0.196	0.127	0.225	0.079
Heel lift	0.247	0.053	0.220	0.086

Table 5. Correlations between foot function and disability

	FFI PF	*P*-value	WOMAC PF	*P*-value	Walking test	*P*-value
PP forefoot	−0.119	0.356	−0.151	0.242	−0.220	0.086
PTI forefoot	0.090	0.488	0.103	0.426	0.102	0.428
Total contact time	0.315	0.013	0.352	0.005	0.790	0.000
Heel lift	0.266	0.037	0.254	0.046	0.273	0.032

Discussion

The aim of this study was to assess relationships between foot function on the one hand and joint damage, pain and disability on the other hand, in patients with RA-related foot complaints.

Significant correlations between forefoot joint damage, measured by the Sharp/van der Heijde score, and increased forefoot pressure were found. Forefoot joint damage was significantly correlated with both PP and PTI under MTP1 and MTP4. Our results confirm the results of a study by Tuna *et al.* [11]. In that study, increased peak pressure in the forefoot and toes was found in a group of RA patients with high erosion scores (using the modified Larsen scoring system) compared with a group with low erosion scores. Joint damage in combination with capsuloligamentous instability can lead to structural deformities of the foot [4]. Foot deformities are supposed to be the cause of high plantar pressures and altered pressure distribution [12, 13]. This seems to be the explanation for the relationship between joint damage and plantar pressure.

Maximum PTI under the forefoot and pain during barefoot walking were significantly correlated. The relationship between high forefoot pressure and foot pain was found in other studies also [9, 14]. In the study by Hodge *et al.* [9] average forefoot pressure, measured with an in-shoe pressure device, was related to foot pain. In our study PP and PTI were measured. PTI was related to foot pain, while no relationship between PP and foot pain was found. According to Otter *et al.* [10], a prolonged duration of loading in a certain region (measured in our study as the PTI) is more straining for the foot than a high PP for a short time, and may therefore cause pain. Our results confirm Otter's hypothesis. As a result of high pressures, skin callosities and bursae can develop at the MTPs as a protective response, but eventually this may exacerbate symptoms [13].

No correlations between pressure and disability in daily activities were found. The lack of a relationship between pressure and disability might be explained by the influence of the shoe and possible shoe modifications or foot orthoses. Pressure is measured barefoot, while most daily activities are performed when wearing shoes. The shoe could decrease pressure under the forefoot and therefore reduce pain and disability during weight-bearing. Recent literature supports this hypothesis. Adequately designed foot orthoses combined with appropriate shoe modifications have been shown to bring functional improvement and pain relief to patients with RA affecting the foot [9, 23–25].

Gait parameters (a prolonged stance phase and delayed heel lift) and disability were significantly correlated. Our results confirm the results of studies of Platto *et al.* [15] and O'Connell *et al.* [16]. Both studies found a relationship between gait parameters and the ambulation subscale of the Sickness Impact Profile. The reduction of the propulsion of gait may be caused the symmetrical weakness in the calf muscles, identified in a study by Keenan *et al.* [26]. Our hypothesis is that the weakness of the calf muscles is mainly a result of pain-avoiding strategies that may alter patterns of muscular activity in RA patients, but this hypothesis is not supported by evidence. In addition, Michelson *et al.* [2] reported that in RA the prevalence of ankle problems is 42%: this may further impair the patient's gait.

Descriptive data on foot impairments and disability in RA patients were obtained in the present study. Compared with the reference values for healthy subjects presented by Bryant *et al.* [27], RA patients in our study showed increased PPs and PTIs in the midfoot, forefoot and hallux. In comparison, values of mean PTIs under the MTPs in healthy subjects ranged from 7.5 to 12.6 (N/cm^2)*s and in our study group from 9.9 to 16.0 (N/cm^2)*s.

The median PF score of RA patients in this study was 19.1% of the maximum score. In a study by Kuyvenhoven *et al.* [20], patients with non-traumatic forefoot complaints visiting a general practice were measured with the FFI. Mean PF scores of 12.9% were found in that study. These scores are lower compared with our group of RA patients, in whom disease was more severe. In a study by Conrad *et al.* [28], older male RA patients with a long disease duration scored a mean of 34.1% on the PF subscale of the FFI.

The mean disease activity score (DAS-44) in our study was 2.4, which represents a moderate disease activity. A cut-off level of the DAS of 1.6 corresponds with being in remission following the ACR criteria [22]. Despite the moderate disease activity, high correlations were found between disease activity and foot pain, and between disease activity and disability. These findings argue in favour of further attempts to suppress disease activity. In addition, conservative therapy for foot complaints is indicated. Orthoses or orthopaedic shoes have been shown to decrease plantar pressure and improve gait, and may therefore reduce pain and disability. Gait training might further influence pressure and gait characteristics.

In clinical practice, pressure and gait data can be obtained from dynamic measurements; for example, using the Emed system. In the absence of a pressure measurement system, physical examination of the foot, pressure patterns in the shoe and blueprints can give information about the locations of high pressure. However, to obtain precise information about location and height of pressure during walking, the use of a pressure measurement system is recommended, either in-shoe or barefoot. Further research is needed to identify the correlation between in-shoe and barefoot measurements.

There are some limitations of this study. We chose to measure plantar pressure during barefoot walking. The limitation of barefoot measurements is that the influence of footwear, including shoe modifications or orthoses, has not been measured. As mentioned, this might be an explanation for the lack of a relationship between pressure and disability in daily activities in this study. Studies investigating the relationship between pressure and disability using in-shoe measurements are recommended.

In addition, our study group was heterogeneous with respect to disease duration. Foot deformities develop during the course of RA. In the early stage of RA, pain and swelling are the predominant foot impairments, whereas in later stages foot deformities rise to prominence. This means that, at different stages of the disease, different processes may be responsible for foot impairments and disability in activities in RA. Our study group was too small to analyse subgroups of patients. Therefore, further research is recommended in homogeneous groups of patients with early and established RA.

Finally, a cross-sectional design was used in this study. To identify cause-and-effect relationships, longitudinal studies are needed.

Conclusion

In this study relationships are identified between foot function on the one hand and joint damage, pain and disability on the other hand, in patients with RA-related foot complaints. Joint damage is related to increased pressure under the forefoot, especially pressure under the first and fourth MTP joints. High forefoot pressure is associated with pain during barefoot walking. A prolonged stance phase and delayed heel lift are related to disability in daily activities. These findings support our model of impairments and disability in patients with RA-related foot complaints. The model might be useful in clinical diagnosis and decision-making regarding the rheumatoid foot.

Rheumatology	Key messages
	• Forefoot joint damage is related to increased pressure under the forefoot in rheumatoid arthritis patients. • High forefoot pressure is associated with pain during barefoot walking. • A prolonged stance phase and delayed heel lift are related to disability in daily activities.

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The authors have declared no conflicts of interest.

References

1. Vaino K. Rheumatoid foot: clinical study with pathological an roentgenographical comments. Ann Chir Gynaecol 1956;45(Suppl.):1.
2. Michelson J, Easley M, Wigley FM, Hellma D. Foot and ankle problems in rheumatoid arthritis. Foot Ankle Int 1994;15:608–13.
3. Wickman AM, Pinzur MS, Kadanoff R, Juknelis D. Health-related quality of life for patients with rheumatoid arthritis foot involvement. Foot Ankle Int 2004;25:19–26.
4. Mann RA, Horton GA. Management of the foot and ankle in rheumatoid arthritis. Rheum Dis Clin North Am 1996;22:457–76.
5. Woodburn J, Helliwell P. Foot problems in rheumatology. Br J Rheumatol 1997;36:932–3.
6. Simkin A. The dynamic vertical force distribution during level walking under normal and rheumatic feet. Rheumatol Rehabil 1981;20:88–97.
7. Minns RJ, Craxford AD. Pressure under the forefoot in rheumatoid arthritis. A comparison of static and dynamic methods of assessment. Clin Orthop Relat Res 1984;187:235–42.
8. Orlin M, Stetson K, Skowronski J, Pierrynowski M. Foot pressure distribution: methodology and clinical application for children with ankle rheumatoid arthritis. Clin Biomech 1997;12:S17.
9. Hodge MC, Bach TM, Carter GM. Orthotic management of plantar pressure and pain in rheumatoid arthritis. Clin Biomech 1999;14:567–75.
10. Otter SJ, Bowen CJ, Young AK. Forefoot plantar pressures in rheumatoid arthritis. J Am Podiatr Med Assoc 2004;94:255–60.
11. Tuna H, Birtane M, Tastekin N, Kokino S. Pedobarography and its relation to radiologic erosion scores in rheumatoid arthritis. Rheumatol Int 2005;26:42–7.
12. Woodburn J, Helliwell PS. Relation between heel position and the distribution of forefoot plantar pressures and skin callosities in rheumatoid arthritis. Ann Rheum Dis 1996;55:806–10.
13. Weijers RE, Walenkamp GH, Mameren van H, Kessels AG. The relationship of the position of the metatarsal heads and peak plantar pressure. Foot Ankle Int 2003;24:349–53.
14. Stockley I, Betts RP, Rowley DI, Getty CJ, Duckworth T. The importance of the valgus hindfoot surgery in rheumatoid arthritis. J Bone Joint Surg Br 1990;72:705–8.
15. Platto MJ, O'Connell PG, Hicks JE, Gerber LH. The relationship of pain and deformity of the rheumatoid foot to gait and index of functional ambulation. J Rheumatol 1991;18:38–43.
16. O'Connell PG, Lohmann Siegel K, Kepple TM, Stanhope SJ, Gerber LH. Forefoot deformity, pain, and mobility in rheumatoid and nonarthritic subjects. J Rheumatol 1998;25:1681–6.
17. Arnett FC, Edworthy SM, Bloch DA *et al*. The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. Arthritis Rheum 1988;31:315–24.
18. van der Heijde D. How to read radiographs according to the Sharp/van der Heijde method. J Rheumatol 2000;27:261–3.
19. van der Leeden M, Dekker JHM, Lek-Westerhof S, Siemonsma PC, Steultjens M. Reproducibility of plantar pressure measurements in patients with chronic arthritis: a comparison of one-step, two-step and three-step protocols and an estimate of the number of measurements required. Foot Ankle Int 2004;25:739–44.
20. Kuyvenhoven MM, Gorter KJ, Zuithoff P, Budiman-Mak E, Conrad KJ, Post MWM. The Foot Function Index with verbal rating scales (FFI-5pt): a clinimetric evaluation and comparison with the original FFI. J Rheumatol 2002;29:1023–8.
21. Roorda LD, Jones CA, Waltz M *et al*. Satisfactory cross cultural equivalence of Dutch WOMAC in patients with hip osteoarthritis waiting for arthroplasty. Ann Rheum Dis 2004;63:36–42.
22. van Riel PLCM. Provisional guidelines for measuring disease activity in RA clinical trials. Br J Rheumatol 1992;31:793–4.
23. Chalmers AC, Busby C, Goyert J, Porter B, Schulzer M. Metatarsalgia and rheumatoid arthritis: a randomized. single blind. sequential trial comparing 2 types of foot orthoses and supportive shoes. J Rheumatol 2000;27:1643–7.
24. Woodburn J, Barker S, Helliwell P. A randomized controlled trial of foot orthoses in rheumatoid arthritis. J Rheumatol 2002;29:1377–83.
25. Kavlak Y, Uygur F, Korkmaz C, Bek N. Outcome of orthoses intervention in the rheumatoid foot. Foot Ankle Int 2003;24:494–9.
26. Keenan MAE, Peabody TD, Gronley JK, Perry J. Valgus deformities of the feet and characteristics of gait in patients who have rheumatoid arthritis. J Bone Joint Surg Am 1991;73:237–47.
27. Bryant AR, Tinley P, Singer KP. Normal values of plantar pressure measurements determined using the EMED-SF system. J Am Podiatr Med Assoc 2000;90:295–9.
28. Conrad KJ, Budiman-Mak E, Roach KE, Hedeker D. Impacts of foot orthoses on pain and disability in rheumatoid arthritis. J Clin Epidemiol 1996;49:1–7.