



Pedobarographic Measurements of Rheumatoid Feet Compared with Clinical Parameters

Romatoid Artritli Hastaların Pedobagrafik Ölçümleri ve Klinik Parametrelerle Karşılaştırılması

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ABSTRACT

Objective: This study aimed to investigate the relationship between plantar pressure pedobarographic measurements and disease activity, radiological abnormalities, and foot indexes in patients with rheumatoid arthritis (RA).

Methods: Sociodemographics, foot symptoms, anatomical distribution, pain intensity and duration, and podiatry services access data were collected. Disease activity scale of 28 joints (DAS28) was used for the disease activity, and Health Assessment Questionnaire (HAQ) was used for the functional status. Foot function index (FFI) was used to measure the impact of foot pathology on its function. The Modified Larsen scoring was used to assess radiological abnormalities. Pedobarographic measurements were used to analyze foot loading characteristics.

Results: A total of 104 feet of 52 patients with RA was evaluated. DAS28 scores did not correlate with the plantar pressure values ($p>0.05$). A significant correlation was found between HAQ scores and right medial midfoot loading pressure ($r=0.355$; $p<0.01$). FFI scores were positively correlated with right lateral midfoot loading pressure ($r=0.302$; $p<0.05$). No relationship was found between Manchester Foot Pain and Disability Index and plantar loading characteristics. The radiological scores were correlated with left lateral hindfoot plantar pressure ($r=0.286$; $p<0.05$).

Conclusions: Pedobarographic measurements can be considered as a follow-up evaluation tool for the evaluation of all foot parts (forefoot, midfoot, and hindfoot). Rheumatoid feet investigation showed that foot involvement is independent of the disease duration, whereas midfoot plantar pressures are associated with the body mass index. Additionally, DAS28 may fall short as a marker of disease activity because it neglects foot problems.

Keywords: Rheumatoid arthritis, foot, plantar pressure, pain

ÖZ

Amaç: Çalışmanın amacı romatoid artritli (RA) hastalarda pedobarografik ölçüm ile değerlendirilen plantar basınç değişiklikleri ile hastalık aktivitesi, radyolojik anormallikler ve ayak indeksleri arasındaki ilişkinin araştırılmasıdır.

Yöntemler: Sosyodemografik veriler, ayak semptomları, anatomik dağılım, ağrının şiddeti ve süresi bilgileri toplandı. Hastalık aktivitesi için 28 eklemden hastalık aktivite skoru (DAS28) ve fiziksel aktivite için Sağlık Değerlendirme Anketi (HAQ) ve ayak fonksiyonlarını değerlendirmek için ayak fonksiyon indeksi (FFI) uygulandı. Radyolojik anormallikleri değerlendirmek için modifiye Larsen skorlaması kullanıldı. Ayak basınç özelliklerini analiz etmek için pedobarografik ölçümler yapıldı.

Bulgular: Elli iki RA hastasının toplam 104 ayağı değerlendirildi. DAS28 skorları plantar basınç değerleri ile korele değildi ($p>0.05$). HAQ skorları ile sağ orta ayak orta yüklem basıncı arasında anlamlı bir ilişki saptandı ($r=0.355$; $p<0.01$). FFI skorları, sağ lateral orta ayak yüklem basıncı ile pozitif korelasyon gösterdi ($r=0.302$; $p<0.05$). Manchester Ayak Ağrısı ve Disabilite İndeksi ve plantar yüklem özellikleri arasında bir ilişki saptanmadı. Radyolojik skorlar sol lateral arka ayak plantar basıncı ile korele idi ($r=0.286$; $p<0.05$).

Sonuçlar: Pedobarografik ölçümler, ayağın tüm bölümlerinin (ön ayak, orta ayak, arka ayak) değerlendirilmesi için bir takip değerlendirme aracı olarak düşünülebilir. Romatoid ayakların pedobarografik incelenmesi, ayak tutulumunun hastalık süresinden bağımsız olduğunu, orta ayak plantar basınçlarının vücut kitle indeksi ile ilişkili olduğunu ve DAS28'in ayak problemlerini ihmal ettiği için hastalık aktivitesinin bir belirteci olarak yetersiz kalabileceğini göstermiştir.

Anahtar kelimeler: Romatoid artrit, ayak, plantar basınç, ağrı

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INTRODUCTION

Rheumatoid arthritis (RA) is a chronic inflammatory disorder that primarily affects the cartilage and bone of small and middle-sized joints¹. Small joint (hand and feet) involvements typically occur in early disease stages². Foot complaints are a major problem in patients with rheumatic diseases³⁻⁵. Three-quarters of patients with RA reported foot pain within 4 years of diagnosis⁶. Shi et al.⁷ reported that foot problems were seen in almost all patients within 10 years of the disease. Many studies in the literature focused on the structural and functional changes in the affected foot in RA⁸⁻¹¹. Despite advances in RA treatment, foot pain remains a common symptom that affects patients' quality of life².

Pedobarography is a tool that measures dynamic foot loading characteristics in rheumatoid foot deformities¹². Plantar pressure measurements can be performed in evaluating the foot in every stage of pathology that leads to deformity¹³. Foot deformities in RA are thought to be caused by increased plantar pressures^{14,15}. The detection of plantar pressure distribution using pedobarography reveals useful information for clinicians¹⁶. Pedobarography is often applied barefoot due to its ease of application. Dynamic plantar pressure changes in patients with RA by barefoot pedobarographic measurements have been previously investigated¹⁷⁻¹⁹. Foot deformities in RA can be detected at an early stage by measuring plantar pressure changes during barefoot walking²⁰. Pedobarography should be interpreted together with clinical and radiographic evaluation and should be utilized in the periodical visits of patients with RA.

The incidence of foot problems was high, even when clinical remission is yielded by disease activity measurements¹. Otter et al.² demonstrated that this statement is true for many patients with RA, regardless of disease duration or therapy, and may particularly be evident in those receiving biological therapy¹⁹.

This study aimed to evaluate the use of pedobarographic measurements for detecting plantar loading characteristic abnormalities and their relation with disease activity, type and frequency of deformities, radiologic foot erosion scores, foot functions, and foot care access in patients with RA.

MATERIALS and METHODS

Design of the Study

This is a cross-sectional observational study that was approved by Istanbul Medeniyet University Goztepe Training and Research Hospital Ethics Committee

(decision no: 28/G, date: 27.11.2012) following the Declaration of Helsinki, and written informed consent was obtained from all patients.

Participants

A total of 52 patients with RA who met the American College of Rheumatology criteria were recruited from the rehabilitation and rheumatology outpatient clinics of the university hospital²¹. Inclusion criteria were age over 18 years, self-reported foot pain, and written informed consent. Patients with systemic diseases like diabetes mellitus, impaired neurological function, another concomitant musculoskeletal disorder, or acute lower extremity trauma, lower extremity operations, walking aids, or congenital deformities that affect the plantar pressure distribution were excluded from the study, as well as patients who did not report foot pain and were unable to walk independently. Furthermore, patients who had cooperation problems or did not provide informed consent, or were unable to complete the questionnaires were excluded.

Data Collection

Sociodemographics, disease duration, current pharmacological treatment, intensity, duration, and anatomical distribution of foot pain data were collected using surveys during outpatient follow-ups. Foot deformities were inspected and noted by the same investigator. Disease activity scale of 28 joints (DAS28)²² and Health Assessment Questionnaire (HAQ) was used for the functional status.

HAQ is a four-level scale that investigates the functioning that consists of 20 questions in eight categories²³. Turkish adaptation and validation were carried out by Küçükdeveci et al.²⁴.

Foot function index (FFI) was administered to all patients. The FFI consists of three subscales (foot pain, foot disability, and activity limitation) that consist of 23 items about the impact of foot impairments on function²⁵. The Turkish adaptation and validation were carried out by Anaforoğlu Külünkoğlu et al.²⁶.

An experienced radiologist performed the Modified Larsen scoring to assess radiological abnormalities²⁷.

The pedobarographic assessment was used to analyze foot loading characteristics. Plantar pressure measurements were simultaneously collected from three barefoot walking trials using a Tek Scan Mat Scan (TekScan Inc., South Boston, USA) pressure mat following a two-step gait initiation protocol. Each foot is divided

into three parts (forefoot, midfoot, and hindfoot) and plantar pressures are calculated (kPa) for each part.

Statistical Analysis

The Statistical Package for the Social Sciences 25.0 package program (IBM, Chicago, IL) was used for the statistical analysis. All descriptive statistics of measurements are presented as mean $\pm$ standard deviation. The frequency for categorical variables is shown together with their percentages. The Student's t-test was used to compare the variables that follow a normal distribution between two groups for the quantitative data analyses. Normal distribution was examined with the Kolmogorov-Smirnov test. The level of correlation between variables was determined using the Spearman rho correlation coefficients since the data were not normally distributed. The effect size of the correlation is determined according to Cohen's classification: 0.10-0.29 as small; 0.30-0.49 as a medium, and 0.50-1.0 as large correlation²⁸. Results were bilaterally evaluated at a 95% confidence interval, with a significance level at $p < 0.05$.

RESULTS

A total of 104 rheumatoid feet of 52 patients were evaluated. Demographic and clinical characteristics of patients were demonstrated in Table 1.

Foot deformity frequency was 55.8%. Foot deformities include hallux valgus, pes planus, hallux rigidus, claw toe, bunion, and hammertoe (Table 2).

Of the patients, 92.3% (n=48) were receiving disease-modifying antirheumatic drugs, 3.8% (n=2) anti-tumor necrosis factor (TNF), and 51.9% steroid therapy.

Plantar pressure measurements of the right and left foot were demonstrated in Table 3.

No statistically significant relationship was detected between DAS28 measurements and right and left foot pressure measurements ($p > 0.05$).

No statistically significant difference was found between the body mass indexes (BMI) in the pain locations of patients ($p > 0.05$).

A statistically significant positive correlation was found between the BMI and the midfoot medial pressure measurements of the right foot at 46.9% ($r = 0.469$; $p < 0.01$). A statistically significant positive correlation was found between the BMI and the midfoot medial pressure measurements of the left foot at 44.9% ($r = 0.449$; $p < 0.01$).

A statistically significant positive correlation was found between the BMI and the midfoot lateral pressure

measurements of the right foot at 47.8% ($r = 0.478$; $p < 0.01$). A statistically significant positive correlation was found between the BMI and the midfoot lateral pressure measurements of the left foot at 37.1% ($r = 0.371$; $p < 0.01$).

The relationship between the HAQ score and plantar pressure measurements is shown in Table 4. A statistically significant positive correlation was found between the HAQ score and the midfoot medial pressure measurements of the right foot at 35.5% ($r = 0.355$; $p < 0.01$).

Table 1. Demographic and clinical characteristics of patients.

	Mean $\pm$ SD (min-max)
Age (years)	53.88 $\pm$ 11.36 (32-78)
Body mass index	29.87 $\pm$ 5.55 (18.37-43.70)
Duration of the disease (day)	116.56 $\pm$ 92.06 (2-480)
Duration of pain (day)	64.94 $\pm$ 87.84 (1-480)
VAS	5.96 $\pm$ 2.60 (0-10)
	n (%)
Gender	
Female	48 (92.3)
Male	4 (7.7)

VAS: Visual analog scale, SD: Standard deviation, min: Minimum, max: Maximum

Table 2. Localization of foot pain and foot deformities of patients.

		n	%
Localization of pain	Forefoot	5	9.6
	Midfoot	10	19.2
	Hindfoot	11	21.2
	Global	12	23.1
	Midfoot + hindfoot	5	9.6
	Forefoot + midfoot	9	17.3
Foot deformity	Yes	23	44.2
	No	29	55.8
Hallux valgus	Yes	39	75.0
	No	13	25.0
Pes planus	Yes	46	88.5
	No	6	11.5
Hallux rigidus	Yes	52	100
	No	0	0
Claw toe	Yes	48	92.3
	No	4	7.7
Bunion	Yes	47	90.4
	No	5	9.6
Hammer toe	Yes	51	98.1
	No	1	1.9

The relationship between the Larsen score and foot pressure measurements is shown in Table 4. A statistically significant negative correlation was found between the Larsen score and the hindfoot lateral pressure measurements of the left foot at 26.8% ($r=0.286$; $p<0.05$).

The relationship between the FFI score and foot pressure measurements is shown in Table 4. A statistically significant positive correlation was found between the FFI score and the midfoot medial pressure measurements

of the right foot at 31.7% ($r=0.317$; $p<0.05$). A statistically significant positive correlation was found between the FFI score and the midfoot lateral pressure measurements of the right foot at 30.2% ($r=0.302$; $p<0.05$).

No statistically significant relationship was found between the disease duration and right and left foot pressure measurements ($p>0.05$).

No statistically significant relationship was found between the visual analog scale score and right and left foot pressure measurements ($p>0.05$).

Table 3. Distribution of patients' right and left foot pressures.

		Mean	SD
Forefoot, medial (kPa)	Right	318.94	148.43
	Left	301.06	133.66
Forefoot, mid (kPa)	Right	316.06	119.38
	Left	299.62	88.78
Forefoot, lateral (kPa)	Right	293.65	94.17
	Left	269.42	83.68
Midfoot, medial (kPa)	Right	86.83	54.49
	Left	78.65	47.15
Midfoot, lateral (kPa)	Right	101.69	62.20
	Left	93.94	54.58
Hindfoot, medial (kPa)	Right	255.48	111.17
	Left	254.71	58.31
Hindfoot, lateral (kPa)	Right	243.94	90.66
	Left	248.85	56.15

SD: Standard deviation

DISCUSSION

One of the common manifestations of RA is foot involvement. Forefoot pain and deformities in RA readily show the devastating effects of synovitis. However, foot involvement has received less attention in the literature and more emphasis has been placed on hand involvement^{29,30}. Usage of pedobarography as an objective measure of foot function in RA has increased^{8,18,31}. This study investigated the associations between foot loading characteristics and clinical symptoms, disease activity, and functional status, as well as radiological damage, and revealed that foot involvement was independent of disease duration, disease activity was detected by DAS28, and midfoot plantar pressures were associated with FFI and BMI.

The DAS28 remission criterion is frequently used to evaluate remission in clinical follow-ups and clinical studies. However, the results of the present study showed

Table 4. Relationship between HAQ, Larsen, FFI scores, and foot pressure measurements.

Foot pressure measurements		HAQ score		Larsen score		FFI score	
		r	p	r	p	r	p
Forefoot, medial	Right	-0.136	0.335	0.251	0.073	0.073	0.609
	Left	-0.063	0.658	-0.050	0.724	-0.074	0.604
Forefoot, mid	Right	-0.160	0.257	0.178	0.206	0.023	0.872
	Left	-0.179	0.205	0.010	0.943	-0.106	0.455
Forefoot, lateral	Right	-0.073	0.606	-0.140	0.321	0.070	0.622
	Left	-0.232	0.098	-0.251	0.073	-0.060	0.672
Midfoot, medial	Right	0.355	0.010**	-0.045	0.751	0.317	0.022*
	Left	0.072	0.612	0.056	0.691	0.070	0.621
Midfoot, lateral	Right	0.250	0.074	-0.110	0.438	0.302	0.030*
	Left	0.041	0.776	0.027	0.847	0.023	0.871
Hindfoot, medial	Right	0.073	0.605	0.205	0.145	0.002	0.986
	Left	-0.070	0.620	-0.207	0.142	-0.049	0.732
Hindfoot, lateral	Right	0.058	0.682	0.100	0.480	-0.031	0.826
	Left	-0.067	0.638	-0.286	0.040*	-0.031	0.825

* $p<0.05$, ** $p<0.01$, r: Spearman correlation coefficient, HAQ: Health Assessment Questionnaire, FFI: Foot function index

no association between plantar pressures and DAS28. van der Leeden et al.³² previously suggested that the DAS28 remission criterion for RA neglects patients with foot involvement. However, van der Leeden et al.³² also found high correlations between disease activity and foot pain when using the DAS44 criterion.

We could not reveal a relationship between disease duration and plantar pressure measurements. Studies revealed that one-third of patients had foot pain as a presentation symptom². Clinical involvements were observed in 50-86% of patients at the time of the study, 90% had foot pain complaints during the disease course, and approximately 90% had radiological abnormalities in the feet^{1,33,34}. Similar to the present study, these studies show that foot involvement is independent of the disease duration.

The present study revealed that FFI and HAQ were associated with right foot midfoot pressures. The most common deformity was pes planus in the midfoot¹. Midfoot problems were reported to be less common; however, similar to our findings, Jeong et al.³⁵ reported that walking difficulty was specifically associated with midfoot involvement and functional status were found to be worse in these patients. Additionally, both right and left midfoot plantar pressures were associated with the BMI. A recent cohort study reported the relationship of BMI with foot pain and foot-related activity limitation; however, the relationship between forefoot plantar pressure (barefoot) and BMI was insignificant³⁶. Thus, midfoot evaluation should not be ignored in plantar pressure measurements in the follow-up of patients with RA.

Plantar pressure measurements in the literature are mostly limited to the forefoot region since it is known as the most affected part of the foot^{8,20}. The evaluation of midfoot and hindfoot, as well as forefoot, is one of the strengths of our study.

The present study revealed no relationship between pain intensity and plantar pressure measurements. Schmiegel et al.³⁷ reported that the pain intensity during walking did not reflect the degree of forefoot deformity. Pedography can be useful for an early diagnosis of deformities. However, Schmiegel et al.³⁷ reported that even though pedographic measurements might show indications for destructive changes, they cannot provide information about erosion severity. The present study revealed a weak relationship between the Larsen score and hindfoot lateral pressure. Therefore, more studies are needed to reveal this relationship.

The study had some limitations. First, the study involved a relatively small number of patients and a lack of prior sample size calculation. Additionally, the study sample mostly consisted of functionally better patients, thus the number of patients receiving anti-TNF therapy was low. Therefore, evaluating patients who received different treatments would be appropriate in future studies. Moreover, plantar pressure measurements were made barefoot in the present study. Nowadays, making measurements barefoot is recommended, as well as in-shoe and orthosis.

CONCLUSIONS

Foot pain and deformities are common in RA; however, they can be overlooked in outpatient follow-up clinics. Foot erosion and deformities can be revealed by plantar pressure changes with pedobarographic examinations, thus more appropriate measures can be taken in the treatment and follow-up.

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Ethics

Ethics Committee Approval: This is a cross-sectional observational study that was approved by Istanbul Medeniyet University Goztepe Training and Research Hospital Ethics Committee (decision no: 28/G, date: 27.11.2012) following the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all patients.

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Author Contributions

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