# Application of plantography examination to the assessment of foot deformity in patients with rheumatoid arthritis

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## Abstract

**Introduction:** Rheumatoid arthritis (RA) is a chronic, inflammatory and multiple-system disorder of connective tissue. It frequently affects joints and periarticular structures of feet that constitute a significant supporting element underlying normal gait and motion of the body centre of gravity. The aim of the study was to evaluate foot deformities on the basis of plantography examination in RA patients according to the severity of the disease.
**Material and methods:** The study was performed on 54 RA patients. The control group consisted of 34 volunteers free of any disorders. Plantography examination was carried out by means of a CQ ST2K podoscope. The following parameters were applied to the assessment of the disturbances of foot statics: hallux valgus angle ($\alpha$), Sztriter-Godunow index (KY), Wejsflog's index (Wwp) and Clarke's angle (CL).
**Results:** Markedly higher values of the $\alpha$ angle were noted in RA patients, reflecting the presence of hallux valgus. Moreover, values of the $\alpha$ angle were higher in patients in the third stage of radiological changes than those in the second one. On the other hand, values of Clarke's angle for the right foot were significantly higher in men in the second and third stage of RA compared to the control group. The most common deformities in RA patients include HV and transverse flat foot, more explicit in women in the third stage of RA.
**Conclusions:** Plantography examination has been shown to constitute a useful diagnostic tool for assessment and monitoring of foot deformities in RA patients.

**Key words:** plantoconturography, foot deformation, rheumatoid arthritis patients.

## Introduction

Rheumatic disorders are considered to be one of the leading causes of permanent damage of motor organs. The most frequent systemic disease of connective tissue is rheumatoid arthritis (RA), which occurs in approximately 1% of the adult population in Poland, translating into 400 thousand cases [1]. The morbidity rate stands at 2–4 patients per every 10 thousand, which equates to 8–16 thousand newly registered cases per year [2]. The disease more frequently affects women, in the proportion of 3 : 1, and its occurrence increases with age [3].

Rheumatoid arthritis is characterised by unspecific, symmetric arthritis with concomitant abarticular changes and organ complications. The disease is chronic, with periods of recurrence and remission. Rheumatoid arthritis ultimately results in joint destruction and consequently joint deformation, leading, especially in the case of the foot, to impaired mobility of patients [4].

Pathological changes in feet contribute to an improper standing mechanism and gait cycle, which in turn increase the risk of collapse and consequently bone fractures [5, 6].

Both the correct body position and appropriate body movement depend on static foot function. Deformities present in RA interfere with the static compression on the lower limb, leading thereby to abnormalities in the foot arch and impairment of the optimal adjustment of the osteoarticular system to static and dynamic compressive loading.

The foot, being part of a structurally complex skeleton, plays a significant role in determining the level of human functional ability [7]. Despite the development of advanced diagnostic methods, clinical evaluation of the degree of rheumatoid changes in the feet still poses numerous difficulties.

The commonly applied radiological examination does not always reveal the severity of clinical disorders [8]. Therefore, work is underway to standardise the criteria of the clinical evaluation of disease progression. The pantographic technique has come to be applied ever more frequently in order to evaluate the distribution of pressure exerted by feet on the ground, reflecting the severity of the disorders of foot statics [4]. Few studies are currently devoted to plantography examinations in patients with rheumatoid arthritis. What they suggest is the application of this method with a view to controlling changes in the biomechanics of the locomotor system in patients with RA. They also highlight its potential with regard to evaluation of foot function, detection and graphic documentation of abnormalities in foot mechanics, detailed projection of the sole of the foot and obtaining specific information about the spatial configuration of foot arching. Among the most significant advantages of the plantography examination, researchers enumerate the comparability of results, precision of evaluation and the possibility to monitor the process of destruction, essential for planning and assessment of the therapeutic process.

The aim of the study was to evaluate the degree of foot deformities by means of selected stabilometric parameters in patients with rheumatoid arthritis, in correlation with the severity of destructive changes in their joints.

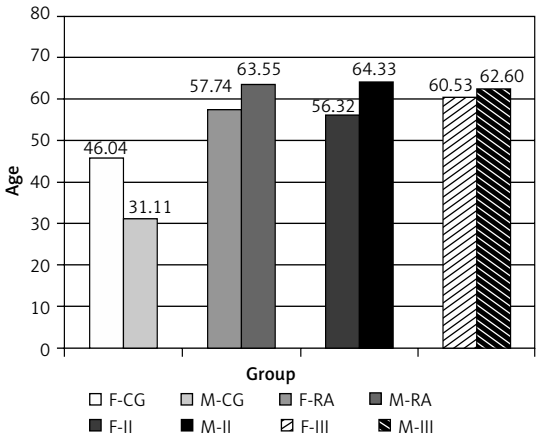


**Figure 1.** Median age of subjects depending on their sex

## Material and methods

The study was conducted in the Department of Rehabilitation at the University Hospital in Bialystok, between 2011 and 2012. The consent for the research was issued by the Bioethical Commission of the Medical University of Bialystok. All patients participated in the study voluntarily.

### Patients

The control group consisted of 25 women and 9 men at the ages of 24–60. The average age was 42.09 ±13.13. The examination included 54 patients with RA (43 women and 11 men) between 35 and 83 years of age, the median age standing at 59.38 ± 9.67. Radiological evaluation indicated stage II, according to Steinbrocker's classification, in 29 patients (23 women, 6 men) and stage III in 27 patients (20 women and 5 men). The duration of the disease ranged between a year and 30 years, the average being 13.42 ± 8.44 years (Table I, Figure 1).

**Table I.** Selected parameters of RA patients

| Parameter | *N* | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|---|
| Age | 54 | 59.38 | 35.00 | 82.00 | 9.67 |
| Body mass | 54 | 71.35 | 47.00 | 106.00 | 14.24 |
| Height | 54 | 163.85 | 152.00 | 189.00 | 7.35 |
| Time | 54 | 13.15 | 1.00 | 30.00 | 8.44 |

## Plantography examination

The plantography examination was conducted by means of a podoscope with a 3D scanner (Electronic System Poland) and the CQ ST2K software for computer feet examination. The device allows for precise diagnostics of foot statics disorders and enables researchers to obtain and describe the results in a repeatable and comparable manner. Apart from producing a precise scan of the foot, it also provides information regarding its spatial form.

Parameters specific for the rheumatoid process, indicating foot deformity, were applied. The hallux valgus angle ($\alpha$), formed between the tangent of the tibial border of the foot and the tangent running from the widest part of the forefoot to the external edge of the hallux, which is normally within 0–9°, was determined. The Sztriter-Godunov index (KY), which represents the ratio between the length of the line segment alongside the foot arch centre (blackened area) and the length of the line segment created by the unblackened part of the plantoconturograph, was also evaluated [$KY = (W - i)/(j - i)$]. Feet classification according to the *KY* index was conducted in compliance with CQ-Stopy producer's instructions (Table II).

Wejsflog's (*W*) index determines the proportion between the length and width of the foot. Physiologically, the value stands a approximately 3 : 1. Values between 2 : 1 and 3 : 1 are considered normal, whereas values close 2 (for example 2.15) to indicate transverse platypodia and close to 3 (for example 2.85) correct transverse foot arch.

Clarke's angle index (CL), was measured by marking a straight line (C-S) which, intersecting the internal tangent, forms the angle under consideration. Table III presents the classification of deformities according to Wejsflog's index. Figure 2 presents parameters determining foot deformities.

**Table II.** Foot classification according to the KY index

| Foot classification | Parameter |
|---|---|
| Calvus foot | 0.00–0.25 |
| Normal foot | 0.26–0.45 |
| Fallen foot arch I° | 0.46–0.49 |
| Fallen foot arch II° | 0.50–0.75 |
| Flat foot | 0.76–1.00 |

**Table III.** Classification of deformities according to Wejsflog's index

| Deformation | Grades |
|---|---|
| Flat foot | x–30° |
| Fallen foot arch | 31–41° |
| Normal foot | 42–54° |
| High-arch foot | 55°–y |

*x – Angle values under 30°, y – angle values over 55°.*

## Statistical analysis

Statistical analysis was conducted by means of Statistica 10.0 PL. We applied descriptive characteristics and calculated both arithmetic means and standard deviation of examined parameters. We used *t* Student's test, Mann-Whitney *U* test, Pearson product-moment correlation and R Spearman correlation index. Values $p < 0.05$ were regarded as statistically significant.

## Results

In the group of patients with RA, tests revealed significantly higher $\alpha$ angle values, reflecting hal-

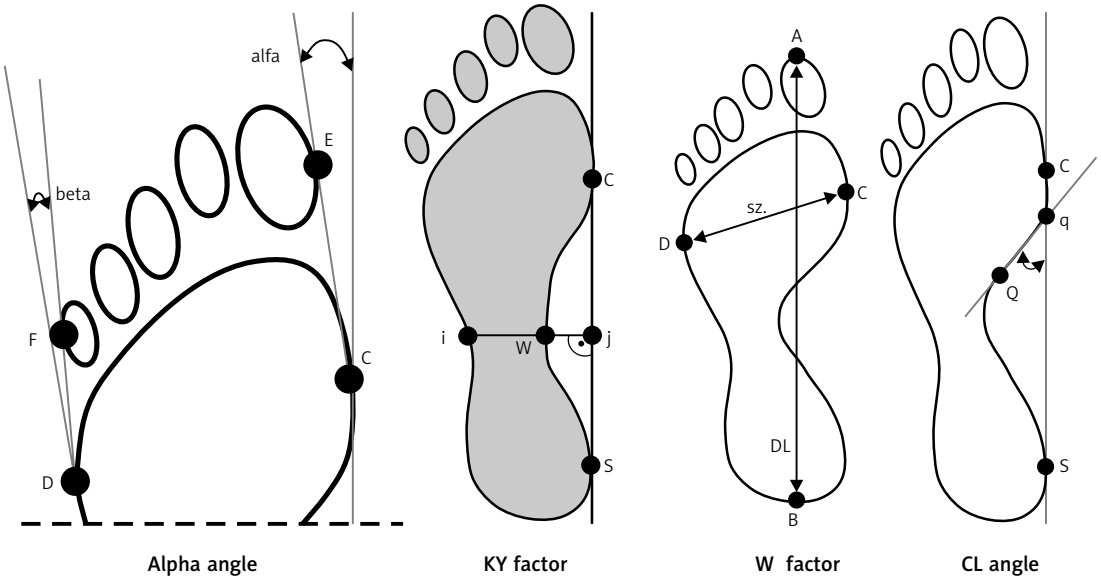


**Figure 2.** Parameters determining foot deformities

lux valgosity. Alpha angle values were higher in stage III of radiological changes in comparison to stage II. Table IV presents precise values of the analysed parameters.

Higher α angle values were demonstrated both in the right and left foot of women with stage III radiological changes. However, Clarke's angle values were statistically significant only in the right foot of men with stage II and III RA.

The highest values of Wejsflog's index, suggesting platypodia, were observed in men with stage II RA, in the right foot.

No differences were observed between groups of patients on the application of the Sztriter-Godunov index. Table V presents statistically significant differences in the analysed parameters.

## Discussion

Disturbed functioning of the locomotor system is mainly caused by injuries and inflammatory or degenerative changes. Epidemiological data reveal that feet deformities affect approximately 46% of the adult population [9, 10].

Functional changes and pain which appear in the earliest stages of RA pose serious diagnostic difficulties. Clinical and diagnostic problems stemming from the lack of correlation between the radiological and clinical degree of disease progression, and developing particularly in the early stage of the disease, prompt the search for new techniques of examination.

Radiological examination and other techniques, such as magnetic resonance imaging (MRI) and ultrasonography (USG), are used to evaluate feet deformities in patients with RA. Their application is limited, however, due to the fact that they require highly specialist equipment and personnel [4].

Implementation of pantographic examinations in diagnostics offers a wider range of practical options to evaluate the degree of foot deformity [11]. Pantographic examination is commonly applied to assess the distribution of pressures exerted by feet on the ground, and to determine the parameters indicating disorders of foot statics [4].

Another method is pedobarography, which allows for evaluation of foot overload. This exam-

**Table IV.** Values of the analyzed parameters in the examined groups of RA patients

| Variable | | Control group | Patients with stage II RA | Patients with stage III RA |
|---|---|---|---|---|
| **Parameter** | **Foot** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** |
| Alpha | R | 6.05 ±9.11 | 10.20 ±9.66 | 11.47 ±8.38 |
| | L | 3.82 ±5.60 | 7.78 ±9.55 | 12.37 ±10.92 |
| KY | R | 0.44 ±0.21 | 0.42 ±0.20 | 0.42 ±0.27 |
| | L | 0.39 ±0.18 | 0.41 ±0.22 | 0.43 ±0.30 |
| W | R | 2.57 ±0.14 | 2.57 ±0.23 | 2.58 ±0.18 |
| | L | 2.70 ±0.18 | 2.60 ±0.17 | 2.66 ±0.20 |
| CL | R | 56.60 ±14.69 | 60.24 ±44.11 | 63.04 ±49.64 |
| | L | 54.74 ±15.78 | 64.59 ±48.94 | 64.59 ±48.94 |

**Table V.** Statistically significant differences in the range of analyzed parameters

| Control group | Alpha angle | | Clarke's angle | | Wejsflog index | | KY index | |
|---|---|---|---|---|---|---|---|---|
| | ***R*** | ***L*** | ***R*** | ***L*** | ***R*** | ***L*** | ***R*** | ***L*** |
| CG-RA (F + M) | $p < 0.05$ | $p < 0.05$ | NS | NS | NS | NS | NS | NS |
| CG-RA II° (F + M) | $p < 0.05$ | NS | NS | NS | NS | NS | NS | NS |
| CG-RA III° (F + M) | $p < 0.05$ | $p < 0.05$ | NS | NS | NS | NS | NS | NS |
| CG-RA III° (F) | $p < 0.05$ | $p < 0.05$ | NS | NS | NS | NS | NS | NS |
| CG-RA III° (M) | NS | NS | $p < 0.05$ | NS | NS | NS | NS | NS |
| CG-RA II° (M) | NS | NS | $p < 0.05$ | NS | NS | NS | NS | NS |
| RA III° (F) – RA III° (M) | $p < 0.05$ | $p < 0.05$ | NS | NS | NS | NS | NS | NS |
| RA II° (M) – RA III° (M) | NS | NS | NS | NS | $p < 0.05$ | NS | NS | NS |

*CG – Control group, RA II° – patient with stage II of radiological changes, RA III° – patient with stage III of radiological, NS – non-insignificant, F – female, M – male, (F + M) – female and male, R – right foot, L – left foot.*

ination is non-invasive and offers the possibility to control changes in biomechanics of the locomotor system, which occur in RA [12, 13].

Few studies are devoted to indices illustrative of foot deformities and evaluated by means of plantoconturography in diseases of the locomotor system.

In the present study, plantoconturography was applied for evaluation of foot statics in patients with RA, and the following parameters were estimated: Clarke's angle, Sztriter-Godunov index Hallux valgus angle ($\alpha$) and Wejsflog's index.

In the RA group, significant differences, in comparison to the control group, were revealed with regard to the $\alpha$ angle, and the most striking differences were observed in women with stage III RA. Significantly higher values of the $\alpha$ angle were observed in 80% of the examined women. In men, the most clearly visible disturbances were connected with Wejsflog's index, rarely with the $\alpha$ angle.

In the group of 60 RA patients qualified for the study, only 6 were in the early stage of the disease. It was too low a number of patients to carry out a statistical analysis. Nevertheless, significant changes could still be observed with regard to the $\alpha$ angle and Clarke's angle, in comparison to healthy volunteers.

Plantography examination reveals deformities not only in the hallux valgus but also in other essential parameters, such as Clarke's angle and the *KY* index, which significantly influence foot statics.

In the present study, the largest deviation of Clarke's angle was demonstrated in the right foot of men with RA, while the highest values were observed in patients with stage III of the disease.

The authors of other studies have reported that, among women, the frequency of occurrence of the right longitudinal flat foot was 54% and of the left foot 55%. Transverse flat foot developed in 56% of right feet and 55% of left feet. Hallux valgosity was diagnosed in 40% of right feet and 38.1% of left feet [14].

Similar results were obtained in this research. Longitudinal flat foot was observed in 51% of right feet and 44.2% of left feet. Transverse flat foot was diagnosed in both feet of the examined women. Hallux valgosity was revealed in the right foot of 67% of women and in the left foot of 51.1%.

It is assumed that changes in the $\alpha$ angle may increase the pain in digital bones and metatarsus of older women [15].

In this study, a statistically significant correlation between the $\alpha$ angle of the right and left foot was established during the examination of hallux valgosity ($\alpha$).

The authors of other studies, in contradiction to our observations, highlight differences in radiological images of hallux valgosity in patients examined in a standing position [16].

The influence of excessive body mass on foot statics was observed in athletes who underwent examinations of the plantar foot surface, and a correlation between Clarke's angle and selected features of physique was demonstrated [17].

Foot statics are evaluated in various diseases, such as diabetes, often accompanied by obesity [18]. There are some interesting studies regarding obese patients, showing how the excessive body mass may predispose them to the occurrence of flat foot [19, 20]. Further examinations confirm the correlation between obesity and disorders of foot statics [21]. Examinations of the pressure of the foot sole in obese women revealed the presence of hallux valgosity in 16 out of 45 examined subjects. Foot deformities were demonstrated in all the examined patients [22].

Examination of foot statics should focus on the foot arch, which ensures appropriate protection from overload. Plantography examination proves extremely important since its findings reveal much more about the disease than direct measurements. The obtained results enable recognition and graphic description of observed disorders [21].

In studies devoted to children and adolescents with low physical activity, the symptoms of flat feet were frequently observed. Transverse flat foot in both feet was recognised even in 3-year-old children. Occurrence of this defect tends to increase with age and intensifies between the ages of 16 and 20 [23].

Examinations conducted in 216 children estimated Clarke's angle of the foot arch. Pantographic examinations revealed a significantly higher percentage of alteration in comparison to clinical estimation. Disorders of the foot arch occurred in as many as 50% of children between the ages of 5 and 6. This confirms the efficacy of pantographic examinations in early prophylaxis of foot deformities [24].

Examination of healthy subjects with a view to evaluating the frequency of occurrence of transverse flat foot in academic young adults revealed transverse platypodia in the right foot of 19% of women and transverse cavus foot in 13%. The left foot was transversely flat in 12% of patients and cavus in 17%. In men, these values were 14% and 18%, 13% and 15%, respectively [25].

In the present study, no significant differences were observed in Clarke's angle and Sztriter-Godunov index, which enable recognition of flat and cavus foot.

The results obtained in the research prove the efficacy of plantography examinations in evaluation of foot disorders in RA patients and in monitoring the results of treatment.

In conclusion, application of plantoconturography in the evaluation of disorders of foot statics allows for proper planning of therapeutic procedures and evaluation of their effectiveness.

## Conflict of interest

The authors declare no conflict of interest.

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