

Gait disturbances in patients with rheumatoid arthritis

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Abstract

Introduction: Rheumatoid arthritis (RA) is a chronic inflammation resulting in the involvement of all the structures constituting a joint. We determined the type and severity of foot deformities, determined the impact of the degree of disturbances of foot statics and the disease activity on the duration of the particular phases of gait, determined the impact of the maximum foot load and the percentage distribution of loads between the forefoot and hindfoot on the duration of the particular phases of gait, and established the link between observed disorders and the stage of rheumatoid arthritis.

Material and methods: The control group consisted of 41 healthy women. Rheumatoid arthritis patients, whose disease had been diagnosed based on the American College of Rheumatology (ACR) criteria, were divided into three groups. Group I consisted of 56 women, Group II of 28 patients in the first and second stage of RA, Group III of 28 patients in the third and fourth stage of the disease. We calculated the disease activity score (DAS28 index) and body mass index, and we conducted a pedobarographic examination.

Results: The results obtained in our study revealed the disturbances of the parameters of foot statics in RA patients. We also detected a prolongation of gait phases, resulting from the disturbances of statics and the displacement of the maximum foot load both in static and dynamic conditions. Increased activity of the disease constituted an additional factor affecting the prolongation of gait phases.

Conclusions: Our results confirm the usefulness of baropodometric examination as an important diagnostic tool in the evaluation of the locomotor system of RA patients.

Key words: rheumatoid arthritis, gait, foot statics.

Introduction

Rheumatoid arthritis (RA) is a chronic inflammatory disease of the connective tissue, characterised by symmetric inflammation of the joints, extraarticular changes and internal organ complications [1]. Etiopathogenetic factors include immunological disturbances, induced environmentally and genetically. The aetiology of the diseases is not fully understood despite years of research [2, 3].

Approximately 1% of adult individuals in Poland are affected by RA, which amounts to around 400,000 patients. The highest incidence rate is observed in adults aged 40-50 years [4, 5].

Destruction of the joints leads to deformation and, as a result, to limited mobility and disability [6–10]. It predominantly regards the small joints of the foot. Hallux valgus is the most frequent deformation in RA patients [11–13].

Rheumatoid arthritis causes damage to the active and passive elements of the joint [3]. Long-lasting inflammation of the joints leads to destruction, deformation, and loss of function and anatomical structure. Pain, the main symptom of the disease, limits the functional capacities of RA patients [14, 15].

The inflammatory process affects the mobility of patients. The disturbance of the body posture essentially influences the quality of life. As a result of incorrect mechanisms of internal compensation and increased muscle tension the disturbances of foot statics and incorrect gait cycle are observed in RA patients. The early diagnosis of foot statics and gait disturbances of RA patients plays an essential role in the therapeutic programme, preventive strategy and improvement of the quality of life of this population [16–18].

Plantar contourography is a good method to assess the sole surface of the foot and its static capability, as well as the deformities connected with RA [19]. Baropodometry has recently been added to the range of tests applied in the diagnosis of RA patients. It helps to evaluate body posture, gait, balance and foot shape disturbances. Thanks to baropodometry and plantar contourography it is possible to determine morphological changes in the initial stage of the disease as soon as possible to monitor the progress of foot deformation and consider an individual targeted therapeutic programme [20]. Currently used methods allow one to evaluate temporal and spatial gait parameters, including the length and frequency of steps, gait speed and the percentage distribution of the individual phases of the gait cycle [21].

The aim of the study was to evaluate gait disturbances in RA patients based on the analysis

of gait cycle parameters and degree of foot deformities in correlation with the Disease Activity Score (DAS28) and body mass index (BMI).

Material and methods

The study was conducted in the Department of Rehabilitation of the Medical University of Białystok. The research was approved by the Local Bioethical Commission of the Medical University of Białystok (agreement No. R-I-002/86/2014) and informed consent was obtained from all participants before inclusion in the study.

The RA group consisted of 56 women aged 28–78 (average 58.2 ± 10.7 years), diagnosed according to the American College of Rheumatology (ACR) and European League Against Rheumatism (EULAR) criteria of 2010. The duration of RA ranged between 1 and 34 years (average 11.2 ± 7.8 years). Patients were divided into subgroups depending on radiological evaluation according to Steinbrocker's classification (Table I).

The control group comprised of 41 healthy women aged 21–71 (average 47.1 ± 16.3).

Participants of the study suffering from intercurrent entities that affect static foot function, such as diabetes, discopathy of the lumbar-sacral segment, cardiovascular diseases, pregnancy, post-traumatic and post-operative conditions within the region of the lower limbs were excluded from the study.

To evaluate the presence of gait disturbances we applied the FreeMEd Posture device. Research conducted on our RA patients consisted of four phases.

Phase 1 – static examination analysing such parameters as the point of maximum pressure (letter M), pressure distribution between the right and left foot, percentage distribution of loading between the forefoot and hindfoot, as well as right and left foot loading measured in kilograms. Phase II consisted in dynamic examination measuring the maximum loading in g/cm^2 ,

Table I. Values of selected parameters in rheumatoid arthritis patients (data are given as mean \pm SD)

Parameter	Control group	All RA patients Group I	Patients with RA stage I/II Group II	Patients with RA stage III/IV Group III
Number of participants (women)	41	56	28	28
Age	21–71 47.1 ± 16.3	28–78 58.3 ± 10.7	34–74 57.3 ± 9.3	28–78 59.3 ± 12.1
BMI	25.4 ± 4.7	25.4 ± 3.8	25.9 ± 3.5	24.9 ± 4.0
Disease Activity Score DAS28	–	1.7 ± 7.1	4.4 ± 1.2	5.1 ± 1.3
Duration of disease	–	11.2 ± 7.8	8.9 ± 7.1	13.6 ± 7.9

RA – rheumatoid arthritis, BMI – body mass index.

Table II. Duration of individual stages of the gait cycle

	Initial contact 2–4%	Early loading 10%	Mid-position 30–32%	Terminal position 50–56%
RIGHT foot	Duration (ms)			
LEFT foot				

Table III. Statistically significant differences between parameters analysed in the control group and the group of rheumatoid arthritis patients

Group I/Control group	Studied parameter		<i>P</i> < 0.05	
Static examination	Loading LF%		0.049	
	Loading RF%		0.049	
Dynamic examination	Max loading LF [g/cm ²]		0.015	
	Max loading RF [g/cm ²]		0.003	
Gait cycle	Initial contact	Duration	L	0.029
	Early loading	Duration	L	0.017
	Mid-position	Duration	L	0.008
	Terminal position	Duration	L	0.005
	Initial contact	Duration	R	0.044
	Mid-position	Duration	R	0.010
	Terminal position	Duration	R	0.017
Podoscopic examination	Wejsflog index		R	0.001
	Wejsflog index		L	0.048
	Heel angle		R	0.0004
	Heel angle		L	0.024
	Body mass			0.005
	Age			0.0009

percentage distribution between the forefoot and hindfoot, as well as gait analysis with regard to the duration of the individual phases of the gait cycle (Table II).

Phase III of the study consisted in analysing selected parameters underlying the shape of feet. We established values of the hallux valgus angle (α), heel angle, Clarke's angle, the Wejsflog index and the Sztriter-Godunow index. Interviews with patients, during which some information regarding the frequency of balance disturbances and falls was gathered, constituted Phase IV of the study.

Disease activity of RA was measured by DAS28. The BMI and gait analysis were also estimated.

Statistical analysis

Statistic analysis assessed normality of distribution by means of the Kolmogorov-Smirnov test with Lilliefors correction and the Shapiro-Wilk test. The analysed quantitative variables did not exhibit normality of distribution. The non-parametric

Mann-Whitney *U* test was applied in two groups in order to compare quantitative variables without normality of distribution. Spearman's rank correlation coefficient was also established. The non-parametric ANOVA Kruskal-Wallis test was used to analyse differences in results among the groups.

Results were considered to be statistically significant for $p < 0.05$. Calculations were performed using the Statistica 10.0 package by StatSoft.

Results

The study exhibited some statistically significant differences in the static and dynamic examinations, in the analysis of duration of the individual gait phase and in the podoscopic examination. Values of the studied parameters obtained in the groups of patients in the 3rd and 4th stage of RA (Group III) were compared to the values obtained in the control group (Table III).

Analysis of parameters between the group of patients in the 1st and 2nd stage of RA (Group II)

Table IV. Statistically significant differences between parameters studied in Group III of rheumatoid arthritis (RA) patients (3rd and 4th stage of RA) and the control group

Group III/Control group			<i>P</i> < 0.05
Loading LF%			0.035
Loading RF%			0.033
CoPX			0.021
Max loading RF [g/cm ²]			0.011
Initial contact	Duration	L	0.031
Early loading	Duration	L	0.022
Mid-position	Duration	R	0.016
Mid-position	Duration	L	0.008
Terminal position	Duration	R	0.036
Terminal position	Duration	L	0.007
Wejsflog index			R 0.009
Heel angle			R 0.0003

P value for multiple comparisons. The Kruskal-Wallis test.

and the control group revealed statistically significant differences only with regard to the Wejsflog index and the heel angle of the right foot (Table IV).

A correlation was detected between the BMI and foot surface in the active and dynamic examinations in all the studied groups. This correlation was also present in Group I between the BMI and the percentage distribution increase in the loading of the forefoot and hindfoot in the dynamic examination. Statistically significant correlations were also found in the control group between the BMI and gait cycle parameters, such as duration of the initial contact of the feet, early loading, mid-position and final position of the right foot. As the BMI value was going up, so was the transverse flatfoot expressed by the value of the Wejsflog index in the control group and Group II. Group III, on the other hand, enabled us to detect positive correlations between the value of BMI and heel angle.

In all groups, a statistically significant positive correlation was found between the DAS28 and the percentage loading of the fore- and hindfoot of the right foot. The dynamic examination revealed significant correlations only in Group III between the DAS28 and the duration of the initial contact of the right foot. The podoscopic examination showed statistically significant correlations in Group I between the heel angle and Clarke's angle, in Group II between the plantar angle and heel angle, and in Group III between the heel angle and the Wejsflog index for the left foot.

In the group of RA patients, foot statics disturbances were detected predominantly with regard

to the Wejsflog index, hallux valgus angle (α) and Clarke's angle. Disturbances of the studied parameters were found in patients with a minor degree of progression of changes in the imaging examination. It was mostly the case of patients with an increased body mass.

A correlation was established between the intensity of foot statics disturbances, longer duration of the individual stages of the gait cycle, the severity of RA and the clinical severity of the disease.

We found a correlation between longer duration of the individual phase of the gait cycle and the percentage loading of the forefoot and hindfoot, as well as shifts of the point of maximum pressure in group III of RA (III/IV stage). It was interesting that these changes were already visible in the early stage of radiological changes. Podometric examination constitutes an important diagnostic tool for evaluating the functional condition of the locomotor system in RA patients.

Discussion

Among the main problems of RA patients are morphological and functional disturbances of the locomotor system. Coupled with more general symptoms, they negatively affect various spheres of life, such as professional career, family relationships, leisure, and sport activities, leading to limited life quality [22]. The violent and active disease process, both in young individuals and people over 60 years old, renders approximately 50% of the patients unable to work and not fully self-reliant within the first 10 years of disease duration [23].

Measurements of the plantar pressure have been taken since as early as 1980. Current pedobarographic tests concentrate predominantly on the examination of the diabetic foot and orthopaedic treatment. Our results confirm the necessity and usefulness of performing foot loading measurements in RA patients.

Change in the foot loading distribution constitutes one of the first statics disturbances in RA patients. Its diagnosis ought to be regarded as a call to start early rehabilitation, which may exert a positive influence by inhibiting deformation in the later stage of disease progression.

Results of our own studies have indicated that foot statics disturbances appear already in the first stage of the disease. In the groups of patients diagnosed with the 1st and 2nd stage of RA, the value of the point of maximum pressure was higher in the static examination compared to the control group. In this group of patients, the biggest differences were detected with regard to the distribution of loading between the right and left foot, and the increase in loading was especially visible

in the left foot. As for the dynamic examination, the value of loading turned out to be the highest in the control group. The biggest loading, both in the static and dynamic examination, occurred within the hindfoot of patients in the advanced disease stages (3rd and 4th degree of the X-ray).

A high value of the maximum foot loading in the static and dynamic examinations was also found in the patients diagnosed with the 1st and 2nd stage of disease severity. As a result, there was a shift in the percentage loading from the forefoot to the hindfoot.

Results of the studied static and dynamic foot parameters in RA patients indicate that the higher the clinical stage of disease severity, the higher the prevalence of abnormal values.

Evaluation of the alpha angle, heel angle, the Wejsflog index and the Sztriter-Godunow index has shown considerable changes in the values of these parameters in the RA patients compared to the women from the control group.

The greatest differences, compared to the control group, were observed in the case of the alpha angle and Clarke's angle, as well as in the duration of the individual gait stages. There were differences in the percentage loading distribution between the forefoot and hindfoot. Elevated hindfoot loading was found in our RA patients, especially in the group in the 1st and 2nd stage of disease severity.

Gait analysis, conducted by means of a baropodometric mat, revealed statistically significant disturbances of the individual gait stages in all the studied groups.

The highest values of Clarke's angle were detected in the patients from Group II. This indicates an elevated foot arch in the patients diagnosed with the 1st and 2nd radiological stage of RA. Patients in the 3rd and 4th stage had lower values, closer to those in the control group. The value of Clarke's angle did not show any statistically significant correlations with regard to other studied parameters in each group of patients, such as the BMI, age and the DAS28 index.

One's job constitutes a factor which might influence foot shape disturbances. Studies carried out by Ślężyński showed that middle-aged and elderly women doing sedentary work had a more positive value of the foot arch index compared to the same age group working in the standing position [24].

In the present study, statistically significant correlations were detected between the Wejsflog index, the BMI and age in Group II and the Wejsflog index, age and the DAS28 in Group III. Having juxtaposed the values of the Wejsflog index of each group of patients, statistically significant differences were found between the control group

and the patients from both Group I (1st and 2nd) and Group II (3rd and 4th).

Normal gait depends on multiple factors. It may be disturbed due to pathological changes within the lower limbs and is frequently observed in rheumatic diseases. Gait disturbances very often affect overweight patients.

The results obtained in the study may be indirectly indicative of the relationship between obesity and the degree of changes in the transverse foot arch in RA patients. Our analysis has demonstrated statistically significant correlations between the BMI and the surface of the right and left foot, as well as a statistically insignificant link between the percentage loading distribution between the forefoot and hindfoot already in the early stage of radiological changes in RA patients. Maximum foot loading was observed in the patients in the 3rd and 4th radiological stage of RA disease.

The latest studies have shown that 18–31% of RA patients are obese, and approximately 60% are overweight [25, 26]. In our study, 54% of all RA patients had an increased body weight. Similarly, in Group II, 39% of the patients were overweight and 14% were obese. Comparison to the control group, in which 58% of the people had an elevated value of the BMI index, revealed no significant differences. The analysis showed that the patients with an elevated BMI index suffered more frequently from the maximum foot loading distribution disturbances and had increased values of the heel angle in the right foot. The results obtained by us revealed correlations between the heel angle and the BMI index in the RA patients from Group III. The patients with abnormal body weight also had a larger foot surface.

All RA patients in the 3rd and 4th stage of the disease had prolonged gait stages. Duration of the individual gait stages increased with age.

There have been no reports on gait disturbances in RA patients, which makes it more difficult to compare the obtained results indicative of disturbances of gait parameters.

Early rehabilitation aimed at improving gait symmetry, pace and balance plays an important role in unaided functioning of patients. It was confirmed by studies carried out on stroke patients who practised walking and exercised the whole trunk for 45–60 minutes daily for 2 weeks. After a series of exercises their gait speed improved considerably. Most reports on foot statics disturbances and gait disturbances present analyses of patients with neurological disturbances of varied aetiology [27].

Few of them regard patients with rheumatic diseases. Our study has shown that the progressive character of the disease constrains the pa-

tients' ability to move. Early diagnosis and implementation of an adequate pharmacological and functional treatment are thus of great importance [28, 29].

Morphological changes observed in imaging studies underlie foot statics disturbances and gait disturbances, which has been confirmed by our study. Observations of the patients whose evaluation of foot static parameters showed greater abnormalities than "expected" with regard to the degree of radiological changes were extremely interesting. This may stem from the fact that the pain influences gait disturbances to a greater degree than morphological changes. Our study indicates that foot statics and gait changes in RA patients may be crucial for the early diagnosis of locomotor system disturbances.

The presence of the hallux valgus concerns mostly patients in the advanced stages of RA. The greatest aberrations were observed in the right foot of these patients. In Group II, on the other hand, it was the case of the left foot.

Hallux valgus is one of the most prevalent deformities among the analysed parameters in the group of RA patients. Correlations were found between the hallux valgus angle in the right foot and age in the group of patients diagnosed with the 3rd and 4th stage of RA.

Excessively lowered forefoot, present among others in overweight patients, increases the risk of hallux valgus. This was confirmed by our study, as it revealed a correlation between an elevated BMI index and the percentage loading distribution of the forefoot of the right foot in the dynamic examination.

The range of diagnostic possibilities available to RA patients has been extended by functional tests. Apart from static examinations, dynamic examinations play an ever greater role.

They are aimed at early diagnosis of functional disturbances within the feet which underlie disturbances of the gait and body posture. Loading distribution on the plantar surface of the foot constitutes one of the most important human foot examinations. Analysis of its results provides information on the shape and functional state of the feet [30].

Current reports prove that plantar contourographic and baropodometric examinations, contrary to the imaging studies, detect functional disturbances stemming from early morphological changes [31].

Elevated foot loading was especially evident in patients in the 1st and 2nd stage of disease severity compared to healthy women.

Studies by Kaz *et al.* indicate that 68% of RA patients belong to the group of a greater fall risk [32].

Our analyses have shown the frequency of falls to be higher in the patients from Group III, whose gait disturbances were characterised by longer duration of the individual gait stages.

Limited physical activity is one of the main factors increasing the fall risk. According to recent studies, RA patients showed a lower functional ability in approximately 60% of the female and 40% of the male population. Reduced life activity was associated with, among others, a higher fall risk and the patients' fear of falling [30–32]. Higher frequency of falls is directly influenced by the clinical stage of disease severity and pain. There exists a kind of "feedback" between the higher frequency of falls and pain intensity affected by the clinical activity of RA [36].

Research carried out by Armstrong *et al.* on a group of 253 RA patients showed that 33% of them experienced falls, and 52% of this subgroup suffered from falls more often than once a year. The authors also detected a correlation between balance disturbances and falls [37–39].

The likelihood of falls is very high for patients with gait disturbances, which is of special clinical significance in the face of an elevated fracture risk in the course of RA. The method of assessing gait stages in this study could provide useful information on abnormalities and help to undertake adequate preventive measures.

There are multiple causes of falls, especially in the case of the elderly. Analysis of studies devoted to the falls of elderly people shows that the causes are most frequently external factors (31%), gait and balance disturbances or weakness (17%), dizziness (13%) and consciousness disturbances (5%) [40]. There are a lot of factors that could be responsible for the fall risk, especially in the elderly patients. There are internal factors (connected with the disease) and external factors (environmental). According to Bączek *et al.*, external factors caused 79% of the falls [33].

The BMI index constitutes an important factor influencing the postural balance disturbances and deformities within the feet. With regard to adults it was proved that the BMI index correlated with the pronated position of the head of the talus and the surface of the longitudinal foot arch. Pronated foot position, which manifests itself in the longitudinal flatfoot, is much more prevalent in the individuals with a higher BMI index [26].

Recent studies have shown the increasing prevalence of obesity and RA leading to restriction of physical activity [25, 41].

Dao observed increased adipose tissue mass and reduced muscle mass in woman with the early stage of RA. Both these elements correlated with disease activity, measured by DAS28 [42].

We analysed possible correlations between the DAS28 index and static foot parameters. Statistically significant correlations were found in RA patients with the 1st and 2nd radiological stage of disease severity between the DAS28 and increase in the percentage loading of both the forefoot and hindfoot in the static examination. Statistically significant negative correlations were detected in the patients in the 3rd and 4th radiological stage between the DAS28 and increased loading of the right and left foot. A positive correlation was revealed between the DAS28 and the Wejsflog index in these patients.

Results of the tests carried out on our control group confirm the existence of a correlation between the BMI index and foot static parameters: the Wejsflog index, percentual loading of the forefoot and hindfoot, as well as between age and the heel angle and the Wejsflog index in the right foot.

Evaluation of movement, including evaluation of the gait, must not be overlooked in the examination of RA patients. Current diagnostic methods are based on modern optoelectronic solutions which facilitate a one-step analysis of the kinetic and kinematic parameters. Results of this method provide information that enables us to analyse the gait and diagnose of functional changes in RA patients, which is crucial for tailoring the optimal rehabilitation treatment methods, their monitoring and evaluation of effectiveness.

The early diagnosis of foot statics and gait disturbances of RA patients coupled with an individually planned rehabilitation, play an essential role in the therapeutic programme, preventive strategy and improvement of the quality of life of this population.

In conclusions in RA patients disturbances of foot static parameters such as the Wejsflog index, alpha angles and Clarke's angle were found. Our data confirm the usefulness of baropodometric examination as an important diagnostic tool in the evaluation of the locomotor system, especially in early stages of RA patients with overweight. Further investigations into the role of foot statics and gait disturbances as postural balance changes may be crucial for the individual therapeutic strategy in RA patients.

Conflict of interest

The authors declare no conflict of interest.

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