Assessment of the frequency and severity of foot deformities in patients with rheumatic diseases

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Abstract

Background: Rheumatic diseases manifest with inflammatory and degenerative changes in the musculoskeletal system, leading to joint deformities, limiting dexterity, causing pain, and being a significant factor affecting disability level. Common causes of foot deformities include arthropathic conditions such as rheumatoid arthritis (RA), ankylosing spondylitis (AS), and some connective tissue diseases such as systemic sclerosis (SS).

Aims: The study aimed to assess the frequency of flat feet occurrence and the regularity of foot structure among patients with rheumatic diseases.

Material and methods: The study included patients suffering from three rheumatic diseases: RA, AS, and SS. The conducted research involved a static assessment of the plantar side of the feet, consisting of creating a detailed imprint using plantar contouring and measurements of podometric parameters for both feet, utilizing a computerized recorder integrated with a podoscope.

Results: In over half of all patients, the presence of valgus deformity of the foot was observed (right foot – 54.4%, left foot – 52.6%), while a small percentage exhibited varus deformity of the foot (both right and left feet – 2.3%). Normal foot arching was found in just under half of the participants (right foot – 43.3%, left foot – 45.1%). Only 24 (14.0%) individuals confirmed awareness of flat feet.

Conclusions: There is a need to assess patients with rheumatic diseases for the presence of functional disorders of the foot to implement early exercise prevention.

Key words

rheumatic diseases, rheumatoid arthritis, ankylosing spondylitis, systemic sclerosis, flat foot, plano-valgus deformity, podometry.

Introduction

Rheumatic diseases are manifested by inflammatory and degenerative changes in the musculoskeletal system, leading to joint deformity, impairing function, causing pain, and being a significant cause of disability. One of the consequences of these diseases is foot deformity, which affects about 4-5% of the general population [1]. Among the more common causes of rheumatic foot deformities are inflammatory arthropathies such as rheumatoid arthritis (RA), ankylosing spondylitis (AS), or certain systemic connective tissue diseases such as systemic sclerosis (SS).

Difficulties in unequivocally defining flat feet and correctly diagnosing the static capacity of the feet are due to the fact that different specialists, often using different concepts, are partly related to the use of different research methods. These difficulties are multiplied by the lack of specific, universally recognized standards that take into account the age of the subjects and the specific conditions under which measurements are taken. There are conflicting results in the literature regarding the prevalence of foot deformities, particularly flat feet, which range from 10% to as much as 90% of the general population [1]. Based on studies of healthy volunteers, the prevalence of flat feet is estimated to be around 3-25% of the general population [2].

Pathological changes in the joints of the feet in RA, caused by the formation of arthritic pannus (rheumatoid granuloma) and pathological processes in bone structures, are clearly visible on X-rays. Even before the changes appear on X-ray, magnetic resonance (MR), and Doppler imaging, heavily vascularized pannus can be visualized, causing joint and tendon destruction [3]. In the course of RA, there is usually symmetrical involvement of the foot joints, as well as global motor impairment of the feet due to their plano-valgus deformity. In this group of patients, lowering the longitudinal and transverse arch of the foot, the formation of a hallux valgus toe, and hammer toes II-V are observed. The described lesions are caused by the valgus position of the heel and foot abduction. In addition, there is a co-occurrence of typical destructive changes of the metatarsophalangeal and interphalangeal joints of the feet, which are aggravated by inflammation of tendons, tendon sheaths, and bursae. The longitudinal and transverse arch is lowered because the head of the metatarsal bone I is insufficiently pinned to the ground by an inefficient peroneus longus muscle or the disfunction of the tibialis posterior muscle [4].

These deformities also indirectly affect the hip and knee joints, potentially resulting in valgus or varus deformity, ultimately leading to impaired gait [5]. Up to 90% of RA patients suffer from foot deformities (mainly forefoot), causing pain, swelling, and destruction of joint surfaces, leading to reduced mobility in the joints of the foot and ultimately impaired supporting function [6].

In turn, in AS, subperiosteal elevations and erosions on the calcaneal tuberosities form in the lower limbs, and inflammation of the Achilles tendon occurs [7].

According to the SS, the main symptom is sclerosing of the skin, beginning amongst other symptoms, with swelling of the feet. The swelling lasts from several weeks to several months, after which there is a gradual thickening of the skin and an increase in skin tightness. In the limited form of SS, symptoms occur, among others, on the distal parts of the lower extremities relative to the knee joints. In addition to skin symptoms, there is fascia and tendon sheath fibrosis. As a result of these changes, restrictions in the mobility of the joints of the feet and flexion contractures are developed. Relatively rarely, painful, hard-to-heal ulcers form on the fingertips, the descent of which are thimble-like scars, while the nails undergo atrophy in the course of the disease process [8,9].

Aims

The study aimed to assess 1) the prevalence of flat feet and 2) the regularity of foot shape on podoscopic examination in patients with diagnosed RA, AS, and SS.

Material and methods

Study group

The study included patients suffering from three well-defined rheumatic diseases: RA, diagnosed based on the 2010 American College of Rheumatology (ACR) / European League Against Rheumatism (EULAR) criteria; AS based on the 2010 Assessment in Ankylosing Spondylitis (ASAS) criteria; and SS based on the 2013 EULAR/ACR criteria.

Study settings

The study was conducted at the Rheumatology Department of the Independent Public Clinical Hospital No. 7 of the Silesian Medical University in Katowice – the Prof. Leszek Giec Upper Silesian Medical Center in Katowice, Poland. In accordance with the requirements of the Declaration of Helsinki, prior to participation in the study, participants were informed of the purpose, nature, and method of the analyses, and were included in the sample after giving written consent.

Study course

The study included a static assessment of the plantar side of the feet, consisting of an accurate print of the plantocontourogram and measurements of podometric parameters of both feet using a computer recorder integrated with the podoscope. The Podoscan 2D Foot Cad (Sensor Medica, Guidonia Montecelio, Italy) and a laptop computer with software for the podoscope (Sensor Medica, Guidonia Montecelio, Italy). The parameters measured during the podoscope examination are shown in **Table 1**.

Table 1. Parameters measured during the podoscopic examination.

Parameters	Unit	Parameters
Length and width of the foot	cm	Length of the foot – it is determined by the segment connecting points A and B. Width of the foot – it is determined by the segment connecting points C and D.
Wejsflog index	n/a	The ratio of length to width of the foot – this ratio should be 3:1.
Angle of hallux valgus α	degree [°]	The angle is determined between the tangent to the medial edge of the foot and the tangent drawn from a point at the widest point of the forefoot to the lateral edge of the toe – the normal value is between 0 and 9 degrees.
Angle of varus toe β	degree [°]	The angle is determined between the tangent to the lateral edge of the foot and the tangent determined by the outermost point of the forefoot edge and the lateral edge of the little toe – the normal value is 0 to 5 degrees
Calcaneal angle	degree [°]	The angle is determined by two tangents to the lateral and medial edges of the foot that intersect outside the heel – the normal value is 15 to 18 degrees.

Sztriter-Godunow index (KY)	n/a	The ratio of the length of the segment located in the center of the longitudinal arch (through the shaded part of the plantocontour) to the length of the segment defined by the unshaded and shaded part of the plantocontour. KY = (W – i) / (j – i) (W – i) – shaded part; (j – i) – shaded and unshaded part. KY index norms: • Hollow foot • 0.00 – 0.25 • Normal foot • 0.26 – 0.45 • Reduced foot I° • 0.46 – 0.49 • Reduced foot II° • 0.50 – 0.75 • Flat foot • 0.76 – 1.00
Longitudinal foot arch depth index	n/a	The index is determined by the segment located at the center of the longitudinal arch on the unshaded part of the plantocontour by the tangent of the medial edge of the foot and multiplied by 100. Point mtt (the line joining the most extreme points on the head of the metatarsal bone I) – the most medially extended metatarsal point [mm]. Point mtf (the line joining the most extreme points on the metatarsal bone V) – the most laterally extended metatarsal point [mm].
Chippaux-Smirak index (CSI)	n/a	The index is determined by dividing the section that runs at the height of the Chopart joint by the parallel section that marks the width of the foot.

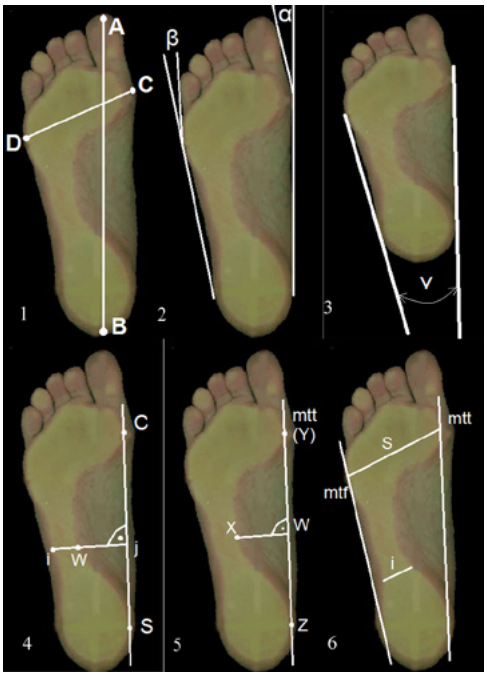

Figure 1. The methodology for the measurement of the parameters is shown in Table 1.

Statistical analysis

Interval scale data with a normal distribution are presented as mean ± standard deviation. Qualitative data were presented as counts and percentages. The normality of the data distribution was assessed using the Shapiro-Wilk test and quantile plot (Q-Q). A two-factor ANOVA with post-hoc contrast analysis was used to compare data on an interval scale between groups. Comparisons between nominal and ordinal scale data were made using χ^2 or Fisher's exact test (depending on Cochran's conditions). Results were presented graphically using column plots and mean values with 95% confidence intervals (CI). Statistically significant parameters were considered variables for which the significance level $p < 0.05$. Calculations were performed using the Statistica 12.0 PL edition (TIBCO, Palo Alto, USA).

Legend: 1) *length* (A-B) *and width* (C-D) *of the foot, Wejsflog index*, 2) *angle of hallux valgus α, angle of varus toe β*, 3) *calcaneal angle γ*, 4) *Sztriter-Godunow index* (KY), 5) *longitudinal foot arch depth index*, 6) *Chippaux-Smirak index.*

Aims

Characteristics of the study groups

A total of 50 patients with AS (aged 37 ± 11 years, mean disease duration 9 ± 8 years), including 18 (36.0%) women; 68 patients with RA (aged 55 ± 12 years, mean disease duration 11 ± 11 years), including 55 (80.9%) women and 53 patients with SS (aged 55 ± 13 years, mean disease duration 5 ± 6 years), including 37 (69.8%) women, were studied.

More than half of all patients had valgus foot (right foot – 54.4%, left foot – 52.6%), a small percentage had varus foot (right and left foot – 2.3%), while normal foot arches were present in less than half of the subjects (right foot – 43.3%, left foot – 45.1%). Only 24 (14.0%) of the subjects confirmed awareness of their flat feet. In addition, the relationship between the presence of flatfoot and valgus or valgus of at least one foot was assessed. Subjects with flat feet were statistically significantly more likely to have a valgus/varus foot compared to those with normal foot arches (74.4 vs. 23.7; $p < 0.001$).

Comparison of the study groups

The highest percentage of foot abnormalities concerning valgus or varus was noted in the group with RA (N = 54; 79.4%), followed by those with AS (N = 31; 62.0%), and the lowest among those with SS (N = 23; 43.4%); $p < 0.05$ – **Fig. 2**. However, there were no statistically significant differences in the subjects' awareness of the presence of flat feet (in the group with AS (N = 8; 16%) of the subjects, in the group with RA (N = 13; 19.1%), and the group with SS (N = 3; 5.7%) ($p = 0.10$).

The highest percentage of abnormalities regarding foot arching was observed in the group with RA (N = 59; 86.8%), followed by the group with SS (N = 40; 75.5%) and AS (N = 43; 68.0%) ($p < 0.05$). The highest percentage of subjects with normal foot arches was observed in the group with AS, followed by the group with SS. Among the subjects with RA, only one in five patients had normal foot instep.

Analysis of the podometric examination

The podometric examination showed statistically significant differences between the study groups in the mean values of toe valgus angle, toe splay angle, and Wejsflog, Sztriter-Godunow, and Chippaux-Smirak indices. However, there were no statistically significant differences for the calcaneal angle and the longitudinal foot arches depth index – **Table 1**. The results are illustrated in **Figs. 3** and **4**.

In the case of the toe valgus angle, it was shown that patients with AS had statistically significantly lower values of this angle than patients with RA and SS (for both feet). In addition, patients with RA had statistically significantly higher values of this angle than patients with SS (for both feet). In contrast, there were no significant differences in this angle between the two feet in the study groups.

In addition, statistically significant differences in the distribution of abnormal values of toe angle α between the study groups for the right foot were shown ($p < 0.001$); the percentage of subjects with an abnormal value in the group with AS was 74.0% (N = 37), with RA it was 26.5% (N = 18) and with SS it was 37.7% (N = 20), as well as for the left foot ($p < 0.001$); the percentage of subjects with an abnormal value in the group with AS was 68.0% (N = 34), with RA it was 26.5% (N = 18), and with SS it was 37.7% (N = 18).

In the case of the varus toe angle, it was shown that patients with RA had statistically significantly higher values of this angle than patients with AS and SS (for both feet). No significant differences were shown in this regard between patients with AS and SS.

For the calcaneal angle, it was shown that RA patients had statistically significantly higher values of this angle than AS patients for the left foot. In addition, the RA patient group showed that the values of this angle were statistically significantly higher for the left foot relative to the right foot. There were no significant differences in this regard between the AS and SS patients' groups.

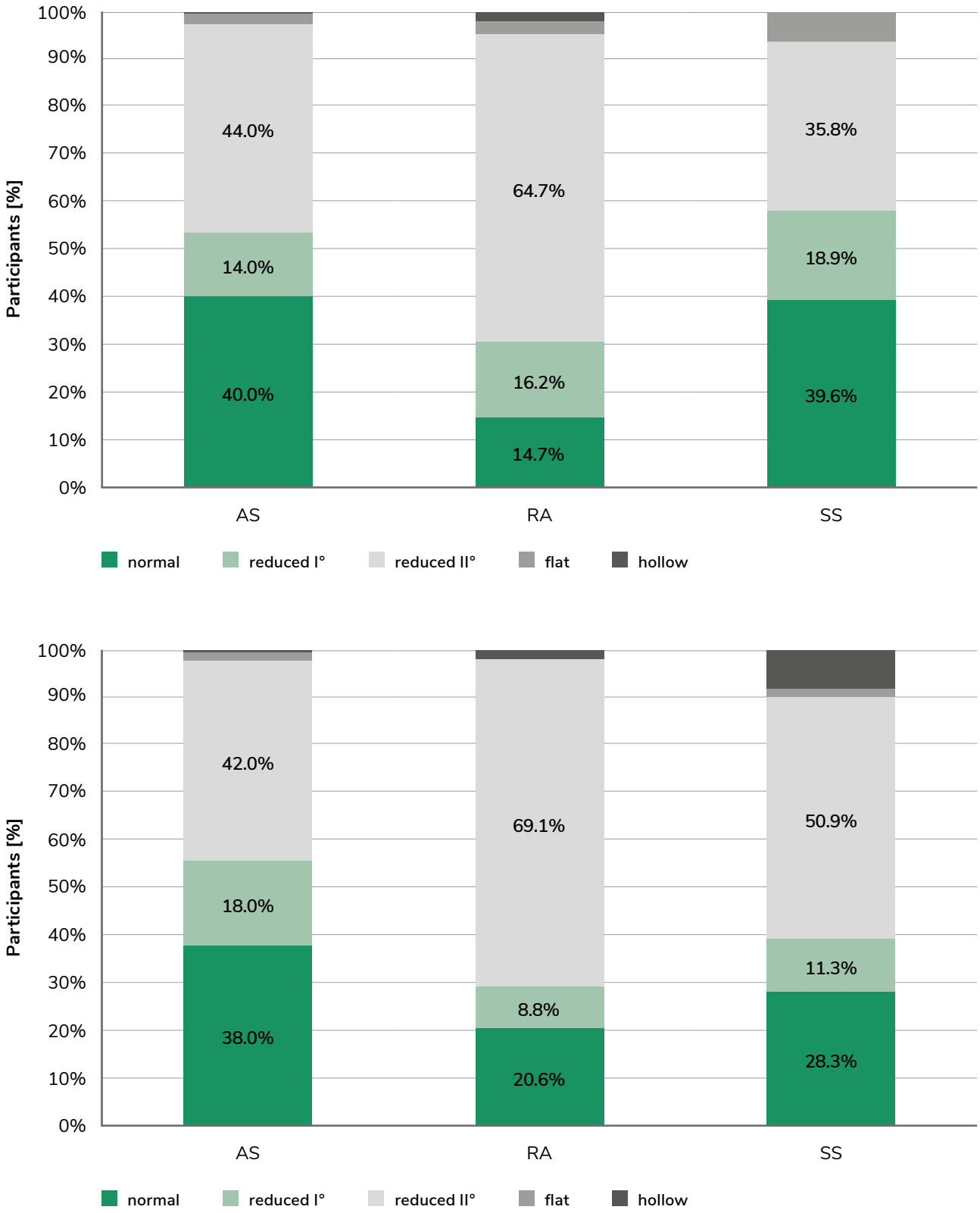

Figure 2. Distribution of the prevalence of right (top) and left (bottom) foot arch abnormalities in the study groups.
Abbreviations: AS – *ankylosing spondylitis*; RA – *rheumatoid arthritis*; SS – *systemic sclerosis*.

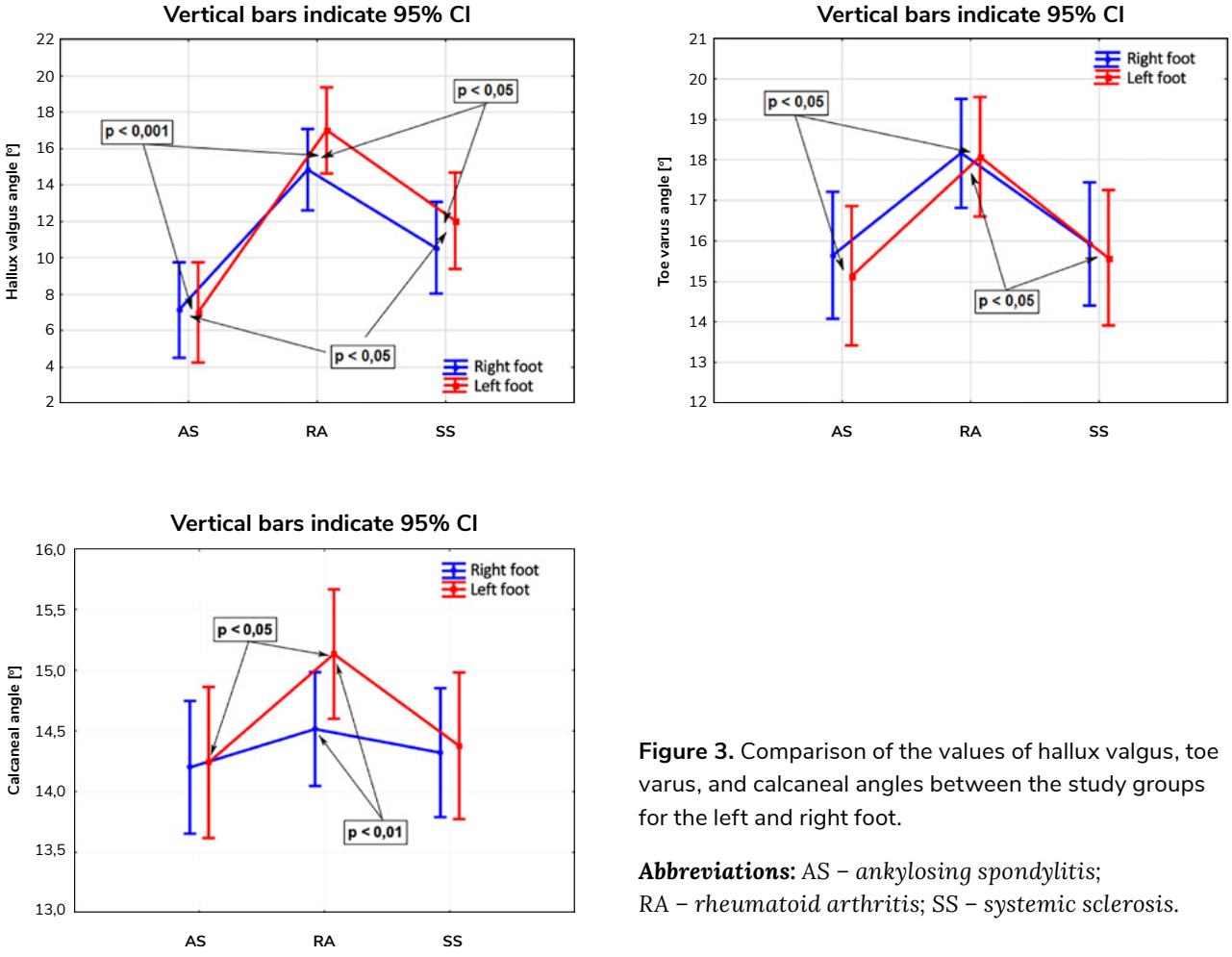

Figure 3. Comparison of the values of hallux valgus, toe varus, and calcaneal angles between the study groups for the left and right foot.

Abbreviations: AS – *ankylosing spondylitis*; RA – *rheumatoid arthritis*; SS – *systemic sclerosis.*

Table 2. Comparison of podometric examination results with analysis of the impact of the group and the tested side.

Parameters	AS		RA		SS		ANOVA		
	R	L	R	L	R	L	p_{group}	$p_{R\ vs.\ L}$	$p_{interaction}$
Angle of hallux valgus α [°]	7.1 ± 10.4	7.0 ± 9.2	14.8 ± 10.0	17.0 ± 10.9	10.5 ± 7.2	12.0 ± 8.8	< 0.001	0.07	0.34
Angle of varus toe β [°]	15.6 ± 3.9	15.1 ± 4.4	18.2 ± 6.9	18.1 ± 7.3	15.9 ± 5.1	15.6 ± 5.9	< 0.05	0.41	0.89
Calcaneal angle γ [°]	14.2 ± 1.9	14.2 ± 2.3	14.5 ± 2.2	15.1 ± 2.4	14.3 ± 1.6	14.4 ± 1.8	0.202	< 0.05	0.06
Wejsflog index	2.6 ± 0.1	2.6 ± 0.1	2.5 ± 0.1	2.5 ± 0.1	2.6 ± 0.1	2.6 ± 0.1	< 0.01	0.73	0.23
Sztriter-Godunow index (KY)	0.48 ± 0.07	0.50 ± 0.07	0.52 ± 0.11	0.52 ± 0.11	0.44 ± 0.11	0.46 ± 0.16	< 0.01	0.06	0.70
Chippaux-Smirak index (CSI)	0.34 ± 0.06	0.35 ± 0.07	0.39 ± 0.11	0.40 ± 0.12	0.38 ± 0.08	0.40 ± 0.11	< 0.05	< 0.05	0.29
Longitudinal foot arches depth index	25.4 ± 3.3	24.6 ± 4.0	23.7 ± 5.1	23.6 ± 5.5	24.9 ± 4.3	24.4 ± 6.4	0.227	0.18	0.65

Abbreviations: AS – *ankylosing spondylitis*; RA – *rheumatoid arthritis*; SS – *systemic sclerosis*; R – *right foot*; L – *left foot*;

Interaction between the group and the right and foot

The Sztriter-Godunow index showed that RA patients had statistically significantly higher mean values for this index than SS patients (for both feet). In contrast, no significant differences were shown between patients with RA and AS, or those with RA and SS. There were also no statistically significant differences between the two feet.

In the case of the Chippaux-Smirak index, it was shown that patients with AS had statistically significantly lower mean values of this index than patients with SS (for both feet). No significant differences were shown in this regard between patients with AS and RA and those with RA and SS. There were also no statistically significant differences between the two feet.

For the Wejsflog index, it was shown that patients with AS had statistically significantly higher mean values for this index than patients with RA. No significant differences were shown in this index between patients with AS and SS and those with RA and SS. It was also shown that for all groups, both for the left foot and the right foot, the values of this index were statistically significantly lower than the reference value of 3.0, indicating that the subjects had a significant degree of flatfoot, with the greatest degree of flatfoot in patients with AS and SS.

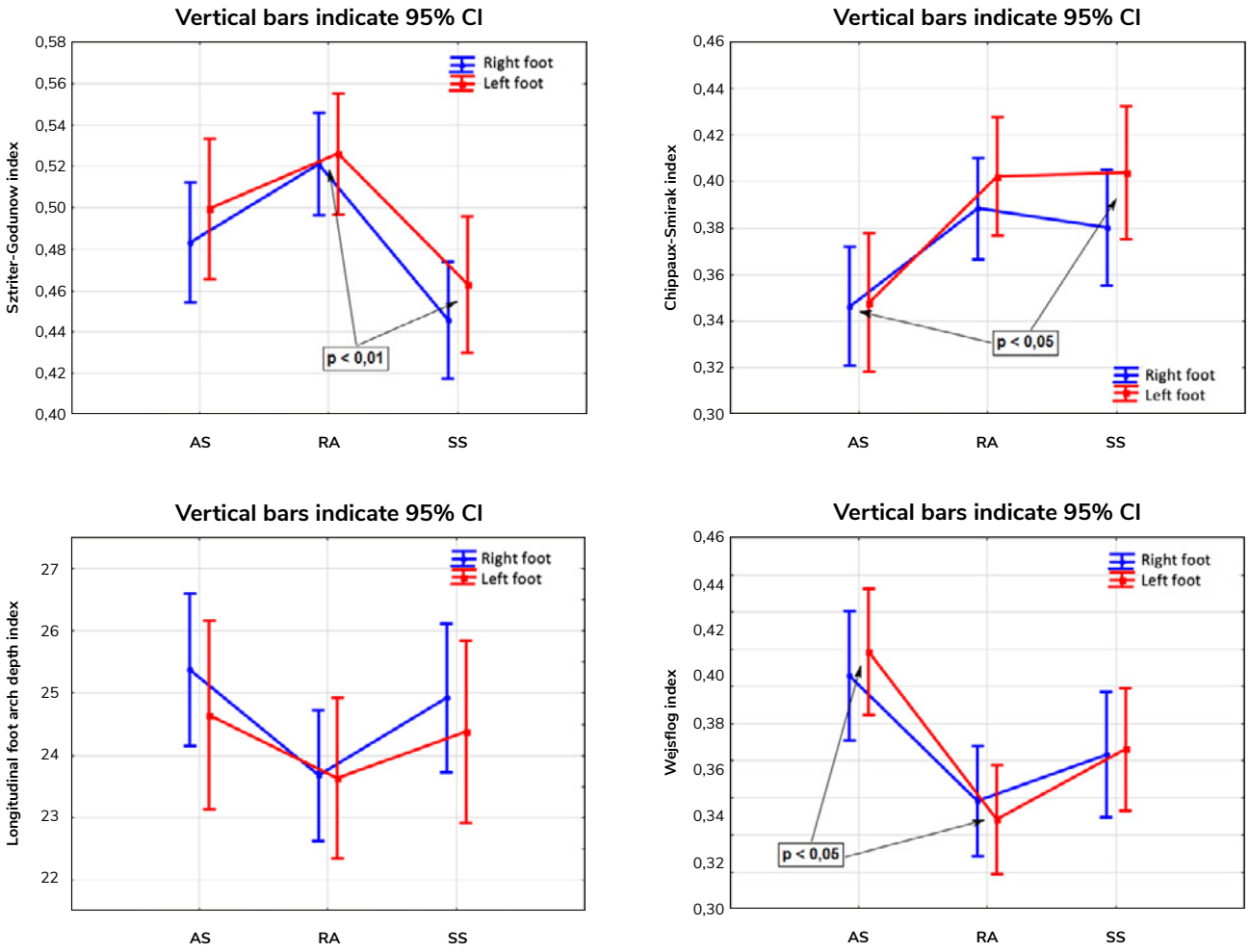

Figure 4. Comparison of the values of the Sztriter-Godunow index, Chippaux-Smirak index, Wejsflog index, and the depth of the longitudinal arch of the foot between the study groups for the left and right foot.

Abbreviations: AS – *ankylosing spondylitis*; RA – *rheumatoid arthritis*; SS – *systemic sclerosis*.

Discussion

Occurrence of flat feet

Functional foot problems affect about 10-24% of the population, and this prevalence increases in patients with RA. Williams et al. [10] report that most RA patients complain of a foot problem even before the disease is diagnosed. Measures to address the problems known as rheumatoid foot have been the subject of many studies. Foot deformities associated with RA reflect impaired static function of the foot and are considered the most common cause of disability. Within the first four years of diagnosis, as many as 75% of patients complain of nagging pain that prevents them from activities of daily living.

Flatfoot is one of the common pathologies in the adult population, as well as children. It consists of a complete or partial loss of the longitudinal arch of the foot that can cause both mild restrictions and severe disability, resulting in major functional limitations. The cause of flat feet among adults can be a congenital defect, trauma, or other musculoskeletal pathology. It is often a complex problem with different types of symptoms and degrees of deformity. The literature on the prevalence of flat feet is poor. Some authors estimate that flat feet occur among 5% of the general population [11].

Harris and Beath [12], studying Canadian army soldiers, showed the presence of flat feet in as many as 23% of the subjects. Our research shows that among people with rheumatic diseases, the longitudinal arch of the foot is lower in about 70% of the subjects. Based on physical examination, it can be concluded that one of the main reasons for flat feet is clubfoot [11]. This is confirmed by the results of our study, in which clubfoot was diagnosed in more than half of the subjects.

Another reason for flat feet is dysfunction of the tibialis posterior muscle tendon [13]. It is estimated that inflammation of the tendon sheath of the posterior tibialis muscle occurs in 13-64% of RA patients [14]. This tendon is the primary dynamic stabilizer of the longitudinal arch of the foot, and its contraction causes inversion of the foot and deepening of the longitudinal arch by locking the metatarsal bones. When the tibialis posterior muscle is impaired, the ligaments and joint capsules in the foot are weakened, resulting in a lowering of the longitudinal arch. In addition, with an injured posterior tibialis muscle, the work of the gastrocnemius muscle is affected, which plays an important role in walking and maintaining balance, and is impossible without it. Risk factors for dysfunction of this tendon include diseases known as seronegative spondyloarthropathies. According to Johnson and Strom [15], the first stage of tibialis anterior muscle dysfunction is caused by inflammation. All subjects showed low awareness of flat feet.

Examination using a podometer

According to a study Kaniewska et al. [10] conducted on 102 patients with RA, involving static assessment of the feet using a podoscope, a correlation was established between foot deformities and quality of life. The study showed that static foot abnormalities had a significant impact on all areas of quality of life.

Also, Sükran Güzel et al. [16] studied 110 patients with AS, finding flat feet in 32.7%, hollow feet in 42.7%, and normal foot arches in only 25.6% of the subjects. They found a high prevalence (74.5% of subjects) of foot deformities in AS patients, which significantly affected patients' pain, disability, and quality of life.

According to a study conducted at the Medical University of Bialystok (Poland), in which static foot assessments were performed among 54 RA patients (43 women and 11 men) and 43 control subjects (35 women and 9 men), it was shown that the most significant differences from the control group occurred in the α angle used to assess toe valgus. Patients with RA had significantly high-

er values of this angle than control subjects. The most remarkable abnormalities were observed in the female group, where as many as 80% had significantly higher values of this α angle than in the control group. In the men's group, on the other hand, the most significant differences were found in the Wejsflog index. Its highest values were shown in men on the right foot. In this study, the most significant variation in the Clarke angle, used to assess flatfoot, was shown in the group of men with RA in the right foot [14].

Longitudinal flatfoot for the right and left foot was noted in 51% and 44.2% of all subjects, respectively. Transverse flatfoot was diagnosed in both feet among all female subjects. In the group of women, hallux valgus toe was observed for the right and left foot in 67% and 51% of the subjects, respectively. The above study showed no significant relationship between Clarke's angle and the Sztriter-Godunow index [17].

The present study confirms the above observations. Indeed, RA patients were characterized by the highest α angle values for both feet and for the Sztriter-Godunow index, they had statistically significantly higher values of this index than SS patients (for both feet). In addition, it was shown that for the Wejsflog index, patients with AS had higher mean values of this index compared to patients with RA. It was also shown that for all groups, both for the left and right foot, the values of this index are lower than the reference value of 3.0, which indicates that the subjects have a significant degree of flat feet, with the changes being most advanced in patients with AS and SS. The above changes can cause serious consequences for the entire musculoskeletal system. A deformed foot can cause secondary deformities in the knee, hip, and spine joints, as well as an abnormal shift of the body's center of gravity, causing pain. Abnormal foot loading promotes the formation of corns and calluses, making it challenging to select and wear shoes. Deteriorating static-dynamic performance of the lower limbs and increasing pain make it difficult to walk and function in activities of daily living.

Conclusions

Based on the conducted observations, it can be concluded that the resulting pathological changes in rheumatic diseases within the foot lead to the formation of the valgus toe and lowering of the longitudinal and transverse arch of the foot, giving a clinical picture of flat feet. There is a need to assess patients with rheumatic diseases for functional disorders of the foot to implement early exercise prevention.

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