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PhD THESIS

MYOTONOMETRIC AND PLANTAR PRESSURE ASSESSMENT IN PATIENTS WITH ANKYLOSING SPONDYLITIS INCLUDED IN A PHYSICAL EXERCISE PROGRAM

- A B S T R A C T -

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Ankylosing spondylitis is an inflammatory condition with chronic evolution in the spine and sacroiliac joints which gradually become ankylosed. In reality, it combines various different severity implications. The disease is part of the family of chronic inflammatory rheumatism. Ankylosing spondylitis is the second most common cause of inflammatory arthritis. As the disease progresses, spinal mobility and physical function are impaired and may affect daily activities. Genetic and environmental factors (microtrauma) are known causes of disease susceptibility and progression.

The name comes from the Greek words “ankylos”, meaning stiffening of a joint, and “spondylo”, meaning vertebra.

In the last decade, ankylosing spondylitis has been labelled as a polygenic autoinflammatory disease. The exact aetiology of this disease is still unknown. Currently, certain factors are known that favour the inflammatory process and, therefore, the pathogenic mechanism:

- a genetic background: 80 to 90% of patients have the HLA B27 genotype.
- in 20 to 30% of cases, there is familial aggregation
- a disorder of the immune system similar to other autoimmune conditions.

In terms of aetiology and mechanism, ankylosing spondylitis (SpA) is the consequence of the combination of genetic triggers (HLA-B27, IL-23, ERAP-1) and environmental factors which also associate changes in the microbiota and bio-mechanical stress. These c-factors are responsible for the activation of numerous pro-inflammatory cytokines, such as TNFα, IL-17, IL-22 and IL-23, promoting inflammation and bone proliferation.

Depending on the main symptom, according to the Assessment of Spondyloarthritis International Society (ASAS) criteria, SpA is classified as axial (axSpA) with predominant involvement of the axial skeleton (sacroiliac joints and spine) and peripheral (pSpA), with peripheral or extra-articular symptoms, such as enthesitis, uveitis, psoriasis or inflammatory bowel disease. Ankylosing spondylitis, currently radiographic axSpA is the form of axSpA with structural damage already occurring in the sacroiliac joints and visible on radiographs, while non-radiographic axSpA is the term used to characterise patients without such injuries.

Although polymorphic, this pathology can be divided into:

1. axial damage: clinical symptoms related to damage to the axis of the body due to damage to the sacroiliac joints, damage to the ligaments and/or joints of the vertebrae, and damage to the joints of the ribcage.
2. peripheral joint damage: in the limbs (shoulders, elbows, hands, knees, hips, etc.). Inflammatory symptoms appear which, because they persist, can cause pain. In this situation, the inflammation of the synovial membrane will abnormally secrete fluid that accumulates in the joint. The inflammation can affect one or more joints.

3. enthesopathic damage: this means damage to the entheses which is the place of insertion between bone and tendons. This is where inflammation starts. Since enthesitis is very common, this differentiates the condition in terms of appearance from rheumatoid arthritis which begins with damage to the synovial membrane.

Pathophysiologically, the condition evolves in four stages: inflammatory stage; bone erosion stage; repair stage with excessive bone synthesis; ankylosis stage.

The condition can start at any age, but most often occurs in young adults between the ages of 20 and 30. There are also juvenile-onset forms that are more common in certain regions; in Maghreb countries, 30% of cases occur before the age of 15. Certain forms may appear late after the age of 50. Regarding the sex ratio, studies showed male predominance, with a male/female ratio of 2-3/1 for ankylosing spondylitis and 1/1 for non-radiological-axSpA.

The chronic evolution of ankylosing spondylitis is intermittent, with periods of remission. It lasts 10 to 20 years, with functional disability in severe cases. As a chronic disease, ankylosing spondylitis with major functional disability has a significant impact on many aspects of the quality of life of patients suffering from this disease. The patients' quality of life, autonomy and independence is significantly affected, the disease impacting negatively posture, lower limb joints, muscle strength and foot functions.

Pain and stiffness caused by the disease can affect the ability to work, social life and physical activity. This disease is a real health problem.

Management can be classified into nonpharmacological and pharmacological treatment. Treatment should be tailored according to the symptoms of the disease, the severity of the symptoms, the patient's clinical condition, and the patient's expectations and wishes.

There is no specific treatment for this disease, but the combined action of medication therapy, lifestyle, physical activity and physical therapy can improve the patient's condition.
Most patients with a clinical diagnosis benefit from several types of investigations regarding spinal and joint damage.

RESEARCH MOTIVATION

The motivation for choosing this doctoral topic lies in the need identified by the PhD Student to supplement the data known in the literature regarding the complex evaluation of patients, considering the myotonometry and plantar pressure investigations in patients with ankylosing spondylitis. The group of patients who were approached are included in medical rehabilitation programs.

The investigation considers and assesses plantar pressure values by applying the foot to a xerography system with the recording of plantar pressures for the metatarsal 1.5 and calcaneus.

In addition, the procedure of objective assessment of the elasticity of the paravertebral muscles with the help of the myotonometer was followed.
The parameters obtained following these measurements facilitate the performance of correlation tests between determined parameters, as well as the quantification of the relationship between the tone, elasticity and stiffness of the tested muscle groups, and of the posture of patients with ankylosing spondylitis.

PHYSICAL EXERCISE PROGRAM

The rehabilitation consisted in an 8-week physical exercise program. The first 2 weeks were performed in the Rehabilitation Department for 10 sessions (5 days per week for 2 weeks, 40 minutes per session) under the supervision of a trained physical therapist. Afterward, the patients continued with a home exercise program that was performed 5 days per week, 40 minutes per session.
The exercise program consisted of motion and flexibility exercises of the cervical, thoracic, and lumbar spine; stretching of the hamstring muscles, erector spine muscle, and shoulder muscles; control abdominal and diaphragm breathing exercises and chest expansion exercises. The mobility exercises were performed lying on the back with the knees bent as follows: raising the knees towards the shoulders; lowering the knees to one side allowing the trunk to rotate; and raising both arms towards the ceiling. Sitting on a gym ball with a neutral spine position, the patients were asked to turn their heads to look over the shoulder as far as they could and then to tuck their chin in to give themselves a double chin. Stretching exercises were done in a standing upright position and against the wall, as well as in the quadruped position (keeping the elbows straight, slowly arching the back as high as possible and then lengthening the neck keeping the nose parallel to the floor and hollow the back). The breathing exercises were performed in a standing position (with legs apart, grasping a stick with both hands and raising it above the head in inspiration; in exhalation, the hands come down in front) and seated on a chair (with a pulley in the hands, the hands extended in front: in inhalation, the hands go to the sides, in exhalation back to the initial position).

RESULTS

1. Assessment of plantar pressure and stabilometry in patients with ankylosing spondylitis included in rehabilitation programs

38 patients with definite radiographic ankylosing spondylitis according to the Assessment of Spondyloarthritis International Society 2009 criteria were recruited for the study from the Rehabilitation and Rheumatology Department of the University County Hospital Timisoara, Romania, by personal invitation (on one of the routine visits). Exclusion criteria consisted of medical conditions that impaired function more than the ankylosing spondylitis: orthopedic pathologies of the lower limbs, history of orthopedic surgery of the lower limbs, foot involvement of AS, current complaints of foot pain, psychiatric disorders (dementia or other disorders that affect rationality), neurological diseases (stroke, Parkinson’s disease, etc.), vestibular or visual disturbances, cardiopulmonary disorders that could affect participation in a physical exercise program. Patients treated with disease-modifying antirheumatic drugs had to be on a stable dosage for at least three months. Medication was not altered during the study period.

10 patients met the exclusion criteria. We enrolled in the study 28 patients. Baseline patients’ characteristics were collected: age, body mass index, duration of ankylosing spondylitis, specific disease functioning scores (Bath Ankylosing Spondylitis Disease Activity Index, Bath Ankylosing Spondylitis Functional Index), and medication.

The study was conducted between December 2023 and April 2024.

For the baseline assessment, the static pressure load distributions in the three testing conditions are presented in Table 1. When comparing the eyes open and eyes closed conditions, there were significant differences for all three sites of the right and left foot, with no differences in the total foot load of the right foot and left foot, respectively. For the right foot, we recorded increased MT1 load) and MT5 load, and decreased heel load for eyes closed testing. For the left foot increased MT1 load and MT5 load, and decreased heel load were noted for eyes closed condition. When comparing the eyes open and head retroflexed conditions, there were significant differences for all three sites of the right and left foot, with no differences in the total foot load of the right foot and left foot, respectively. For the right foot increased MT1 load and MT5 load, and decreased heel load were registered when testing with the head retroflexed. For the left foot increased MT1 load and MT5 load, and decreased heel load were reported for head retroflexed condition. When comparing the eyes closed and head retroflexed conditions, there were no significant differences for the right and left foot, and the three sites (MT1, MT5, and calcaneus), except for left MT5 (decreased load in head retroflexed condition.

Table 1. Static pressure load distribution in the testing conditions (baseline assessment).

Variables	Eyes open	Eyes closed	Head retroflexed
Right foot (%)	50.00 ± 3.00	50.00 ± 3.98	49.64 ± 5.59
Right MT1 (%)	18.43 ± 5.98	21.29 ± 5.85	21.21 ± 6.38
Right MT5 (%)	33.00 ± 5.93	35.79 ± 5.32	35.29 ± 5.22
Right heel (%)	48.36 ± 9.48	42.93 ± 9.03	43.64 ± 9.64
Left foot (%)	50.00 ± 3.00	50.00 ± 3.98	50.36 ± 5.59
Left MT1 (%)	18.79 ± 4.55	22.07 ± 5.70	21.79 ± 7.27
Left MT5 (%)	27.57 ± 4.26	30.43 ± 3.66	28.79 ± 3.98
Left heel (%)	53.64 ± 6.87	47.36 ± 7.09	49.50 ± 9.87

For the second assessment (after an 8-week physical exercise program), the static pressure load distributions in the three testing conditions are presented in Table 2. When comparing the eyes open and eyes closed conditions, as well as eyes closed and head retroflexed conditions, there were no significant differences for the right and left foot, and the three sites (MT1, MT5, and calcaneus). When comparing the eyes open and head retroflexed conditions, there were significant differences for right and left MT1 (increased load in head retroflexed condition) and right and left heel (lower load in head retroflexed condition).

Table 2. Static pressure load distribution in the testing conditions (assessment after physical exercise program)

Variables	Eyes open	Eyes closed	Head retroflexed
Right foot (%)	52.07 ± 14.47	53.00 ± 14.71	50.93 ± 7.06
Right MT1 (%)	21.50 ± 7.87	21.71 ± 6.50	23.79 ± 9.73
Right MT5 (%)	33.71 ± 8.49	33.57 ± 8.08	35.21 ± 6.99
Right heel (%)	44.64 ± 13.26	44.71 ± 10.98	40.93 ± 13.23
Left foot (%)	47.93 ± 14.47	47.00 ± 14.71	49.07 ± 7.06
Left MT1 (%)	20.64 ± 8.32	21.36 ± 8.63	23.00 ± 10.46
Left MT5 (%)	31.36 ± 12.05	31.64 ± 12.14	30.50 ± 7.42
Left heel (%)	49.00 ± 16.25	47.50 ± 15.98	46.36 ± 15.60

Table 3 includes the stabilometric data in the three testing conditions at the baseline assessment. When comparing the eyes open and eyes closed conditions, there were significant differences in CoP path length, 90% confidence ellipse area, and maximum CoP speed, with higher values when tested with eyes closed. When comparing the eyes open and head retroflexed conditions, there were significant differences in CoP path length (increased values for eyes open condition) and maximum CoP speed (higher speed for head retroflexed condition). When comparing the eyes closed and head retroflexed conditions, there were significant differences in CoP path length and 90% confidence ellipse area; the increased values were recorded when tested with eyes closed.

Table 3. Stabilometric data in the testing conditions (baseline assessment)

Stabilometric data	Eyes open	Eyes closed	Head retroflexed
CoP path length (mm)	523.3 ± 22.6	783.9 ± 12.8	338.5 ± 85.31
90% confidence ellipse area (mm^2)	121.6 ± 9.66	263.1 ± 31.9	177.9 ± 29.18
Maximum CoP speed (mm/s)	62.29 ± 19.71	95.57 ± 7.04	92.64 ± 33.71

Table 4 presents the stabilometric data in the three testing conditions after 8-week physical exercise program. When comparing the eyes open and eyes closed conditions, there were significant differences of CoP path length, 90% confidence ellipse area, and maximum CoP speed, with higher values when tested with eyes closed. When comparing the eyes open and head retroflexed conditions, there were significant differences of 90% confidence ellipse area and maximum CoP speed; higher values were registered when assessed with head retroflexed. There were no significant differences in the stabilometric data when comparing the eyes closed and head retroflexed conditions.

Table 4. Stabilometric data in the testing conditions (assessment after physical exercise program)

Stabilometric data	Eyes open	Eyes closed	Head retroflexed
CoP path length (mm)	264.8 ± 58.42	385.4 ± 95.43	295 ± 39.35
90% confidence ellipse area (mm^2)	115.9 ± 8.39	258.1 ± 13.97	161.6 ± 17.8
Maximum CoP speed (mm/s)	52.86 ± 18.03	88.43 ± 33.39	76.21 ± 25.84

We also compared the stabilometric data of the same testing condition at the two evaluations (baseline and after an 8-week physical exercise program). There were no significant differences between the first and second assessments, except for CoP path length (lower values after an 8-week exercise program, p=0.018) for the head retroflexed condition.

2. The relationship between myotonometry parameters and spinal mobility in ankylosing spondylitis patients included in a physical exercise program

41 patients with definite radiographic ankylosing spondylitis according to the Assessment of Spondyloarthritis International Society 2009 criteria were recruited for the study from the Rehabilitation and Rheumatology Department of the University County Hospital Timisoara, Romania, by personal invitation (on one of the routine visits). Exclusion criteria were: disk hernia, moderate or severe scoliosis, history of spinal surgery, history of vertebral fracture, psychiatric disorders (dementia or other disorders that affect rationality), neurological

diseases (stroke, Parkinson's disease, etc.), cardiopulmonary disorders that could affect participation in a physical exercise program, body mass index ≥ 35 kg/m2. Patients treated with disease-modifying antirheumatic drugs had to be on a stable dosage for at least three months. Medication was not altered during the study period.

5 patients met the exclusion criteria. We enrolled in the study 36 patients. 2 patients were lost to follow-up. 34 patients completed the physical exercise program and their data were analyzed.

The sample size was calculated using G*Power 3.1.9.7 (Heinrich-Heine-Universität, Düsseldorf, Germany), with a significance level of 0.05, 0.95 power, and an effect size of 0.8. 20 participants represent the minimum sample size.

Baseline patients' characteristics were collected: age, body mass index, duration of ankylosing spondylitis, specific disease functioning scores (Bath Ankylosing Spondylitis Disease Activity Index, Bath Ankylosing Spondylitis Functional Index), and medication.
The study was conducted between December 2023 and May 2024.

Table 1 includes the results of myotonometer assessment of the longissimus capitis muscle at baseline and after the 8-week physical exercise program. Statistically significant differences were recorded for frequency for both the right and left longissimus capitis muscle, with higher values after the physical exercise program.

Table 1. Myotonometer parameters of the longissimus capitis muscle before and after physical exercise program

Myoton parameters	**Right side**		**Left side**	
	Baseline	After 8-week physical exercise program	Baseline	After 8-week physical exercise program
Frequency (Hz), mean (SD)	17.34 (3.76)	18.24 (4.38)	17.94 (4.19)	19.25 (4.83)
Stiffness (N/m), mean (SD)	374.00 (88.69)	369.1 (97.69)	397.2 (129.8)	389.2 (136.2)
Decrement, mean (SD)	1.4 (0.25)	1.43 (0.28)	1.3 (0.16)	1.28 (0.16)
Relaxation (ms), mean (SD)	14.03 (2.89)	14.55 (3.56)	13.45 (2.55)	14.23 (4.17)
Creep, mean (SD)	0.83 (0.15)	0.89 (0.18)	0.84 (0.13)	0.87 (0.23)

Table 2 presents the results of myotonometer assessment of the lumbar erector spinae muscle at baseline and after the 8-week physical exercise program. We recorded statistically significant differences in stiffness and decrement for the right lumbar erector spinae muscle. The stiffness decreased, while the decrement increased after the exercise program. The relaxation time was significantly higher for both the right and left lumbar erector spinae muscle at the 8-week assessment.

Table 2. Myotonometer parameters of the lumbar erector spinae before and after the physical exercise program

Myoton parameters	Right side		Left side	
	Baseline	After 8-week physical exercise program	Baseline	After 8-week physical exercise program
Frequency (Hz), mean (SD)	14.18 (4.58)	13.88 (4.09)	14.14 (2.91)	14.39 (3.16)
Stiffness (N/m), mean (SD)	341.6 (21.6)	302.0 (88.5)	363.5 (128.9)	327.5 (133.3)
Decrement, mean (SD)	1.46 (0.46)	1.55 (0.48)	1.58 (0.43)	1.63 (0.49)
Relaxation (ms), mean (SD)	19.51 (6.85)	21.31 (7.26)	16.47 (5.57)	18.49 (6.33)
Creep, mean (SD)	1.21 (0.39)	1.28 (0.39)	1.04 (0.32)	1.12 (0.35)

After the physical exercise program, the cervical spine range of motion improved significantly for all the tested movements (flexion, extension, right and left rotation, right and left lateral flexion). All the assessed distances decreased after rehabilitation, proving an increased mobility of the cervical spine. Moreover, for the chin to sternum distance and left chin to acromion distance the values were significantly lower after the 8-week physical exercise program (Table 3).

Table 3. Cervical spine assessment before and after physical exercise program

	Baseline	**After 8-week physical exercise program**
Flexion (°), mean (SD)	28.2 (8.8)	30.8 (8.8)
Extension (°), mean (SD)	26.5 (12.9)	27.9 (13.2)
Right rotation (°), mean (SD)	36.1 (15)	38 (15.6)
Left rotation (°), mean (SD)	37.4 (12.7)	39.5 (12.5)
Right lateral flexion (°), mean (SD)	24.2 (11.5)	24.7 (11.7)
Left lateral flexion (°), mean (SD)	24.4 (12.4)	25 (12.4)
Chin to sternum distance (cm), mean (SD)	4.3 (3.4)	3.8 (3)
Right chin to acromiom distance (cm), mean (SD)	7.7 (6.4)	7.5 (6.4)
Left chin to acromiom distance (cm), mean (SD)	8.4 (7.3)	8.2 (7.2)
Right tragus to acromion distance, mean (SD)	8.4 (6.7)	8.2 (6.7)
Left tragus to acromion distance, mean (SD)	8.4 (6.6)	8.3 (6.6)

The lumbar spine range of motion improved after rehabilitation for all four tested movements (right and left rotation, right and left lateral flexion). Both the right and left rotations were significantly higher after the 8-week physical exercise program. The patients had better mobility after rehabilitation; the Schober had significantly increased values, while the finger-to-floor test decreased significantly (Table 4).

Table 4. Lumbar spine assessment before and after the physical exercise program

	Baseline	**After 8-week physical exercise program**
Right rotation (°), mean (SD)	27 (9.1)	28.2 (9.4)
Left rotation (°), mean (SD)	28.4 (10.1)	29.4 (10)
Right lateral flexion (°), mean (SD)	21 (6.2)	21.4 (6.3)
Left lateral flexion (°), mean (SD)	21.4 (6.3)	21.8 (7.9)
Schober test (cm), mean (SD)	2.8 (0.8)	3 (0.8)
Finger to floor test (cm), mean (SD)	13.7 (9.3)	12.3 (9.1)

Table 5 includes the correlations between the stiffness of the longissimus capitis muscle and cervical spinal mobility (rotation and lateral flexion) and distances (chin to acromion and tragus to acromion), and the correlations between stiffness of the lumbar erector spinae and lumbar spinal mobility (rotation and lateral flexion). The correlations were recorded for the muscle and the range of motion and distances on the same side. We recorded statistically significant negative correlations between right lumbar rotation and right lumbar lateral flexion at both baseline and 8-week assessments. With the decrease of right lumbar erector spinae stiffness, the range of motion of right lumbar rotation and right lumbar lateral flexion is higher. Although there were no other significant correlations, for most of the compared parameters indirect correlations were noted; the more the stiffness decreases, the better is the cervical and lumbar mobility.

Table 5. Correlation of spinal motion and distances with stiffness

Spinal motion/distances	**Baseline**		**After 8-week physical exercise program**	
	r	p	r	p
Right cervical rotation	-0.114	0.51	-0.271	0.12
Left cervical rotation	-0.048	0.78	-0.084	0.63
Right cervical lateral flexion	-0.149	0.39	-0.322	0.06
Left cervical lateral flexion	0.013	0.93	-0.025	0.88
Right chin to acromion distance	-0.145	0.41	0.138	0.43
Left chin to acromion distance	-0.198	0.26	-0.11	0.53
Right tragus to acromion distance	-0.192	0.27	0.105	0.55
Left tragus to acromion distance	-0.206	0.24	-0.123	0.48
Right lumbar rotation	-0.41	**0.015**	-0.362	**0.035**
Left lumbar rotation	-0.179	0.3	-0.009	0.95
Right lumbar lateral flexion	-0.41	**0.015**	-0.429	**0.011**
Left lumbar lateral flexion	-0.096	0.58	-0.255	0.14

GENERAL CONCLUSIONS AND ORIGINAL CONTRIBUTIONS

In the study “Evaluation of static plantar pressure and stabilometry in patients with ankylosing spondylitis included in a physical exercise program”, we included 28 participants, of whom 20 men (71.4%), and 8 women (28.6%), with an average age of 56.64 years, an average body mass index of 29.4, a batch BASFI score of 4.1, and a BASDAI score of 1.9. Patients took medication throughout the study, as follows: N SAISs - 12 (42.8%), SSZ - 6 (21.4%), biological - 4 (14.2%), SSZ + biological - 4 (14.2%), N SAIDs + MTX - 2 (7.1%), N SAIDs + SSZ + biological - 2 (7.1%).

Static pressure and stabilometry measurements were performed for each participant in the following situations: eyes open, eyes closed, and head retroflexed, at baseline and after completing the exercise program performed 5 days per week for 8 weeks.

Evaluation under different testing conditions of static plantar pressure and stabilometry in patients with ankylosing spondylitis showed notable differences. When we compare the result of testing with eyes open with the result of testing with eyes closed, and with eyes open and head in extension, significant differences were noted.

Differences were only seen after the 8-week exercise program when the eyes-open position was compared with the head-retroflexed position.

Lower values of stabilometric parameters were recorded after the exercise program, showing better stability.

In the study "The relationship between myotonometric parameters and spine mobility in patients with ankylosing spondylitis included in a physical exercise program", we assessed 34 patients, of whom 25 men (73.5%), and 9 women (26.5%), with an average age of 54.1 years, an average body mass index of 29.03, an average BASFI score of 4.31, and an average BASDAI score of 1.99. All patients in the took medication throughout the study, as follows: N SAIDs - 18, SSZ - 6, biological therapy - 4, SSZ + biological therapy - 4, N SAIDs + MTX - 2, N SAIDs + SSZ + biological therapy - 2.

In this study, we assessed the cervical spine with the help of the goniometer, measuring flexion, extension, right and left rotation, right and left lateral flexion, and we measured the menton-to-sternum, menton-to-acromion (right and left) and tragus-to-acromion distance with the measuring tape. The lumbar spine was assessed with the goniometer (right and left rotation, right and left lateral flexion), and the measuring tape (Schober test and index-to-ground).

Referring to the relationship between myotonometric parameters and spinal mobility in patients with ankylosing spondylitis who were included in an exercise program for 8 weeks, we noted significant differences for the frequency of the longissimus capitis muscles, for stiffness and right erector spinae tonus and for bilateral erector spinae relaxation.

The stiffness of both muscles was negatively correlated with most spinal mobility parameters (cervical spine: flexion, extension, right and left rotation, right and left lateral flexion, menton-to-sternum distance, menton-to-acromion distance, tragus-to-acromion distance, lumbar spine: right and left rotation, right and left lateral flexion, index-to-ground distance, Schober test).

Improvement of cervical and lumbar spine movements can be analysed in relation to mechanical muscle properties in patients with ankylosing spondylitis who followed an exercise program over a period of 8 weeks.

Most of the patients included in these two studies (96.8%) followed the exercise program. The program was designed to be easy to do at home without the need for expensive equipment.

The tools for assessing plantar pressure, stabilometry, myotonometry were easy to use, providing additional data related to postural balance and the properties of the paravertebral muscles.

The assessments were serial, and were repeated after completing the recovery program. We also emphasised the importance of the best possible postural balance in these patients.

We propose the inclusion of exercises to improve postural balance in the physical therapy programs of patients with ankylosing spondylitis.

We believe that the following exercises could contribute to achieving a better balance:

- Draw a line, with hands out to the sides, and follow the line back and forth;
- In a hip-width stance, with hands on the hips, raise the leg the knee in extension up front, hold for 5 seconds, then repeat with the other leg;
- Place the knee on the balance ball and lean on it with the arms; the head is in line with the spine; while exhaling, raise and straighten the right arm and the left leg at the same time, then return to the initial position; repeat the exercise with the left hand and right leg;
- With both feet on the balance ball, arms by the body, spine straight; while exhaling, raise one leg, and bend the knee at hip level; hold the position for 5 seconds, then lower the leg, and repeat the movement with the other leg;

With both feet on the balance ball, arms by the body, spine straight, do squats with hands up front.