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ORIGINAL ARTICLE

A Preliminary Study on the Correlation Between Spinopelvic Parameters and Balance in Ankylosing Spondylitis

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ABSTRACT

Objectives: This study aims to identify the relationship between balance and sagittal spinopelvic alignment (SSA) in ankylosing spondylitis (AS) and compare patients with or without lumbopelvic mismatch in terms of balance.

Patients and methods: We enrolled 41 patients (22 males, 19 females; mean age 41.3±8.9 years; range 21 to 57 years) into the study. SSA was evaluated measuring thoracic kyphosis, lumbar lordosis, sacral slope, pelvic tilt and pelvic incidence on lateral standing X-rays of the whole spine including the femoral heads. Patients were grouped according to presence of lumbopelvic mismatch (lumbar lordosis-pelvic incidence >10º). Clinical parameters including age, body mass index, pain (Visual Analog Scale), disease activity (Bath Ankylosing Spondylitis Disease Activity Index), and disease duration were recorded. Posture was evaluated measuring tragus-to-wall distance, modified Schober's test and chest expansion. A computerized pressure plate system (NeuroCom Balance Master®) was used for evaluating static and dynamic balance. Correlations between SSA parameters and balance were analyzed. Patients with or without lumbopelvic mismatch were compared in terms of balance.

Results: Patients took shorter steps, as thoracic kyphosis increased and sacral slope decreased (r= -0.391, p=0.012; r=0.344, p=0.028). Patients with lumbopelvic mismatch had significantly higher sway velocity on firm base with eyes closed and on foam base when the eyes open and closed . They also walked more slowly compared to patients without lumbopelvic mismatch (p>0.05).

Conclusion: Lumbopelvic mismatch impaired both static and dynamic balance, while increased thoracic kyphosis and decreased sacral slope impaired only the dynamic balance in patients with AS. Further studies with larger sample size and longer follow-ups need to be conducted to identify the mechanism of spinal deformities and balance disorders in patients with AS.

Keywords: Ankylosing spondylitis; balance; lumbopelvic mismatch; sagittal spinopelvic alignment.

Ankylosing spondylitis (AS) is a chronic inflammatory disease characterized by progressive inflammation of the vertebral joints.[1] Either inflammation of the vertebral joints, or antalgic posture may cause postural changes including flattened lumbar lordosis, increased thoracic kyphosis and hip flexion in patients with AS.[1-5] Khan[6] suggested that postural changes were associated with poor balance in patients with AS. It has also been reported that patients with AS had poorer balance than healthy controls.[3] It has been shown that dynamic balance was impaired as tragus-to-wall distance increased and lumbar spine mobility decreased.[7-10] However, the association between the sagittal spinopelvic alignment (SSA) and balance is still unclear.

Thoracic kyphosis, lumbar lordosis, sacral slope, pelvic tilt and pelvic incidence are the major components of the SSA. Radiological parameters that most highly correlate with pain and disability in spinal deformities are sagittal vertical axis, pelvic tilt, and the balance of pelvic incidence and lumbar lordosis. The difference between pelvic

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incidence and lumbar lordosis should be less than 10° for ideal spinopelvic alignment. Since pelvic incidence is set by adulthood, corrective surgeries should be planned on achieving the appropriate lumbar lordosis.[11]

It has been reported that patients with AS had lower pelvic incidence, lumbar lordosis, sacral slope and higher pelvic tilt and sagittal vertical axis when compared to healthy controls.[7,12] Sagittal vertical axis, lumbar lordosis and sacral slope were suggested as predictive factors for the clinical outcomes in AS.[12]

Improvement of the lumbar lordosis after corrective osteotomies was associated with better clinical outcomes.[13] Postoperative spinal alignment should be properly planned before the spinal deformity surgery.[14] Fall prevention is important, since falls increased the morbidity and mortality in patients with AS.[15,16] Risk factors for falls and impaired balance should be understood to prevent falls in patients with AS. Also, assessment of the association between sagittal spinopelvic parameters and balance may provide better surgical plans and outcomes. The balance impairment and risk factors for falls in patients with AS were previously reported.[15] However, to our knowledge, none of the previous studies focused on the association between the SSA and balance in patients with AS. Therefore, in this study, we aimed to identify the relationship between balance and SSA in AS and compare patients with or without lumbopelvic mismatch in terms of balance.

PATIENTS AND METHODS

We enrolled 41 patients with AS (22 males, 19 females; mean age 41.3±8.9 years; range 21 to 57 years), who visited the rheumatology outpatient clinic of Marmara University School of Medicine Department of Physical Medicine and Rehabilitation between January 2014 and December 2015. The institutional review board approval was obtained from the Ethics Committee of Marmara University School of Medicine (Approval date: 12/06/2013, project number: 09.2013.0316). Oral and written informed consents were obtained from all participants. This study was conducted in accordance with the principles of the Declaration of Helsinki. Patients were excluded if they met any of the following criteria: age >70 years, having severe ankylosis and range of motion limitation in lower extremity joints due to advanced AS, patients with orthopedic problems in the lower extremities due to other problems (osteoarthritis etc.), history of previous spinal and/or lower limb surgery, cardiovascular disorders, neuromuscular or systemic disease that may affect balance (multiple sclerosis, diabetes mellitus etc.), malignancy, psychiatric disorders, cognitive impairment, visual and auditory deficits, presence of vitamin D deficiency or osteoporosis.

It was calculated that 18 individuals for each group (lumbopelvic mismatch and lumbopelvic match) should be recruited to have 80% power with 5% type 1 error level to detect a minimum clinically significant difference of pelvic incidence, when the average expected value in the first group was 39.8, with a standard deviation of 10.8 and the average expected value in the second group was 48.6, with a standard deviation of 8.7 based on the previous research conducted by Lee et al.[17] evaluating sagittal spinopelvic parameters in AS patients.

Demographic and clinical parameters including age, body mass index, pain (Visual Analog Scale), disease activity (Bath Ankylosing Spondylitis Disease Activity Index), and disease duration were captured. Posture was evaluated using the core set of Assessment in Spondyloarthritis International Society, tragus-to-wall distance, modified Schober's test and chest expansion.[18] All patients had standing lateral spine X-rays (long-cassette) from a 72-inch distance including the femoral heads. SSA was evaluated measuring thoracic kyphosis, lumbar lordosis, sacral slope, pelvic tilt and pelvic incidence on lateral standing X-rays using Surgimap™, version 2.2.9.6 (Surgimap Spine Software, Nemaris Inc., New York, USA) (Figure 1).

Thoracic kyphosis:[19] The angle between the upper endplate of the T_4 vertebra and the lower endplate of the T_{12} vertebra.

Lumbar lordosis:[20,21] The angle between the upper endplate of the L1 vertebra and the lower endplate of the S1 vertebra.

Sacral slope:[22,23] The angle between the upper sacral endplate and the horizontal plane.

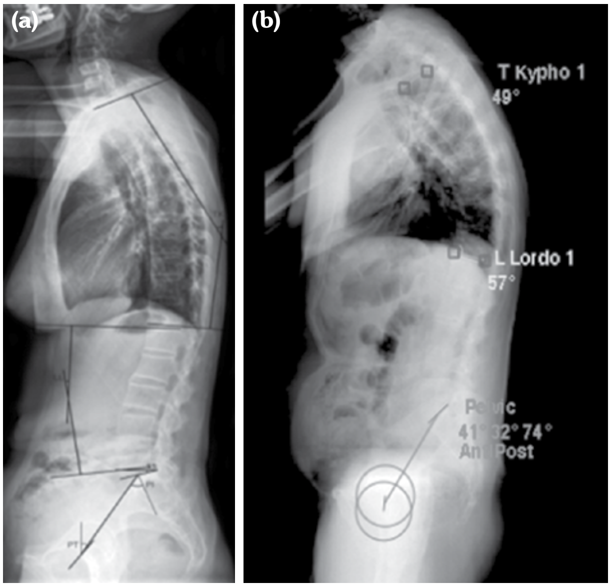

Figure 1. (a) Lateral radiographs illustrating sagittal plane spinopelvic profile parameters in patients with ankylosing spondylitis. **(b)** Illustrative diagrams of measurements of thoracic kyphosis, lumbar lordosis and pelvic parameters by Surgimap®.

Pelvic tilt:[22,23] The angle between the line joining the middle of the sacral endplate and hip axis and the vertical line.

Pelvic incidence:[24] The angle between a line perpendicular to the sacral endplate at its midpoint and a line joining the midpoint and the hip axis.[12,17]

Then lumbopelvic mismatch (lumbar lordosis-pelvic incidence) was calculated on the basis of target lumbar lordosis (=pelvic incidence±9°) as reported by Schwab et al.[14]

Table 1. Clinical parameters, postural parameters and sagittal spinopelvic alignment parameters in patients with ankylosing spondylitis

	Median	Min-Max
Age (year)	41	21-57
Body mass index (kg/m^2)	26.16	17.10-37.11
Disease duration (years)	5	1-31
Visual Analog Scale (0-10 cm)	5	0-10
Disease activity (BASDAI)	3.70	0-9
Tragus-to-wall distance (cm)	15	7-33.5
Modified Schober's test (cm)	20	10-24
Chest expansion (cm)	4	1.5- 8
T_4-T_{12} angle (°)	42	0-91
Lumbar lordosis (°)	49	0-78
Sacral slope (°)	32	0-46
Pelvic tilt (°)	17	0-43
Pelvic incidence (°)	48	0-87

BASDAI: Bath Ankylosing Spondylitis Disease Activity Index.

Balance was evaluated using weight bearing squat, modified clinical test of sensory interaction (standing on firm or foam bases), walk across, tandem walk, step and quick turn tests of Neurocom Balance Master System® (NeuroCom. International, Inc., Clackamas, Orlando, USA).

All patients were assessed in the afternoon to eliminate the effects of morning stiffness. In weight bearing squat test, we evaluated the difference in percentage of body weight on each foot while standing, and then with knees flexed at 30°, 60°, and 90°.

Table 2. Correlation of sagittal spinopelvic alignment with age, pain, disease activity and disease duration

	T_4-T_{12}	Lumbar lordosis	Sacral slope	Pelvic tilt	Pelvic incidence
Age					
r	0.147	-0.088	-0.169	0.377*	0.074
p	0.360	0.583	0.291	0.015	0.646
VAS					
r	-0.010	0.256	0.209	0.029	0.339*
p	0.951	0.106	0.190	0.857	0.030
Disease activity (BASDAI)					
r	-0.010	0.303	0.150	-0.068	0.264
p	0.951	0.057	0.357	0.675	0.100
Disease duration					
r	-0.004	-0.038	-0.066	0.294	0.149
p	0.979	0.813	0.683	0.062	0.353

VAS: Visual Analog Scale; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; * $p<0.05$.

Table 3. Correlation of sagittal spinopelvic alignment with balance in patients with ankylosing spondylitis

	T_4-T_{12}	LL	SS	PT	PI
T_4-T_{12}					
r	1	0.393*	-0.067	0.105	-0.038
p		0.011	0.678	0.513	0.814
LL					
r	0.393*	1	0.575**	-0.350*	0.201
p	0.011		0.000	0.025	0.207
SS					
r	-0.067	0.575**	1	-0.344*	0.479**
p	0.678	0.0001		0.028	0.002
PT					
r	0.105	-0.350*	-0.344*	1	0.537**
p	0.513	0.025	0.028		0.0001
PI					
r	-0.038	0.201	0.479**	0.537**	1
p	0.814	0.207	0.002	0.0001	
WBS 0					
r	0.283	0.125	-0.206	0.088	0.064
p	0.073	0.438	0.197	0.584	0.693
WBS 30					
r	0.064	0.155	0.130	-0.220	0.007
p	0.691	0.333	0.418	0.168	0.964
WBS 60					
r	0.118	0.067	0.239	-0.072	0.048
p	0.462	0.677	0.132	0.656	0.767
WBS 90					
r	0.274	0.049	0.162	-0.107	-0.084
p	0.083	0.760	0.311	0.507	0.600
mCSV EO					
r	0.059	-0.124	0.079	-0.006	-0.011
p	0.715	0.441	0.623	0.969	0.945
mCSV EC					
r	0.051	-0.116	0.125	-0.130	-0.076
p	0.752	0.469	0.438	0.418	0.638
mCSVf EO					
r	0.206	0.054	0.053	0.033	0.018
p	0.196	0.739	0.741	0.836	0.911
mCSVf EC					
r	0.080	-0.159	-0.171	0.220	-0.052
p	0.619	0.320	0.284	0.168	0.747
WA step width					
r	-0.391*	-0.076	0.265	-0.227	0.014
p	0.012	0.638	0.094	0.153	0.929
WA step length					
r	-0.146	0.023	0.344*	-0.147	0.161
p	0.363	0.887	0.028	0.359	0.315
WA speed					
r	-0.159	0.127	0.055	-0.158	-0.040
p	0.321	0.430	0.734	0.324	0.805
WA step length symmetry	-0.026	-0.246	0.125	0.263	0.209
r	0.870	0.122	0.436	0.096	0.189
p					
TW step width					
r	-0.154	-0.046	0.111	0.104	0.179
p	0.337	0.773	0.489	0.519	0.263
TW speed					
r	-0.032	0.101	0.195	-0.052	0.124
p	0.842	0.528	0.223	0.748	0.440

Table 3. Continued

	T_4-T_{12}	LL	SS	PT	PI
TW end sway					
r	0.174	0.011	0.026	0.127	0.105
p	0.276	0.946	0.870	0.428	0.514
SQT turn time left					
r	0.125	0.276	0.266	-0.094	0.220
p	0.436	0.081	0.093	0.560	0.167
SQT turn time right					
r	0.152	0.069	0.090	0.057	0.116
p	0.343	0.666	0.578	0.723	0.471
SQT turn sway left					
r	0.179	0.191	0.245	0.134	0.350*
p	0.263	0.231	0.123	0.404	0.025
SQT turn sway right					
r	0.283	0.125	-0.206	0.088	0.064
p	0.073	0.438	0.197	0.584	0.693
SQT turn time					
r	0.064	0.155	0.130	-0.220	0.007
p	0.691	0.333	0.418	0.168	0.964
SQT turn sway					
r	0.118	0.067	0.239	0.072	0.048
p	0.462	0.677	0.132	0.656	0.767

T_4-T_{12}: Thoracic kyphosis; LL: Lumbar lordosis; SS: Sacral slope; PT: Pelvic tilt; PI: Pelvic incidence; WBS 0, 30, 60, 90: Weight bearing squat test with knees flexed at 0°, 30°, 60°, 90°; mCSV EO: Modified sway velocity of firm base- eyes open; mCSV EC: Modified sway velocity of firm base- eyes closed; mCSVf EO: Modified sway velocity of foam base-eyes open; mCSVf EC: Modified sway velocity of foam base- eyes closed; WA: Walk across test; TW: Tandem walk test; SQT: Step and quick turn test; * $p<0.05$; ** $p<0.01$.

The modified clinical test of sensory interaction on balance had two parts. In the first part, the patient was requested to stand on a firm base with eyes open. Then, patient stood on a firm base with eyes closed. This test was also repeated on a foam base. Each part was performed three times. Then, we calculated the means of sway velocity of firm or foam bases when the eyes open and closed.

In walk across test, patient was asked to walk as usual for three times. Then, the mean values of step width, step length, step length symmetry and speed were calculated.

The tandem walk test was also repeated for three times. Then, the mean values of step width, speed and end sway were calculated.

The step and quick turn test was also repeated for three times for each side. In this test, patient was asked to step forward and turn 180° back without taking the step off. The mean values of turning time and sway were calculated.

Statistical analysis

G*Power version 3.1.9.2 (Heinrich Heine University, Dusseldorf, Germany) was used for sample size estimation. Data were analyzed using IBM-SPSS for Windows version 22.0 (IBM Corp., Armonk, NY, USA). The histogram and normality plots and Shapiro-Wilk normality test were used for data distribution analysis. Analysis of the main characteristics of patients was performed using descriptive studies. Data were expressed by mean ± standard deviation. The two groups (patients with or without lumbopelvic mismatch) were compared using Mann-Whitney U test and data were expressed as median (minimum-maximum). Spearman's rank was used for analyzing the association of SSA with balance. A *p* value of <0.05 was considered statistically significant.

RESULTS

Demographic, clinical, postural parameters and SSA parameters in patients with AS were presented in Table 1.

Patients with AS moderately increased their pelvic tilt, as they got older (r=0.377, p=0.015). They felt more pain, as they had higher pelvic incidence (r=0.339, p=0.03) (Table 2).

Table 4. Clinical parameters and balance in patients with or without lumbopelvic mismatch

	Patients with lumbopelvic mismatch (n=26)	Patients without lumbopelvic mismatch (n=15)	
	Mean±SD	Mean±SD	*p*
Age (year)	40.4±9.3	43±8.2	0.360
Disease duration (years)	7.8±6.3	8.7±8.7	0.940
Bath Ankylosing Spondylitis Disease Activity Index	3.4±2.4	4.2±2.4	0.360
Weight bearing squat at 0° (%)	9.8±7.6	7.6±5.9	0.390
Weight bearing squat at 30° (%)	9.2±7.6	7.2±5.3	0.620
Weight bearing squat at 60° (%)	8.2±7.3	9.6±7.5	0.600
Weight bearing squat at 90° (%)	7.5±6.8	6.4±6.1	0.600
Sway velocity on firm base-eyes open (degrees/second)	0.3±0.2	0.2±0.3	0.100
Sway velocity on firm base-eyes closed (degrees/second)	0.3±0.3	0.2±0.2	**0.030***
Sway velocity on foam base-eyes open (degrees/second)	0.8±0.3	0.5±0.3	**0.009***
Sway velocity on foam base-eyes closed (degrees/second)	1.5±0.6	1.1±0.4	**0.011***
Walk across-step width (cm)	16.1±5.4	17.8±2.1	0.620
Walk across-step length (cm)	49.7±9.8	49.5±7.3	0.870
Walk across-speed (cm/second)	58.1±11.7	65.2±14.8	**0.040***
Walk across-step length symmetry (%)	17.0±13.7	17.2±14.2	0.760
Tandem walk-step width (cm)	7.1±1.7	6.4±0.9	0.090
Tandem walk-speed (cm/second)	23.7±6.9	22.1±3.5	0.590
Tandem walk-end sway (degrees/second)	4.7±2.5	4.4±1.4	0.980
Step and quick turn-time (second)	2.3±3.1	1.4±0.5	0.450
Step and quick turn-sway (°)	32.2±14.1	25.1±7.7	0.140

SD: Standard deviation; * p<0.05.

As thoracic kyphosis increased and sacral slope decreased (in other words, as the spine became C-shaped on lateral X-rays), patients took moderately shorter steps (r=-0.391, p=0.012; r=0.344, p=0.028). Among sagittal alignment parameters, the most significant correlations were detected between the lumbar lordosis and sacral slope, as expected (r=0.570, p<0.001). Pelvic tilt increased, as patients with AS had higher pelvic incidence (r=0.537, p<0.001) (Table 3). Patients with lumbopelvic mismatch (males=13, females=13) had significantly higher sway velocity while standing with eyes closed on firm base and with eyes open and closed on foam base. They also walked more slowly compared to patients without lumbopelvic mismatch (Table 4).

DISCUSSION

In this study, we aimed to identify whether SSA was associated with balance in patients with AS. We also aimed to analyze the association of lumbopelvic mismatch with balance in patients with AS.

Our study showed that patients with AS increased their pelvic tilt by retroverting their pelvis, as they got older. Shin et al.[12] also reported a positive correlation between age and pelvic tilt in patients with AS. Consistent with the literature, patients with higher pelvic incidence were found to feel more pain.[17] Since they felt more pain as they had higher pelvic incidence, they might have retroverted their pelvis as a compensatory mechanism.

Postural changes in AS such kyphosis occur due to prolonged progressive stiffening of the spine and thorax. As AS advances and causes thoracolumbar kyphosis, forward head posture increases with decreased level of horizontal gaze, while sagittal balance declines. We also found that patients walked with slightly shorter steps, as thoracic kyphosis advanced. It has also been reported that advanced kyphosis impaired dynamic balance in patients with AS.[7,8,10,25] Our study showed that patients with AS walked with shorter steps, as the sacral slope decreased. It has been demonstrated that sacral slope is the most important indicator of sagittal balance.[26] It has also been reported that sacral slope was related with kyphosis in Chinese patients with AS.[27] We suggest that patients with AS walked in shorter steps, as their spine became C-shaped.

The orientation and harmonization of the lumbosacral pelvic junction play a key role in SSA of the spine. Lumbopelvic mismatch is an important measure for SSA and it is strongly associated with postoperative pain and disability.[11] Measurement of SSA is neglected in daily practice although surgical treatment of spinal deformities in AS increased in recent years.

Neither disease activity nor disease duration was associated with the SSA parameters. Our patients had relatively shorter disease duration and lower disease activity compared to the literature. In this study, we would like to point the possibility of balance disorders even in early terms of AS. To our knowledge, no previous study investigated the associations between disease activity, disease duration and SSA parameters in patients AS. Neither pain nor disease activity was significantly correlated with balance and posture in AS, previously.[3,7,8] In order to clarify the association between the disease duration and SSA parameters, further studies with larger sample size and longer duration of disease should be conducted. Moreover, the association of lumbopelvic mismatch with balance in patients with AS has not been reported yet.

In our study, patients with lumbopelvic mismatch had poorer balance while standing on firm or foam bases. It has been reported that patients with AS had proprioceptive deficits when compared to healthy subjects.[3,8] However, to our knowledge, no previous study compared patients with or without lumbopelvic mismatch. In the present study, patients with lumbo-pelvic mismatch walked more slowly. In our previous study, we observed that patients with AS had worse dynamic balance while walking compared to healthy subjects. Patients with AS widened their steps and walked more slowly to compensate their poor dynamic balance.[8]

Sagittal spinopelvic alignment parameters were associated with pain, and balance. Lumbopelvic mismatch impaired both static and dynamic balance. We suggest a comprehensive evaluation of the spine, pelvis, and femoral shaft to avoid balance disorders in patients with AS.

Our study has some limitations. First, we did not have a control group of healthy volunteers, since it would have been unethical to take X-rays of people when there was no health benefit for them. Second, we did not include interactions with hip, knee and ankle and sacroiliac joints, which are important in AS. However, we excluded patients with severe ankylosis and range of motion limitation in lower extremity to eliminate these effects.

In conclusion, lumbopelvic mismatch impaired both static and dynamic balance, while increased thoracic kyphosis and decreased sacral slope impaired only the dynamic balance in patients with AS. To the best of our knowledge, this is the first study to identify the association of SSA with balance in patients with AS. Further prospective studies with larger sample size and longer disease duration need to be performed to understand the mechanism of the SSA and balance in patients with AS.

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