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Effects of a 12-week Baduanjin regimen on biomechanical properties of axial muscle fascia in ankylosing spondylitis

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Abstract

Background: This study aims to evaluate the effects of a 12-week Baduanjin regimen on the biomechanical properties of axial muscle fascia in patients with ankylosing spondylitis (AS) through a randomized controlled trial, and to explore the underlying mechanisms of Baduanjin in AS treatment.

Methods: Thirty patients with AS were randomly assigned to either the Baduanjin intervention group or the nonintervention group, with 15 patients in each group. The intervention group underwent a 12-week Baduanjin fitness program, while the nonintervention group continued their usual lifestyle and medication. Biomechanical parameters of muscle fascia, including muscle stiffness (N/m), muscle tension (frequency, Hz), and muscle elasticity (logarithmic decrement of oscillation amplitude), were measured at specified spinal locations using the MyotonPRO® soft tissue tester at baseline (week 0) and after 12 weeks (week 12).

Results: The Baduanjin group exhibited significant improvements in muscle fascia stiffness, tension, and elasticity in the lumbar and cervical spine compared to the nonintervention group, with notable differences in lumbar stiffness and tension ($P < .05$). Postintervention, lumbar stiffness and tension were significantly reduced, and elasticity increased in the Baduanjin group, indicating beneficial effects on the biomechanical properties of axial muscle fascia in AS patients. No significant changes were observed in the nonintervention group. The Baduanjin group reported only mild muscle pain initially, which resolved with appropriate management, with no serious adverse effects noted.

Conclusion: The findings suggest that Baduanjin significantly enhances the biomechanical properties of axial muscle fascia in AS patients. By improving these properties, Baduanjin may reduce mechanical stress, alleviate micro-damage and inflammation at attachment points, regulate downstream signaling pathways, and potentially limit new bone formation. This study provides scientific support for the use of Baduanjin in managing AS and offers a foundation for future research.

Abbreviation: AS = ankylosing spondylitis, NSAIDs = nonsteroidal anti-inflammatory drugs, TCM = traditional Chinese medicine.

Keywords: ankylosing spondylitis, axial muscle fascia, Baduanjin, biomechanical properties, MyotonPRO tester, randomized controlled trial

1. Introduction

Ankylosing spondylitis (AS) is a chronic inflammatory disease primarily affecting the spine and sacroiliac joints, leading to spinal stiffness and functional impairment.[1–5] The pathogenesis of AS is complex, involving both genetic factors and environmental triggers, characterized by bone hyperplasia and joint ankylosis, with the main lesions located in the spine, sacroiliac joints, and large joints of the limbs.[6,7] This disease significantly impacts patients' quality of life, often presenting with morning stiffness, fatigue, and chronic pain. Traditional Chinese medicine (TCM) attributes AS to the invasion of "wind, cold, and dampness" evils, leading to poor circulation of qi and blood, and thus, treatments often focus on promoting blood circulation, removing blood stasis, and relieving pain.[8–10] Baduanjin, a traditional TCM fitness practice, is highly regarded for its simplicity and effectiveness.[11,12] Through gentle body movements and breathing regulation, Baduanjin can achieve the effects of unblocking meridians, harmonizing qi and blood, and strengthening the body.[13]

In recent years, as understanding of traditional TCM fitness practices has deepened, more research has focused on the application of Baduanjin in various chronic diseases. Previous studies have shown that Baduanjin can improve cardiopulmonary

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function, enhance immunity, and alleviate stress and anxiety in middle-aged and elderly people.[14–16] However, research on the application of Baduanjin in AS patients remains limited, especially regarding its effects on the biomechanical properties of axial muscle fascia. AS patients often exhibit biomechanical abnormalities in axial muscle fascia, such as increased muscle stiffness and decreased elasticity.[17,18] These abnormalities not only exacerbate patients' pain and functional impairment but may also, through the transmission of mechanical stress, induce and aggravate spinal lesions. Therefore, improving the biomechanical properties of axial muscle fascia in AS patients has become an important therapeutic goal.[18,19,20] Based on this background, this study aims to explore the effects of Baduanjin on the biomechanical properties of axial muscle fascia in AS patients through a randomized controlled trial and preliminarily investigate its mechanism of action. The hypothesis of the study is that practicing Baduanjin can restore the normal biomechanical properties of axial muscle fascia, thereby alleviating AS symptoms and improving patients' quality of life.

Baduanjin is a comprehensive fitness system consisting of 8 independent movements, each with its specific effects.[13] For example, "Holding the Sky with Two Hands to Regulate the Triple Burner" stretches and relaxes the upper limbs and spine, helping to relieve muscle tension in the upper limbs and back; "Drawing the Bow to Shoot the Eagle" simulates archery movements to enhance the strength and flexibility of the shoulders and back; "Separating Heaven and Earth" involves twisting and stretching the waist to regulate internal organ functions. These movements, through stretching and twisting various parts of the body, can effectively improve the biomechanical properties of muscles and fascia. The biomechanical properties of axial muscle fascia are closely related to mechanical transmission: the higher the tension, the greater the stiffness, the poorer the elasticity, and the smaller the mechanical transmission attenuation. If the stiffness of the axial muscle fascia increases and elasticity decreases, the stress transmitted to the spine is reduced, making it easier for the forces generated during daily activities such as walking and jumping to be transmitted along the axial muscle fascia. This increases mechanical pressure at the spinal attachment points. In AS, the increased pressure load is more likely to cause micro-damage, which, once exceeding a threshold, activates downstream signaling pathways, inducing enthesitis; if the pressure load persists, continuous micro-damage triggers pathological repair processes, eventually leading to new bone formation, a characteristic AS change.

Moreover, muscles have optimal biomechanical properties in terms of length, stiffness, and elasticity.[21] If muscles remain at inappropriate lengths, stiffness, and tension for prolonged periods, small blood vessels within the muscles become compressed, leading to inadequate oxygen supply. This forces muscles into anaerobic metabolism, accumulating metabolic byproducts that trigger inflammation, marking the first step in the inflammatory cascade of AS. Additionally, these metabolic byproducts, such as lactic acid, can further induce inflammation and degeneration of muscle fascia, potentially causing increased muscle fascia tension, exacerbating biomechanical changes, and creating a vicious cycle.

2. Materials and methods

2.1. Study design

This study was approved by the Ethics Committee of Nanjing University of Chinese Medicine. Thirty eligible AS patients were divided into a Baduanjin intervention group and a control group. After baseline measurements, participants were informed of their group allocation by phone. Although the nature of the intervention prevented double-blinding, outcome assessors and statisticians remained blinded.

Patients in the intervention group participated in a structured 12-week Baduanjin program, while those in the control group maintained their usual lifestyle without any changes to their medication. Biomechanical measurements of the muscle fascia were taken at baseline (0 weeks) and post-intervention (12 weeks) using the MyotonPRO device. The study followed the ethical principles of the Declaration of Helsinki, and all participants provided written informed consent.

2.2. Sample size determination

Sample size calculation was based on previously reported effects of physical interventions on muscle biomechanics in AS patients. Assuming an effect size of 0.8, a significance level of 0.05, and a power of 80%, the minimum sample size required for each group was determined to be 15 participants.

2.2.1. Inclusion and exclusion criteria. Inclusion criteria: (1) patients diagnosed with AS. (2) Aged 18 to 60 years. (3) No recent treatment (within the last month) with biologics, antirheumatic drugs, or nonsteroidal anti-inflammatory drugs (NSAIDs). (4) BASDAI score ≥ 4. (5) Not participating in any exercise programs (e.g., yoga, tai chi, or regular swimming) at the time of screening. (6) High compliance, with signed written informed consent.

Exclusion criteria: (1) unable to complete the entire Baduanjin program due to severe activity limitations, as assessed by the researcher. (2) Unsuitable for Baduanjin practice due to conditions like vertebral compression fractures, severe lumbar disc herniation, or severe cardiopulmonary diseases, as assessed by the researcher. (3) Incapable of providing informed consent due to mental or behavioral disorders. (4) History of or suspected alcohol or drug abuse. (5) Presence of other diseases that may reduce the likelihood of enrollment or complicate participation.

Participants were recruited by rheumatologists at Jiangsu Provincial Hospital of Traditional Chinese Medicine. Recruitment information was disseminated through internet media, social media, and QQ/WeChat groups. Potential participants who contacted the recruiters underwent screening to determine eligibility for the clinical trial. Eligible participants were enrolled in the study.

2.3. Intervention

2.3.1. Baduanjin intervention group. Patients in the Baduanjin intervention group underwent a 12-week, two-phase Baduanjin fitness program. The full Baduanjin exercise set in this study includes 10 movements. In the first phase, patients attended classes twice a week for 4 weeks. Instructors provided detailed explanations of Baduanjin movements and guided the exercises. Adjustments to the movements were allowed based on individual physical conditions. Research assistants closely monitored participants during Baduanjin practice to ensure proper and safe execution. Participants received a Baduanjin video tutorial and were encouraged to practice at home. At the end of the 4-week phase, a Baduanjin proficiency test was conducted. Patients unable to complete the test were excluded from the study.

In the second phase, participants practiced Baduanjin at home at least 3 times a week for 8 weeks, using the video tutorial. Two researchers randomly contacted participants by phone to encourage and supervise.

During the 12-week Baduanjin fitness program, participants were required to maintain their current lifestyle. Changes in AS treatment regimens were not allowed; for patients not using NSAIDs before enrollment or using NSAIDs as needed, temporary use of NSAIDs was permitted, with a maximum of 2 days per week and doses not exceeding the long-term anti-inflammatory dose specified in the instructions (e.g., celecoxib 400 mg/day, etoricoxib 60 mg/day, diclofenac 150 mg/day, meloxicam 15 mg/day). Changes in medication for other diseases were allowed. Participation in other exercise programs such as yoga, tai chi, and gymnastics was not permitted. General activities such as occasional walking, jumping, stretching, or swimming were not prohibited. All adverse events were recorded and reported to the researchers.

2.3.2. Nonintervention group. Participants in the nonintervention group were asked to maintain their current lifestyle for 12 weeks. Changes in AS treatment regimens were not allowed; for patients not using NSAIDs before enrollment or using NSAIDs as needed, temporary use of NSAIDs was permitted, with a maximum of 2 days per week and doses not exceeding the long-term anti-inflammatory dose specified in the instructions (e.g., celecoxib 400 mg/day, etoricoxib 60 mg/day, diclofenac 150 mg/day, meloxicam 15 mg/day). Changes in medication for other diseases were allowed. Participation in other exercise programs such as yoga, tai chi, and gymnastics was not permitted. General activities such as occasional walking, jumping, stretching, or swimming were not prohibited. All adverse events were recorded and reported to the researchers.

2.4. Evaluation indicators

The primary outcome was muscle stiffness (S, N/m).

Secondary outcomes included muscle tension (F, frequency, Hz) and muscle elasticity (D, logarithmic decrement of oscillation amplitude).

All outcome measurements were obtained at baseline (0 weeks) and at the end of the treatment period (12 weeks) in a resting state. Differences between baseline and posttreatment values (Δ) were compared between groups.

Measurements were also taken before the Baduanjin test at week 4 (resting state) and 30 minutes after the training (postexercise state). Differences between postexercise and resting states (Δ) were compared between groups.

2.5. Measurement method

During MyotonPRO measurements, participants lay prone on an examination bed with arms naturally placed at their sides, fully exposing the neck, back, and lumbar regions. Participants were asked to hold their breath for 5 seconds after exhalation to minimize abdominal influence on the test. The MyotonPRO probe was first pressed to the required depth (indicated by a green light), and then a pulse was applied to the muscle. During the trial, the coefficient of variation for each trial result was observed. If coefficient of variation exceeded 3%, the trial was repeated.

Measurement sites included the lumbar and cervical spine. The lumbar spine was measured at 2.5 cm lateral to the L4 to 5 interspace (midpoint of the iliac crest line), averaging data from both sides. The cervical spine was measured at 2.5 cm lateral to the C7 vertebra, averaging data from both sides.

2.6. Statistical analysis

Statistical analysis was performed using SPSS version 22.0.0 (IBM Corporation, Armonk, NY). Means and standard deviations were calculated for all dependent variables. The Kolmogorov–Smirnov test was used to check the normality of quantitative data. Independent *t* tests were used if the data were normally distributed; otherwise, the Mann–Whitney *U* test was used to evaluate differences between groups at baseline and posttreatment. For ordinal data, the Mann–Whitney *U* test was used to test differences between groups. Chi-square tests were used for categorical variables and count data. A *P* value < .05 was considered statistically significant.

3. Results

As shown in Figure 1, out of the 42 subjects screened, 30 were selected and randomly assigned to the Baduanjin intervention group and the nonintervention group (n = 15 per group). All patients completed the study and were included in the final statistical analysis.

At baseline, there were no statistically significant differences between the 2 groups in demographic characteristics, BASDAI

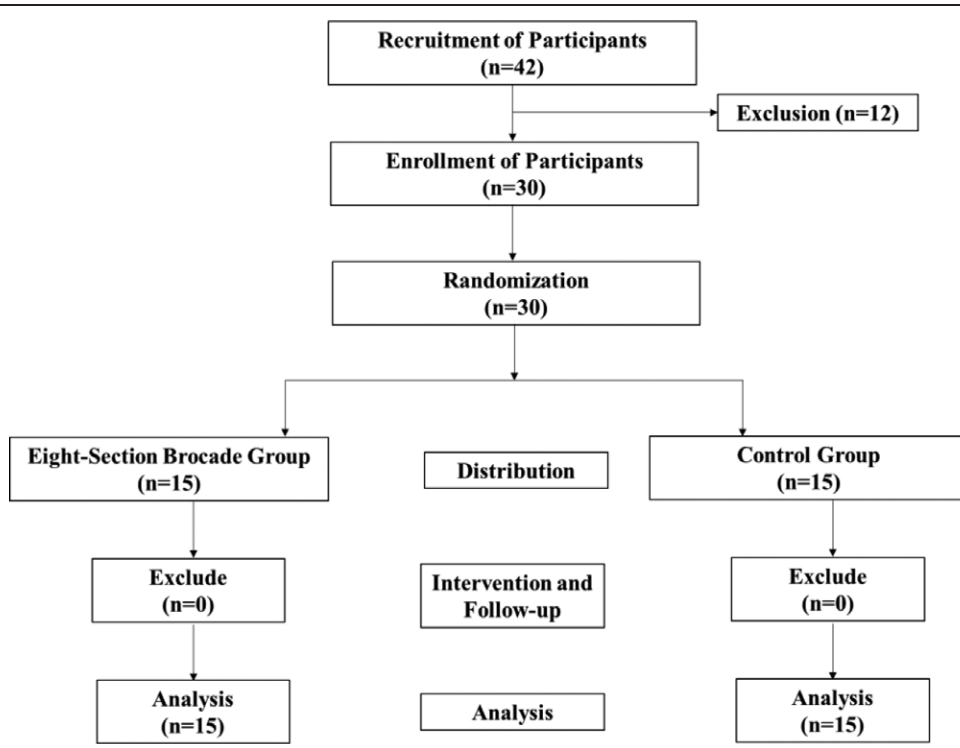

Figure 1. Experimental design flowchart.

scores, spinal curvature distance, modified Schober test results, cervical spine range of motion, ankle spacing, muscle stiffness, muscle tension, or muscle elasticity of the lumbar and cervical regions (*P* > .05), as shown in Table 1.

Comparing the outcome parameters at the end of treatment between the 2 groups (Table 2), there were statistically significant differences in muscle fascia stiffness adjacent to the lumbar and cervical spine, as well as muscle fascia tension adjacent to the lumbar spine (*P* < .05). After the intervention, the difference in muscle fascia elasticity adjacent to the lumbar spine between the 2 groups was also statistically significant (*P* < .05), as shown in Figure 2.

No severe adverse reactions were reported by the subjects. In the Baduanjin intervention group, 5 subjects reported mild muscle pain in the thighs and calves during the first 2 weeks of treatment, and 1 patient reported mild lower back pain, which improved after taking etoricoxib 60 mg once daily for 2 days.

4. Discussion

This study, through a randomized controlled trial, explored the effects of the fitness exercise Baduanjin on the biomechanical properties of the axial muscle fascia in patients with AS. The results indicated that after 12 weeks of Baduanjin intervention, there was a significant reduction in muscle fascia stiffness and tension in the lumbar and cervical regions of AS patients, with an improvement in elasticity. This finding not only provides new scientific evidence for the application of Baduanjin in AS treatment but also lays the foundation for further understanding its mechanisms of action.

Firstly, Baduanjin may effectively improve the biomechanical properties of the axial muscle fascia in AS patients through a series of stretching, twisting, and relaxation movements. Specifically, Baduanjin movements like "Two Hands Hold up the Heavens" and "Drawing the Bow to Shoot the Hawk" involve stretching and extending in different directions and angles, which help to alleviate muscle tension and stiffness, thereby reducing muscle hardness.[16,22] Additionally, Baduanjin emphasizes slow and coordinated movements, and this low-intensity, sustained exercise modality can effectively increase blood circulation in the muscles, promote the clearance of metabolic waste, and reduce muscle fatigue and stiffness.[23]

Table 1

Data comparison between the 2 groups before intervention.

Metric	Intervention group (mean ± SD)	Nonintervention group (mean ± SD)	*P*-value
Gender			.624
Male (n)	28	27	
Female (n)	2	3	
Age (years)	34.33 ± 9.04	32.53 ± 10.29	.615
BASDAI	1.77 ± 0.75	1.57 ± 0.76	.476
Scoliosis distance (cm)	13.10 ± 3.53	14.20 ± 4.02	.432
Modified Schober test (cm)	3.07 ± 0.76	3.37 ± 0.82	.318
Cervical range of motion (°)	65.60 ± 10.78	69.93 ± 11.05	.286
Ankle separation (cm)	110.87 ± 7.21	113.07 ± 7.12	.407
Lumbar stiffness (0 w)	283.13 ± 42.37	286.93 ± 47.77	.819
Cervical stiffness (0 w)	277.20 ± 40.25	278.93 ± 50.53	.918
Lumbar tension (0 w)	14.81 ± 1.54	15.29 ± 1.73	.428
Cervical tension (0 w)	14.11 ± 1.46	14.64 ± 1.66	.364
Lumbar elasticity (0 w)	1.30 ± 0.13	1.30 ± 0.17	.923
Cervical elasticity (0 w)	1.30 ± 0.11	1.28 ± 0.16	.737

The metrics include lumbar paraspinal muscle-fascia stiffness (S, stiffness, measured in N/m), which assesses the hardness of the lumbar muscles and fascia. Similarly, cervical paraspinal muscle-fascia stiffness (S, stiffness, measured in N/m) evaluates the stiffness of the cervical muscles and fascia. However, it's worth noting that the tension metrics, lumbar paraspinal muscle-fascia tension and cervical paraspinal muscle-fascia tension, are typically measured in a force unit like Newton (N) rather than frequency (Hz), as mentioned earlier. Lastly, lumbar paraspinal muscle-fascia elasticity and cervical paraspinal muscle-fascia elasticity are both assessed using the logarithmic decrement of oscillation amplitude (D), which provides information on the elasticity of the respective muscle-fascia structures.

Table 2

Data of the 2 groups after intervention and the differences before and after.

	Ba Duan Jin intervention group		Nonintervention group		
Project metrics	Mean	SD	Mean	SD	*P*-value
Lumbar stiffness (12 weeks)	273.73	37.7	290.93	45.84	.277
Lumbar stiffness Difference (pre-post)	-9.2	16.45	4	13.38	.023*
Cervical stiffness (12 weeks)	268.93	35.23	282.53	45.62	.369
Cervical stiffness difference (pre-post)	-8.27	16.34	3.6	14.27	.043*
Lumbar tension (12 weeks)	14.2	1.68	15.43	1.65	.053
Lumbar tension difference (pre-post)	-0.61	0.76	0.13	1.01	.030*
Cervical tension (12 weeks)	13.69	1.46	14.73	1.58	.072
Cervical tension difference (pre-post)	-0.43	0.83	0.087	0.74	.085
Lumbar elasticity (12 weeks)	1.22	0.13	1.32	0.13	.043*
Lumbar elasticity difference (pre-post)	-0.077	0.16	0.017	0.17	.122
Cervical elasticity (12 weeks)	1.26	0.15	1.32	0.14	.264
Cervical elasticity difference (pre-post)	-0.042	0.16	0.037	0.18	.204

*There was a statistically significant difference between the 2 groups ($P < .05$). Lumbar stiffness: stiffness of the paraspinal muscles and fascia in the lumbar region (S, stiffness, N/m). Cervical stiffness: stiffness of the paraspinal muscles and fascia in the cervical region (S, stiffness, N/m). lumbar tension: tension of the paraspinal muscles and fascia in the lumbar region (F, frequency, Hz). Cervical tension: tension of the paraspinal muscles and fascia in the cervical region (F, frequency, Hz). Lumbar elasticity: elasticity of the paraspinal muscles and fascia in the lumbar region (D, logarithmic decrement of oscillation amplitude). Cervical elasticity: elasticity of the paraspinal muscles and fascia in the cervical region (D, logarithmic decrement of oscillation amplitude).

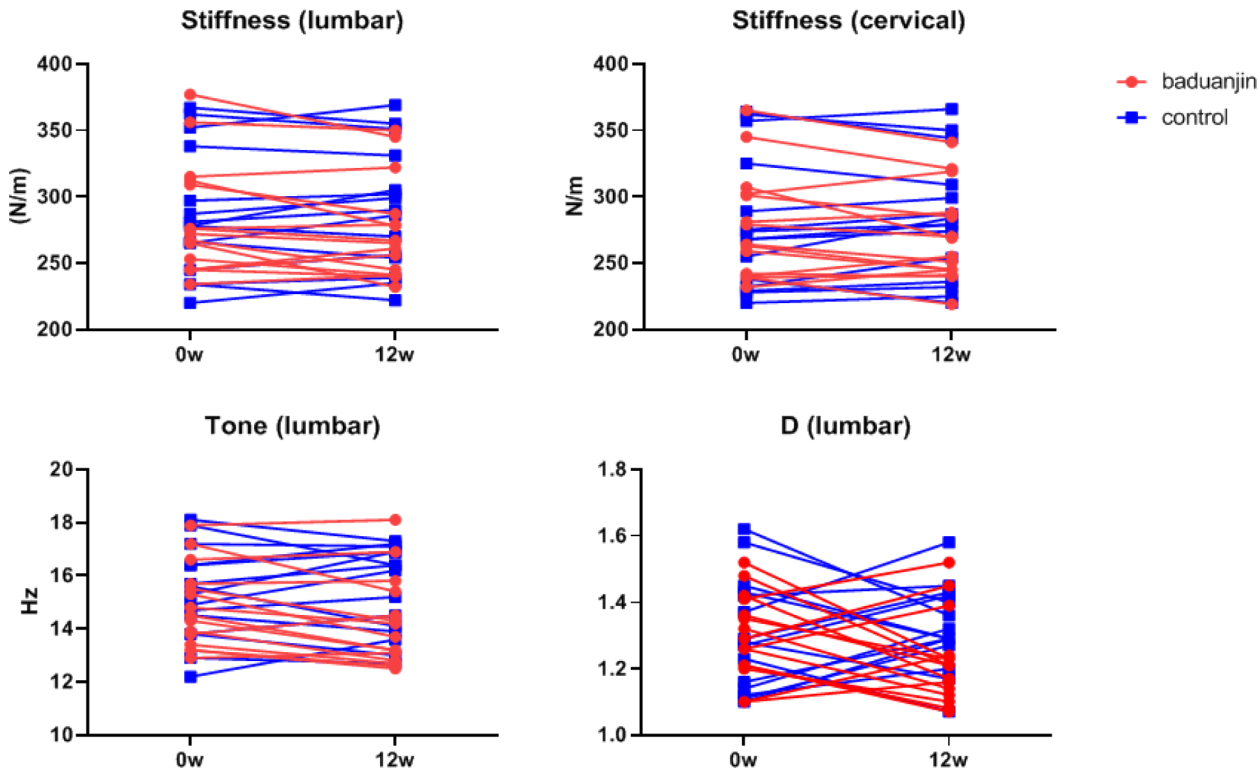

Figure 2. Differences in cervical and lumbar stiffness, lumbar tension, and lumbar elasticity before and after intervention.

Secondly, Baduanjin may improve the motor function and quality of life of AS patients by regulating the tension and elasticity of the axial muscle fascia. Due to biomechanical abnormalities of the axial muscle fascia, AS patients often experience symptoms such as limited movement, pain, and morning stiffness.[23,24] Baduanjin provides systematic whole-body exercise, giving the muscles and fascia around the spine ample training and relaxation, thereby restoring their normal biomechanical properties.[25] The study results showed significant reductions in muscle fascia stiffness and tension in the lumbar and cervical regions in the Baduanjin intervention group, with an improvement in elasticity, indicating that Baduanjin has a positive effect on improving the biomechanical properties of the axial muscle fascia in AS patients.

Furthermore, the potential mechanisms of Baduanjin in AS treatment may involve regulating inflammatory responses.[26] AS is a chronic inflammatory disease characterized by inflammation, fibrosis, and new bone formation at the tendon and ligament attachment sites.[27,28] By improving the biomechanical properties of the axial muscle fascia, Baduanjin may reduce micro-injuries and inflammation at the attachment sites. Specifically, the practice of Baduanjin helps to alleviate muscle tension and stiffness, reducing the transmission of mechanical stress, thereby lowering micro-injuries at the attachment sites. Moreover, Baduanjin increases blood circulation and metabolism in the muscles, promoting the clearance of inflammatory mediators, reducing local inflammation, and inhibiting the cascade reaction of inflammation.

The study also showed that no serious adverse reactions were reported by the participants in the Baduanjin intervention group. Only a few patients reported mild muscle pain in the first 2 weeks, which improved with appropriate treatment. This suggests that Baduanjin, as a non-pharmacological treatment, is safe and feasible. Compared to drug therapy, Baduanjin, as a traditional Chinese fitness exercise, is simple to perform and easy to promote. It not only effectively relieves AS symptoms but also enhances physical fitness and immunity, having a positive impact on overall health.

However, this study has certain limitations. Firstly, the sample size is relatively small, with only 30 patients, which may affect the generalizability and statistical power of the results. Future studies should consider increasing the sample size to further verify the effects of Baduanjin on the biomechanical properties of the axial muscle fascia in AS patients. Secondly, the intervention period of this study was 12 weeks, which did not assess the long-term effects of Baduanjin. AS is a chronic disease, and its treatment effects need long-term observation and evaluation. Future studies should consider extending the follow-up period to understand the long-term efficacy and sustainability of Baduanjin. Additionally, this study only measured the biomechanical properties of the muscle fascia in the lumbar and cervical regions, not comprehensively assessing the effects of Baduanjin on the whole body's muscle fascia. Future studies could consider expanding the measurement range to fully understand the overall impact of Baduanjin on the muscle fascia system in AS patients.

The innovation of this study lies in the first use of the MyotonPRO® soft tissue tester to objectively measure the biomechanical properties of the axial muscle fascia in AS patients, providing quantitative evaluation indicators. MyotonPRO® measures parameters such as muscle vibration frequency, logarithmic decrement of oscillation, and stiffness, which can truly and objectively reflect the functional state of the muscle fascia, providing scientific evidence for evaluating the efficacy of Baduanjin. Moreover, this study is scientifically designed, adopting a randomized controlled trial method, which eliminates the influence of confounding factors and enhances the reliability and scientific validity of the results.

The study had several limitations that should be addressed in future research. Firstly, the small sample size of only 30 patients limits the generalizability of the findings. Increasing the sample size in future studies would help provide more robust and widely applicable results. Secondly, the lack of long-term follow-up restricts the understanding of Baduanjin sustained effects on AS patients. Extending the follow-up period is recommended to evaluate the long-term efficacy and potential benefits of Baduanjin. Additionally, a more comprehensive evaluation of the entire muscle fascia system, beyond the lumbar and cervical regions, could offer deeper insights into Baduanjin therapeutic effects on the overall musculoskeletal health of AS patients.

In conclusion, this study demonstrates through a randomized controlled trial that Baduanjin significantly improves the biomechanical properties of the axial muscle fascia in AS patients. This finding provides new scientific evidence for the application of Baduanjin in AS treatment and lays the foundation for further exploration of its mechanisms. Future studies should consider increasing the sample size, extending the follow-up period, and comprehensively evaluating the long-term efficacy of Baduanjin and its effects on the whole body's muscle fascia in AS patients. Additionally, further exploration of Baduanjin application in other chronic diseases could promote the scientific and modern development of traditional Chinese fitness exercises in modern medicine.

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