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REVIEW ARTICLE

THE ROLE OF CORE STABILITY AND CORE MUSCLES IN ANKYLOSING SPONDYLITIS: A REVIEW OF FUNCTIONAL AND CLINICAL IMPORTANCE

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ABSTRACT

Purpose: Physiotherapy and exercise training are one of the cornerstones in the treatment of patients with ankylosing spondylitis (AS). However, although the effects of exercise programs and their superiority over each other have still not been determined, research on this subject is continuing in the literature day by day. Due to the pathophysiology of AS, the spine is one of the most affected areas of the musculoskeletal system. Therefore, stabilization of the lumbopelvic region and the spine, which is the reference point for the core muscles, is important for the treatment and management of this disease. In this review, we summarize the available literature on the involvement of core muscles and core stability in patients with AS and the studies on core training programs.

Keywords: Ankylosing spondylitis, axial spondyloarthritis, core stability, core muscles, exercise

INTRODUCTION

Ankylosing Spondylitis (AS), also known as radiographic axial spondyloarthritis (axSpA), is a subgroup of chronic rheumatic diseases called spondyloarthritis (SpA) (1). It is a chronic, autoimmune, inflammatory disease that primarily affects the axial skeleton (2). It is characterized by chronic low back pain, stiffness, and loss of mobility (3). The disease can occur at any age, but it commonly occurs between the ages of 10 and 40. The global prevalence of AS has been reported to range between 0.01% and 0.2%. (4). It has a prevalence of 0.049 % in Turkey (5).

The most common clinical feature is inflammatory back pain. In the early stages of the disease, the pain is intermittent, but in the late stages it is persistent (1). The pain also occurs in the thoracic spine. Pain in the cervical spine is rare in this disease, unlike pain in the lumbar and thoracic spine (6). Another common clinical feature is stiffness that lasts longer than 30 minutes in the morning. It subsides with movement and worsens with rest (1). The stiffness leads to postural changes such as loss of lumbar lordosis (posterior pelvic tilt), increased thoracic kyphosis, and forward head posture. To compensate for the postural changes caused by these deformities, patients perform knee flexion and plantar flexion. All these deformities result in a loss of balance. Patients cannot control the center of gravity, and as a result, their balance deteriorates. Impaired gaze stability due to advanced kyphosis and forward head posture results in impaired static balance. Not only static balance but also dynamic balance is impaired. Due to the compensation of the balance disturbances, walking with widened steps can be observed. Impaired balance can lead to falls and fractures. These fractures lead to higher morbidity and mortality in patients with AS (7). In the later stages, inflammation leads to fusion in the sacroiliac joint and spine, known as the "bamboo spine", which impairs mobility. So this situation leads to disability and a decreased quality of life (8). AS affects not only the spine but also the costovertebral and costotransverse joints, as well as the costosternal and manubriosternal joints, resulting in limited expansion of the rib cage due to increased kyphosis (9).

AS affects mainly the axial skeleton as well as the tendons, ligaments, and peripheral joints, including the hip and knee. In addition to musculoskeletal manifestations, it is associated with several extraarticular features signs such as anterior uveitis, psoriasis, inflammatory bowel disease, upper-lobe pulmonary fibrosis, heart involvement, chronic prostatitis, and cauda equina syndrome (8, 10, 11).

Pain, stiffness, fatigue, and sleep disturbances are common symptoms of AS, and they are all linked to a reduction in physical activity. Sleep deprivation has been associated to negative mood and increased stress in patients, as well as poor quality of life, pain, and disease activity. Over half of patients with AS suffer from fatigue. For many years, AS-related fatigue was largely ignored. Later, fatigue was included as a main symptom of the disease (2, 12, 13).

The muscles surrounding the lumbopelvic region (also known as core muscles) are connected to the thoracolumbar fascia and spinal vertebrae. They play an important role in maintaining spinal stability (14). Core strengthening and stabilization exercises, which have been shown to be effective for many musculoskeletal problems, have taken their place in the physiotherapy literature and have become a method frequently used by physiotherapists in clinical practice (15, 16). As mentioned earlier, musculoskeletal problems are very common in AS and it is believed that core strengthening and stabilization exercises can be effective in the treatment and management of this disease.

In this review, it is summarized how AS affects the core muscles and core stability, which exercises are applied to train AS patients' core muscles, the outcomes and significance of these exercises in AS patients, and how these results can help future rehabilitation programs for AS patients.

Core Stability and Core Muscles Definition

Over the last three decades, “core muscles” and “core stability” terms have gained popularity in especially musculoskeletal and sports rehabilitation areas (15). Several terms are used to describe the concept of core stability in literature and there is still no consensus regarding the definition of core stability and which muscles contribute to the core region. According to the Akuthota and Nadler, the core is described “as a box with the abdominals in the front, the paraspinals and gluteals in the back, the diaphragm as the roof and the pelvic floor and hip girdle musculature as the bottom” (17). This cylinder-like structure with muscular boundaries that stabilize the trunk and spine in a corset-like pattern (14). According to the Kibler et al. the core musculature includes the muscles of the trunk and pelvic region (18). The core is essential for local strength and balance, and it is at the foundation of almost all kinetic chains in body movements. It provides an anatomical base for the motions of the distal components. This is referred to as "proximal stability for distal mobility" (18). The core muscles have two basic functions: a) protect the spine from potentially harmful stresses, and b) create and transport forces throughout the body. Physical performance is dependent on the development and transmission of forces between body parts. Failure to transmit forces through the body may result in inferior performance and increase the risk of injury (19).

According to Kibler et al., core stability is the ability to manage the position and motion of the trunk over the pelvis and legs, allowing for optimal force and motion production, transmission, and control to the terminal segment during integrated kinetic chain activities. Exercises that challenge spinal stability and trunk postural control while stimulating specific motor patterns in the trunk muscles are known as core stability exercises. (18).

The diaphragm serves as the core's roof. Simultaneous contractions of the diaphragm, pelvic floor muscles, and abdominal muscles are required to increase intra-abdominal pressure and generate a more rigid cylinder for trunk support. This core exercise relieves pressure on the spine muscles and improves trunk stability. The diaphragm contributes to intra-abdominal pressure before limb motions begin, which helps to maintain spine/trunk stability. In the absence of respiratory actions, this activation occurs (20, 21).

Abdominal muscle contractions contribute to the formation of a rigid cylinder, which increases the stiffness of the lumbar spine. Prior to the start of big segment upper limb movement, contractions that increase intraabdominal pressure occur. Before limb movements, the spine and core of the body are stabilized, allowing the limbs to have a secure platform for mobility and muscle activation (22-24).

Pelvic floor muscles form the bottom of the cylindrical structure of the core. The multifidus on the posterior of the trunk offers single-joint segmental stabilization, allowing the longer multi-joint muscles to regulate spine motions more effectively. The transversus abdominis, multifidus, and pelvic floor muscles all have synergistic activation patterns that assist the trunk and spinal muscles (25-27).

Core stabilization is quite popular for musculoskeletal injuries such as lower back, neck, and lower extremity injuries, as well as injury prevention in athletes. (14, 28) Although limited, there have been recent studies in the literature highlighting its importance on AS and focusing on this topic.

Core Stability and Core Muscles in Ankylosing Spondylitis

According to the literature, there are studies indicating that AS causes fatty degeneration, atrophy, and weakness in muscle groups such as the quadriceps and paravertebral muscles due to chronic inflammation, cytokine-mediated fibrosis, immobility, and postural abnormalities (29-32).

In the previously published review articles, it was stated that chronic inflammation in patients with AS reduces bone density due to its effect on bone metabolism, thus reducing spinal stability, leading to new bone formation in the cortical bone and causing ankylosis. Therefore, the importance of exercise and physiotherapy methods focusing on the core stabilization is emphasized, as they may have positive effects on bone metabolism and controlling inflammation in these patients (33, 34).

We conducted a literature search for studies evaluating core muscles and its clinical significance in patients with AS and summarized them in Table 1.

Romagnoli et al. compared AS patients with healthy controls in terms of chest wall kinematics and respiratory muscle activation, the diaphragm and abdominal muscles assisted thoracic expansion in AS patients, regardless of the severity of their disease (35).

In another study, no compensatory increase in diaphragmatic movement was found in people with AS compared to the healthy group due to the limitation of thoracic expansion. In addition, it has been shown that increased cervical and lumbar limitations caused by AS are associated with diaphragmatic movement, and it has been emphasized that more comprehensive studies should be conducted to better understand this issue (36).

Individuals with AS and healthy controls were examined in terms of abdominal muscles, which is another core muscle group, in a study conducted by Üşen et al. Their results showed no difference in ultrasonographic muscle thickness values. However, when patients with AS were divided into groups based on their level of physical activity, it has been shown that the thickness of the internal oblique and transversus abdominis muscles is significantly lower in subjects with low physical activity level compared to healthy individuals. The authors stated that their findings are notable and improving abdominal muscles with an appropriate exercise regimen in AS patients is essential (37).

We came across three studies assessing core muscle endurance, the first of which was the study of Acar et al. This study compared the core stability and balance in patients with AS and healthy individuals. According to their results, AS has a negative impact on core stability and balance, and findings suggesting that core stability and balance training might be incorporated in the rehabilitation programs of these patients (38).

A study of Rausch et al. indicated that strength evaluation in individuals with AS should focus on core

Table 1. Characteristics of studies evaluating the core muscles in AS patients.

Author	Year	Participant characteristics		Outcome measures	Clinical findings related core muscles
		Groups	Number of subjects (mean age in years)		
Romagnoli et al. (35)	2004	AS* Healthy controls	6 (46.0) 7 (35.4)	BASDAI, BASFI, BASRI, Pulmonary functions test, Chestwall kinematics (optoelectronic plethysmography), transdiaphragmatic pressure (balloon catheter system)	Diaphragm and abdominal muscles assisted thoracic expansion independent of the degree of AS disease.
Ünlü et al. (36)	2012	AS* Healthy controls	33 (36.7) 14 (35.1)	BASDAI, ASDAS, BASFI, BASMI, BASRI, Diaphragmatic motion with Ultrasonography	Increased cervical and lumbar limitations are associated with increased diaphragma movement.
Üşen et al. (37)	2017	AS* Healthy controls	35 (35.27) 35 (32.57)	TrA, IO, and EO muscle thicknesses with Ultrasonography, IPAQ, ODI, RMDQ, GSS, PSQI, BDI, CRP levels, ESR levels, 25(OH)D levels	AS patients who were less physically active had also decreased thickness of IO and TrA muscles.
Acar et al. (38)	2019	AS* Healthy controls	64 (39.9) 64 (38.1)	BASDAI, ASDAS, BASFI, BASMI, Core Muscle Endurance Times, Isometric hip strength, Balance	AS has negative effects on core stability and balance.
Rausch et al. (39)	2021	AS*	62(54.6)	aCSE, Pain intensity, BASDAI, BASFI, FFB-Mot.	AS-specific assessments were not associated with aCSE.
Sarac et al. (40)	2022	AS*	51(41)	CME Times, Balance, Thoracic Kyphosis Angle, Physical Activity, Fatigue	CME times were related to PA level, fatigue, and balance, but not to thoracic kyphosis angle.
Wang et al. (41) **	2022	AS* Healthy controls	30 (29.53) 27 (27.48)	elasticity, cross-sectional area and thickness of lumbar multifidus (Ultrasound shear-wave elastography)	AS patients had decreased lumbar multifidus muscle mass and function compared to healthy controls.

* Patients who meet the modified New York criteria for ankylosing spondylitis (42).
** This article was a preprint. It might not have been peer-reviewed.
BASDAI = Bath Ankylosing Disease Activity Index. ASDAS = Ankylosing Spondylitis Disease Activity Score. BASFI = Bath Ankylosing Spondylitis Functional Index. BASMI = Bath Ankylosing Spondylitis Spinal Metrology Index. BASRI= Bath Ankylosing Spondylitis Radiology Index. FFB-Mot. = Physical fitness questionnaire. aCSE = adapted Core Strength Endurance Test Battery for axSpA patients. CME = Core Muscle Endurance. IPAQ = The International Physical Activity Questionnaire. ODI = Oswestry Disability Index. RMDQ = Roland-Morris Disability Questionnaire. GSS = General self-efficacy scale. Pittsburg Sleep Quality Index (PSQI). BDI = Beck Depression Inventory. CRP = C-reactive protein. ESR = Erythrocyte sedimentation rate. 25(OH)D = 25-hyroxyvitamin D.

muscle strength endurance rather than peripheral muscles. Therefore, the core strength endurance test battery (CSE), which is generally used in the evaluation of athletes, was adapted for patients with axSpA (abbreviated as aCSE), and a reliability study was carried out. The aCSE has been shown to be a reliable test battery for measuring core strength and endurance in axSpA patients. However, no disease-specific characteristics were found to be associated with aCSE performance (39).

In 2022, another study was conducted in patients with AS to evaluate the possible association between core muscle endurance times and balance, fatigue, physical activity level, and thoracic kyphosis angle. The decrease in core muscle endurance times was associated with a loss of postural stability, a low level of physical activity, and an increased experience of fatigue, but not with a thoracic kyphosis angle. As a result of this study, the authors recommended that prior to prescribing exercises, assessment of trunk musculature, balance, and fatigue can help design programs for patients (40).

Wang et al. published their preliminary results in 2022 by using ultrasound shear-wave elastography to objectively quantify the elasticity, cross-sectional area, and thickness of the lumbar multifidus. They noted that AS patients had affected stiffness and decreased muscle mass and function of lumbar multifidus than healthy controls (41).

We conducted a literature search for randomized controlled trials that trains core muscles in patients with AS and summarized them in Table 2.

The diaphragm contributes to core stabilization as well as its role in ventilation by working synergistically with other core muscles (18, 19). Inspiratory muscle training (IMT), which predominantly trains the diaphragm, has been shown in two studies to improve inspiratory muscle strength and functional exercise capacity, increase chest expansion, and positively

Table 2. Characteristics of randomized controlled trials (RCTs) that train core muscles in AS patients.

		Intervention group*			Control group*			
Author	**Year**	**Number of subjects (mean age in years)**	**Intervention**	**Duration**	**Number of subjects (mean age in years)**	**Intervention**	**Outcome measures**	**Clinical findings related core muscles**
Altan et al. (45)	2012	29 (46.5)	Pilates training	12 weeks	24 (43.6)	Usual care	BASFI, BASDAI, BASMI, Chest expansion, ASQoL	In intervention group, BASFI showed significant improvement at week 12 and week 24.
Roşu et al. (46)	2014	48 (25.9)	Pilates, McKenzie and Heckscher exercises	48 week (home-based after 12 weeks)	48 (24.9)	Step-aerobic + pulmonary exercises	BASFI, BASDAI, BASMI, VAS, FFD, Chest expansion, Vital capacity	Pain, spine mobility, physical functioning, and pulmonary function improved in the intervention group.
Drăgoi et al. (43)	2016	23 (47.7)	IMT + Conventional exercise training	8 weeks	24 (49.4)	Conventional exercise training	BASFI, BASDAI, Cardiopulmonary exercise test (CPET), Pulmonary functions test,	Improvements in aerobic capacity, resting pulmonary function, ventilatory efficiency, and chest expansion
Başakçı Çalık et al. (44)	2018	16 (35.6)	IMT + Conventional exercise training	8 weeks	16 (39.1)	Conventional exercise training	BASFI, BASDAI, BASMI, PImax, PEmax, 6MWT	In intervention group, PImax and 6MWT were significantly better
Öksüz et al. (47)	2021	13 (46.2)	Clinical Pilates Exercises + Aerobic Training	8 weeks	13 (41.7)	Aerobic Training	BASFI, BASDAI, BASMI, 6MWT, ASQoL, MAF, PSQI, HADS, TSK, Back scratch test, Functional reach test, Single leg stance test, Back muscle strength, Lower extremity muscle strength, Chair sit and stand test	In intervention group, spinal mobility, disease activity, upper extremity flexibility, dynamic balance, quality of life, and fatigue severity improved compared to the control group
Bağlan-Yentür et al. (48)	2022	19(43.42)	Pilates training	8 weeks	17(44.29)	Conventional exercise training	BASDAI, BASMI, PImax, PEmax, Pulmonary functions test, 6MWT, ASQoL, Thoracic pain (VAS), Chest expansion,	Pilates training and home-based exercises were useful in improving respiratory muscle strength.

* Patients who meet the modified New York criteria for ankylosing spondylitis (42).
BASDAI = Bath Ankylosing Disease Activity Index. BASFI = Bath Ankylosing Spondylitis Functional Index. BASMI = Bath Ankylosing Spondylitis Spinal Metrology Index. IMT = Inspiratory muscle training. VAS = Visual Analog Scale. FFD = Finger-to-floor distance. MAF = Multidimensional Assessment of Fatigue. PSQI = Pittsburgh Sleep Quality Index. HADS = Hospital Anxiety Depression Scale. TSK = Tampa Scale of Kinesiophobia. PImax = Maximal inspiratory pressure. PEmax = Maximal expiratory pressure. 6MWT = 6-min walk test.

contribute to the reduction of disease activity in patients with AS (43, 44).

According to a study comparing Pilates training (an exercise approach that includes core stability) to usual care in patients with AS, it was found that Pilates training produced significant improvement in clinical parameters compared to the control group. The authors of the study concluded that Pilates training is an effective and safe way to increase physical capability (45). Another study by Roşu et al. found that Pilates, McKenzie, and Heckscher exercises improved pain, spinal mobility, physical functioning, and pulmonary function in patients with AS when compared to the control group (46). Öksüz et al. investigated the effects of clinical pilates exercises (a modified form of Pilates for rehabilitation) added to an aerobic exercise program in patients with AS. Authors found that it showed significantly better results in functional and psychosocial parameters than the group that received aerobic exercise training only (47). According to Balan-Yentür et al., pilates training and home-based exercises were effective in enhancing respiratory muscle strength without the use of any extra exercise method or equipment designed to improve respiratory muscle strength (48).

Patients with AS require physiotherapy and exercise as part of their treatment. Although some types of exercise have been shown to be beneficial in this disease group, and it has been suggested that exercise programs should include components such as aerobic (cardiorespiratory), flexibility, resistance (strength), and neuro-motor exercise, there is no consensus on which exercises should be performed and at what intensity. For this reason, it has been reported that the physical activity recommendations of ACSM (American College of Sports Medicine) for healthy individuals can be suggested in this patient group (49-51).

Although studies on core muscles in AS is limited, research on this topic has increased in recent years. Given the consequences of AS disease, it is reasonable to believe that the core is one of the key locations impacted throughout the disease's progression. Since core is the center of the kinetic chain in the body, it might contribute to functional impairments in individuals. According to studies, AS disease has a negative impact on the core region. Furthermore, exercise regimens that target this region have been shown to be useful in coping with the symptoms of AS.

CONCLUSION

It is known that spine is one of the most affected regions in AS, but studies examining core stability and core muscles, the disease-related changes in these muscles, and the results of core stability training in patients with AS are limited.

Although the benefits of exercise and physiotherapy in patients with AS are studied, the superiority of these methods over each other and the optimum rehabilitation programs are still unclear. So far, exercise studies involving core training in patients with AS have shown promising results. Considering the structural and functional effects on the core muscles of AS, it is important to carry out further studies on the efficacy of treatments targeting the core region in patients with AS, in order to improve the rehabilitation programs for these patients and to provide maximum benefit in clinical practice.

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