Original papers

Med Ultrason 2023, Vol. 25, no. 3, 279-287
DOI: 10.11152/mu-3973

Ultrasound characteristics of soft tissues near sacroiliac joints and in the lumbar region of patients with ankylosing spondylitis

Ko-Jen Li[1], Huan-Chen Lin[2], Chiao-Feng Cheng[3], Chih-Chien Hung[4], Tiffany Ting-Fang Shih[5], Cheng-Hsun Lu[1], Peemongkon Wattananon[6], Wen-Shiang Chen[7], Hsing-Kuo Wang[2]

[1]Division of Allergy, Immunology, and Rheumatology, Department of Internal Medicine, National Taiwan University Hospital, Taipei City, Taiwan, [2]School and Graduate Institute of Physical Therapy, college of medicine, National Taiwan University; Center of Physical Therapy, National Taiwan University Hospital, Taipei, Taiwan, [3]Department of Internal Medicine, National Taiwan University Hospital Yun-Lin Branch, Yun-Lin County, Taiwan, [4]Department of Orthopedic Surgery, National Taiwan University Hospital Yun-Lin Branch, Yun-Lin County, Taiwan, [5]Department of Medical Imaging, National Taiwan University Hospital, Taipei City, Taiwan, [6]Faculty of Physical Therapy, Mahidol University, Bangkok, Thailand, [7] Department of Physical Medicine and Rehabilitation, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei City, Taiwan

Abstract

Aims: To investigate the musculoskeletal morphomechanical properties (i.e., the thickness and elastic modulus) and the total count of power Doppler signals near the sacroiliac joints in patients with ankylosing spondylitis (AS) and non-AS individuals. **Material and methods:** Twenty participants with AS [median age (interquartile range): 31.7 (11.04) years] and 19 controls [36.3 (10.5) years] with no AS history were recruited. Bilateral ultrasound image acquisition was performed, including the short posterior sacroiliac ligament, interosseous sacroiliac ligament, long posterior sacroiliac ligament, iliolumbar ligament, proximal piriformis muscle, and sacrotuberous ligament. The intraclass correlation coefficients (ICC) of ultrasound parameters, laboratory test results of human leukocyte antigen B27, C-reactive protein, and erythrocyte sedimentation rate, and self-reported physical and disease activity scores were also obtained. **Results:** The ligaments and piriformis muscle were thicker and stiffer (greater elastic modulus) in participants with AS than in non-AS participants (all $p<0.01$). The measurements showed good or excellent reliability (all $ICC_{(3,1)}>0.85$). The numbers of power Doppler signals detected in the iliolumbar ligament, proximal piriformis muscle, and sacrotuberous ligament were higher in participants with AS than in non-AS participants (all $p<0.001$). A correlation was identified between disease duration and the elastic modulus of the piriformis muscle ($r=0.640$, $p=0.003$). **Conclusion:** We conclude that the ligaments and proximal piriformis muscle of AS participants have increased thickness, elastic modulus, and power Doppler signal than those of non-AS individuals. These reliable findings may serve as potential markers for the early diagnosis of AS and for assessing medication effects.

Keywords*:* spondyloarthritis; sacroiliac joints; elastography; ligament; power Doppler

Received 25.11.2022 Accepted 10.07.2023
Med Ultrason
2023, Vol. 25, No 3, 279-287
Corresponding author: Hsing-Kuo Wang
Sports Physiotherapy Laboratory,
School and Graduate Institute of
Physical Therapy,
College of Medicine,
National Taiwan University,
17 Xuzhou Rd., Zhongzheng District,
Taipei City 100, Taiwan
Fax/phone: 886 2 33668160
886 2 33668134
E-mail: hkwang@ntu.edu.tw

Introduction

Ankylosing spondylitis (AS) is a type of axial spondyloarthropathy involving immune-mediated inflammation in the sacroiliac, vertebral, and peripheral joints and entheses [1-3]. The global prevalence of AS is approximately 7.4–37.0 per 10,000 people, and AS is three times more prevalent in men than in women [1,4]. Patients with AS typically present pain in the lumbosacral region with limited movement in the lumbar spine and thoracic cage, a diagnosis based on the modified New York criteria [5]. The pathogenesis of AS is multifac-

torial, involving genetic predisposition, such as human leukocyte antigen B27 (HLA-B27), and environmental triggers, including mechanical stress [6,7]. The association between HLA-B27 and ankylosing spondylitis is one of the strongest known relationships between an HLA allele and disease [8]. Typically, AS inflammation begins in the entheses, which are characterized by high levels of mechanical stress [9,10]. Microdamage has been described in peripheral entheses in AS, suggesting that an inflammatory response is responsible for the maladaptation of ligaments and tendons in response to mechanical stress near insertion sites [9,10]. To interpret the histological findings of lesions in the entheses and joints of patients with AS, Masi et al proposed a novel mechanism that integrates immunobiological and mechanobiological processes [11], in which mechanical forces cause strain or microinjury in soft tissues, leading to the overactivation of the innate immune system, inflammatory changes, and new bone formation [11]. This mechanism suggests the potential for maladaptation in response to mechanical stress in the soft tissues around the axial spine, especially in the lumbopelvic region.

Ultrasonographic studies comparing patients with AS against non-AS individuals have observed a significant increase in the thickness of the middle third of the Achilles tendon [12] and tendon softening in the distal third of the Achilles tendon as quantified by strain sonoelastography [13]. As mentioned above, the tendon softening was associated with enthesopathy findings, including the presence of power Doppler activity [13]. In addition, a significant improvement in subclinical Achilles enthesitis, based on semi-quantitative ultrasonographic scores in B-mode, was observed after two months of tumor necrosis factor-alpha (TNF-α) antagonist therapy [14]. Previous studies collectively indicate that morphological or mechanical profiles of the Achilles tendon at the enthesis can serve as a powerful index for assessing and distinguishing spondyloarthropathy from rheumatoid arthritis [15]. The morphological or mechanical profiles of the ligaments and muscles in the lumbopelvic region may, therefore, potentially contribute to AS early diagnoses, as these soft tissues are located near the sacroiliac joint where patients with AS first experience symptoms and are responsible for transmitting or producing mechanical forces that act on the posterior kinetic chain [16-18].

We hypothesized that the differences in morphomechanical properties (i.e., increases in thickness and Young's modulus) and the total count of positive directional power Doppler signal in the ligaments and muscles around the sacroiliac joints, including the iliolumbar ligament, dorsal sacroiliac ligament, and piriformis, can be used to differentiate patients with AS from non-AS individuals. In addition, since piriformis syndrome has been reported as an early symptom of AS [19], it may be possible to observe the demonstration of long-term and cumulative effects of AS disease activity on the muscle. Therefore, we hypothesized that these morphomechanical properties are associated with AS disease history.

Materials and methods

This study was approved by the Institutional Review Board of National Taiwan University Hospital (reference no. 202012206RINC) and was performed in accordance with the ethical standards established by the 1964 Declaration of Helsinki. Written informed consent was obtained from all participants prior to their participation. This study utilized a cross-sectional design comparing a group of participants with AS against a non-AS group with no AS history and matched for demographic characteristics (age and sex). This study was conducted from August 2021 to May 2022. Participants with AS were recruited from the Division of Allergy, Immunology, and Rheumatology, Department of Internal Medicine, National Taiwan University Hospital. Inclusion criteria were men aged 20–45 years with a diagnosis of AS, according to the revised New York criteria or The Assessment of SpondyloArthritis International Society criteria [2,5,20]. Men were included in this study because they have more severe radiographic changes with longstanding AS, while self-reported functional limitations are worse for women, indicating that gender may be a confounding factor for our outcome measurements [1,4]. Based on our pilot work with participants with and without AS and based on a value of 0.05 for alpha (α) and a power of 0.80 for the statistical test, the minimum sample size required for significant morphomechanical differences between AS and non-AS groups for the short posterior sacroiliac ligament was 15. The non-AS group consisted of men aged 20-45 years with no history of low back pain or medication used to treat low back pain in the past 12 months and no family history of AS or axial spondyloarthritis (healthy volunteers). Exclusion criteria for both the AS and non-AS groups included any history of sacroiliac joint injury or fracture, hypertension, diabetes, coronary heart disease, peripheral arterial disease, heart failure, smoking, elevated C-reactive protein due to infection or cancer in the past year, and body mass index (BMI) >30 kg/m^2, which may compromise the visualization of target soft tissues on ultrasound. All participants were invited but not required to participate in a reliability test, in which ultrasonographic measurements were repeated later during the same week.

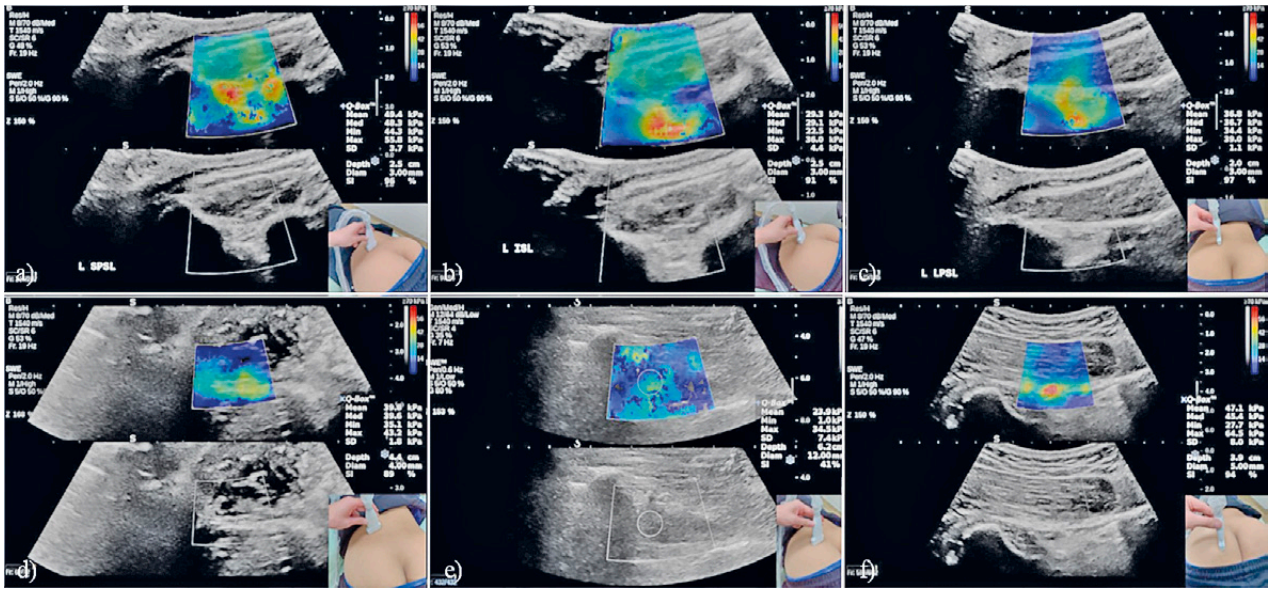


Fig 1. Measurement of elastic modulus a) short posterior sacroiliac ligament, b) interosseous sacroiliac ligament, c) long posterior sacroiliac ligament, d) iliolumbar ligament, e) proximal piriformis muscle, f) sacrotuberous ligament

Laboratory testing

Clinical data for recruited participants with AS, including disease history, medications received, and blood tests, such as HLA-B27, C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR) [20], were obtained from the last bimonthly laboratory testing prior to performing ultrasonographic measurements.

Ultrasonographic measurements

Bilateral ultrasound image acquisition was conducted in the medical imaging department of the National Taiwan University Hospital using an ultrasound system (Aixplorer® system, Supersonic Imagine, Aix-en-Provence, France) coupled with a XC6-1 (1–6 MHz) probe. Targets included the bilateral short posterior sacroiliac ligament (SPSL, fig 1a), interosseous sacroiliac ligament (ISL, fig 1b), long posterior sacroiliac ligament (LPSL, fig 1c), iliolumbar ligament (ILL, fig 1d), the proximal piriformis muscle (PPM, fig 1e), and sacrotuberous ligament (STL, fig 1f). During all ultrasonographic measurements, participants were lying on a bed in the prone position with a pillow placed under their abdomen to ensure that the lumbar lordosis region was flattened and straight. The thickness, elastic (Young's) modulus, and directional power Doppler activity (fig 2) of these ligaments were measured and recorded in longitudinal views. The morphomechanical characteristics (thickness and elasticity) of the ligaments and PPM were individually determined at the midpoint of the length (length measured including the ligament portions at the attachments) and at a point approximately 1 cm away from the muscle attachment, and all directional power Doppler activity within the ligaments or PPM were recorded. Thickness (in mm) was measured as the distance between the superficial and deep borders using dedicated cursors on the ultrasound machine in B-mode. Thickness and Young's modulus values for each target structure were averaged between the left and right sides, and the occurrence of positive power Doppler signals, which were defined as dot-type or line-type signals, were recorded. The total count of occurrence of positive directional power Doppler in each

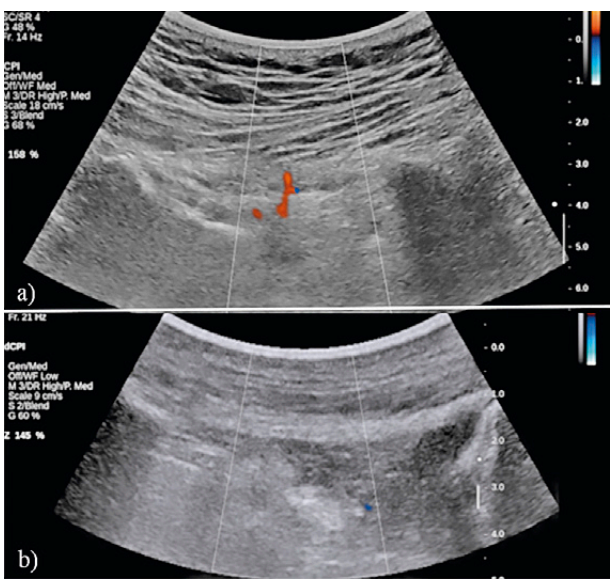


Fig 2. Examples of directional power Doppler signal in the sacrotuberous ligament in one participant with AS (a) and another participant from the control group (rb).

target structure in the AS and non-AS groups was used for between-group comparisons. The ultrasound scanning protocols and probe positioning for the ligaments and PPM were as previously described [21–25].

Briefly, for the SPSL and LPSL [21], the probe was first positioned between the posterior tuberosity of the ilium and the sacrum. The SPSL was identified as the oblique ligament stretching from the posterior tuberosity of the ilium to the sacral wings [21]. The probe was then rotated into a sagittal, slightly oblique position, and the LPSL was identified as a ligamentous structure attached superiorly to the posterior superior iliac spine and inferiorly to the third sacral transverse tubercle [21]. For the dorsal ISL [22], the probe was placed on the skin at the spinous process of the first and second sacral level in a transverse orientation relative to the sacrum. The probe was moved to the lateral edge of the sacrum to allow for the identification of the ilium contour. The ISL was visualized above the joint cleft between the ilium and sacrum [22]. For the ILL [23], the probe was first placed over the sacroiliac joint and oriented in the caudad–cephalad direction to identify the third lumbar spinous process (L3). The probe was moved to the L3 position, turned 90 degrees, and positioned inferiorly and laterally to allow the visualization of the transverse process of the fourth lumbar vertebrae (L4). The probe was then reoriented obliquely to identify the iliac crest. The hyperechoic structure below the erector spinae muscles joining the L4 to the iliac bone is the target ILL [23]. For the PPM [24], the probe was positioned horizontally, inferior to the posterior superior iliac spine, to identify the lateral edge of the sacrum and the posterior inferior iliac spine (PIIS). The PIIS end of the probe moved inferiorly to the level of the greater trochanter, retaining the sacrum end of the probe at the lateral end of the sacrum. The PPM was identified as deep to the lateral sacral border, traversing from cephalomedial to caudolateral beneath the gluteus maximus. The STL [25] was measured after the PPM, and the probe was rotated from the position used to measure the PPM using the sacrum end of the probe as the axis. The probe was moved slightly distal to the longitudinal axis of the STL to visualize the ischial spine on the lateral edge of the greater sciatic notch. The STL was identified as a light hyperechoic line deep within the gluteus maximus muscle [25].

To standardize and optimize the image and avoid variability between measurements, the B-mode gain was adjusted to default settings (30–63), the focus area was increased to maximum, and these settings were used across all participants. Elasticity (Young's modulus in kPa) in the ligaments and PPM was assessed using a round region of interest with different diameters (SPSL, ISL, and LPSL: 1–3 mm, ILL: 3–5 mm, PPM: 8–12 mm, STL: 8–12 mm), and the mean value between sides was recorded. During each elasticity measurement, the ultrasound transducer was maintained stationary for 10 s during image acquisition. The directional power Doppler gain was used at default settings during scanning (52–80).

After the ultrasound examination, the subjects were asked to respond to self-report questionnaires, including Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) and The International Physical Activity Questionnaire-Taiwan full version (IPAQ) [26]. Then, the lumbar spine mobility of the participants was assessed using a modified Schober test [27].

Statistical analysis

All data are presented as the median (interquartile range). The Shapiro–Wilk test was used to determine whether the data for all variables were normally distributed. The Mann–Whitney U test was used to analyze differences between the AS and non-AS groups, with alpha at 0.05. Intraclass correlation (ICC) was used to measure the intra-rater reliability of ultrasonographic measurements. The Chi-square test was used to compare the total count data of positive directional Doppler signal in the AS group and the non-AS group, with alpha at 0.05. Spearman's rank correlation coefficient was used to analyze correlations between the ultrasonic parameters (thickness and elastic modulus) of the PPM and disease activity, with a post hoc significance level of p=0.025 adjusted for two separate tests of the disease activity. All analyses were performed using SPSS 22.0 for Windows (SPSS Inc, Chicago, IL, USA).

Results

Clinical characteristics and demographics

A total of 20 participants with AS and 19 demographically matched controls with no history of AS were recruited for this study. No potential participants were excluded due to the established exclusion criteria. The characteristics of all participants are summarized in Table I. Although the CRP (median 0.30 and <cut-off value for inflammation 10 mg/dl) and ESR (median 10 and <cut-off value for inflammation 13 mm/h) results indicated that some of the AS participants did not present with inflammation, the results of the BASDAI score (median 4.35 and >4 implies active disease) and the modified Schober test (median 5.90 and normal value for spinal mobility 7 cm) suggested an active disease state [26] and poor lumbar flexibility [27] among the AS participants. More than half of the AS participants were treated with non-steroidal anti-inflammatory drugs or disease-modifying antirheumatic drugs. No significant differences

in physical characteristics (such as age, height, weight, BMI, or physical activity levels assessed by the IPAQ) were observed between the AS and non-AS groups (all p>0.05; Table I).

Reliability and correlations

Nine (three AS and six control) participants volunteered for the test-retest assessment of ultrasonographic measurement reliability. The thickness and elastic modulus measurements showed good or excellent intra-rater reliability (all $ICC_{(3,1)}$>0.85; Table II). The thickness and elastic modulus results demonstrated that the target ligaments and PPM in AS participants were thicker and stiffer than those of the non-AS participants (all p<0.01; Tables III and IV). In addition, the numbers of directional power Doppler occurrences in the ILL, the PPM, and the STL were larger in the AS group than in the non-AS group (Table V). A positive correlation was identified between disease duration and the elastic modulus of the PPM (r=0.640, p=0.003), but no correlation was identified between disease duration and PPM thickness (r=−0.261, p=0.266).

Discussion

This study found that compared with non-AS participants, participants with AS had thicker and stiffer liga-

Table I. Demographic characteristics of patients with ankylosing spondylitis and healthy controls

	Patient group (N=20)	Control group (N=19)	Mann–Whitney U test P-value
Age (years)	31.69 (11.04)	36.30 (10.49)	0.919
Height (cm)	176.5 (6.0)	175.0 (7.0)	0.284
Weight (kg)	77.0 (21.0)	72.0 (13.0)	0.193
BMI (kg/m^2)	24.93 (7.07)	23.18 (2.94)	0.249
IPAQ (MET-min/W)	3734 (6189)	3456 (8205)	0.663
Disease duration(years)	4.68 (8.21)	–	–
HLA-B27–positive	19/20	–	–
CRP (mg/dl)	0.30 (1.63)	–	–
ESR (mm/h)	10.00 (12.50)	–	–
BASDAI	4.35 (3.84)	–	–
Modified Schober test (cm)	5.90 (2.85)	–	–
Medication			
Corticosteroids	2/20	–	–
NSAIDs	18/20	–	–
csDMARDs	13/20	–	–
Biologic agent	1/20	–	–

Results are presented as the median (interquartile range). BMI, body mass index; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent of task; W, week; HLA-B27, human leukocyte antigen-B27; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; NSAIDs, non-steroidal anti-inflammatory drugs; csDMARDs, conventional synthetic disease-modifying anti-rheumatic drugs.

Table II. Reliability of the ultrasonographic scanning method for the target ligaments and piriformis muscle.

	B-mode Thickness measurement (N=9)			SWE Elastic modulus (N=9)		
	Intra-rater reliability $ICC_{(3,1)}$	SEM	$MDC_{95\%}$	Intra-rater reliability $ICC_{(3,1)}$	SEM	$MDC_{95\%}$
SPSL	0.986	0.01	0.02	0.959	2.85	7.91
ISL	0.969	0.02	0.04	0.875	3.61	10.01
LPSL	0.885	0.02	0.06	0.970	2.06	5.70
ILL	0.968	0.03	0.08	0.879	4.72	5.17
PPM	0.976	0.16	0.44	0.987	1.87	5.17
STL	0.959	0.04	0.12	0.888	10.64	29.51

SWE, shear wave elastography; ICC, intraclass correlation coefficient; SEM, standard error of measurement; $MDC_{95\%}$, minimal detectable change of 95%; SPSL, short posterior sacroiliac ligament; ISL, interosseous sacroiliac ligament; LPSL, long posterior sacroiliac ligament; ILL, iliolumbar ligament; PPM, proximal piriformis muscle; STL, sacrotuberous ligament.

ments and piriformis muscle involved in stabilizing the iliolumbar and iliosacral joints. Additionally, these ligaments and piriformis muscle showed a higher prevalence of positive directional power Doppler singles. A moderate level of association was found between the elastic modulus of the PPM and AS disease duration. The morphomechanical properties of the ligaments and PPM measured in this study are also reliable. These results support our hypotheses that changes in the morphomechanical properties occur in the ligaments and muscles in the sacroiliac joint and lumbar region of AS patients. The findings of this study highlight the potential clinical significance of using the morphomechanical properties of ligaments and muscles for early AS diagnosis and the assessment of rehabilitation or treatment effects.

Our observations of increased thickness and elastic modulus revealed the presence of morphomechanial adaptations in the ligaments and PPM near the iliolumbar and lumbosacral joints among participants with AS. These morphomechanical changes may be partially represented by fibrosis and calcification of the soft tissues adjacent to the spinal and sacroiliac joints, which have been reported in advanced AS cases [28]. We infer, as Masi et al proposed, that the ligaments and muscles surrounding the central spine and involved in the kinetic movement chain are vulnerable to mechanical stress in patients with AS due to the expression of susceptibility genes or proinflammatory cytokines, which is reflected in our morphomechanical findings [11]. The inference is based on experimental models, including TNF overex-

Table III. Thickness of target ligaments and piriformis muscle (unit: cm).

	Patient group (N=20)	**Control group (N=19)**	**Mann–Whitney U test P-value**	**Effect size Cohen's d**
SPSL	0.31 (0.06)	0.20 (0.02)	<0.001	2.46
ISL	0.30 (0.06)	0.21 (0.07)	<0.001	1.38
LPSL	0.26 (0.06)	0.19 (0.03)	<0.001	1.48
ILL	0.65 (0.15)	0.39 (0.05)	<0.001	2.33
PPM	2.44 (0.47)	2.17 (0.48)	0.002	0.57
STL	0.60 (0.20)	0.43 (0.15)	<0.001	0.96

Results are presented as the median (interquartile range). SPSL, short posterior sacroiliac ligament; ISL, interosseous sacroiliac ligament; LPSL, long posterior sacroiliac ligament; ILL, iliolumbar ligament; PPM, proximal piriformis muscle; STL, sacrotuberous ligament.

Table IV. Elastic modulus values for the target ligaments and piriformis muscle (unit: kPa).

	Patient group (N=20)	**Control group (N=19)**	**Mann–Whitney U test P-value**	**Effect size Cohen's d**
SPSL	39.00 (12.41)	23.00 (8.98)	<0.001	1.48
ISL	39.60 (13.45)	27.85 (6.92)	<0.001	1.17
LPSL	38.28 (17.33)	24.23 (6.85)	0.003	1.06
ILL	48.15 (15.88)	33.45 (13.75)	0.001	0.98
PPM	36.21 (26.04)	14.85 (6.02)	<0.001	1.13
STL	58.60 (30.58)	32.25 (6.40)	<0.001	1.19

Results are presented as the median (interquartile range). SPSL, short posterior sacroiliac ligament; ISL, interosseous sacroiliac ligament; LPSL, long posterior sacroiliac ligament; ILL, iliolumbar ligament; PPM, proximal piriformis muscle; STL, sacrotuberous ligament.

Table V. Total count of positive directional power Doppler signal in the target ligaments and proximal piriformis muscle.

	Patient group (N=20)	**Control group (N=19)**	**Chi-square test P-value**
SPSL	0/40	0/38	NS
ISL	2/40	0/38	NS
LPSL	1/40	0/38	NS
ILL	23/40	2/38	<0.001
PPM	31/40	4/38	<0.001
STL	26/40	3/38	<0.001

NS, non-significant difference; SPSL, short posterior sacroiliac ligament; ISL, interosseous sacroiliac ligament; LPSL, long posterior sacroiliac ligament; ILL, iliolumbar ligament; PPM, proximal piriformis muscle; STL, sacrotuberous ligament.

pression and IL-23 overexpression, that are associated with AS phenotypes commencing at the Achilles tendon [8]. It is further strengthened by the finding of directional power Doppler signal in the ILL, PPM, and STL (Table V). Power Doppler is clinically recommended for the detection of enthesitis in AS patients due to its ability to assess the entheses and its sensitivity to changes, which facilitates monitoring of the response to treatment [14]. Inflammation is characterized by increased vascularization [29], which is one of the major features of power Doppler signal found in this study. Our study found that directional power Doppler signals were present in the spinal ligaments and PPM, indicating enthesitis or inflammatory abnormalities in these structures and supporting our explanation of the morphological findings. However, in this study, among AS participants with poor lumbar spine mobility and an active disease state, the results of blood tests for acute phase reactants (CRP or ESR) may not be well-detected for chronic immune-mediated inflammation [1].

Overall, our study was able to detect morphomechanical, and vascular changes in the ligaments and muscle near the spine and sacroiliac joint in AS participants using ultrasonography, and these changes could serve as potential markers for the screening or early diagnosis of AS. At present, diagnosis and follow-up of AS rely primarily on characteristic radiological and/or magnetic resonance imaging (MRI) findings for the spine or sacroiliac joints [30]. A previous study reported a high negative predictive value (97%) for detecting sacroiliitis using contrast-enhanced Doppler ultrasound [31]. Therefore, future studies are recommended to examine the sensitivity and specificity of the morphomechanical changes in axial AS detected with ultrasonography.

We also identified a positive correlation between disease duration (medical history) and the elastic modulus of the PPM, possibly due to piriformis syndrome or sacroiliitis being an early and persistent symptom of AS [15,18,19]. The piriformis is responsible for external hip rotation and sacroiliac joint stabilization [30]. Long-term inflammatory arthritis of the sacroiliac joint in AS may exacerbate inflammation and fibrosis in the PPM [30] and, therefore, increase the stiffness of the PPM. The identified correlation between disease duration and PPM elasticity indicates that using shear wave elastography to assess the PPM could assist clinicians in estimating the duration or severity of sacroiliitis in AS. Future studies are suggested to investigate whether rehabilitative interventions that reduce sacroiliitis in AS could reverse the high stiffness of the piriformis.

The objective of this study was also to determine the reliability of ligament and muscle thickness/stiffness by using ultrasonographic measurements. Overall, these morphomechanical assessments of spinal ligaments and PPM showed $ICC_{(3,1)}$ values between 0.75 and 0.9 and values greater than 0.90, indicating good and excellent reliability, respectively. These data suggest that B-mode ultrasonography and shear wave elastography can be used clinically to assess changes in thickness and stiffness of spinal ligaments and muscles over time as a non-invasive method to monitor morphomechanical adaptations and changes in AS patients during rehabilitation and medication. Our $ICC_{(3,1)}$ values of ligament thickness and PPM stiffness are respectively less and greater than the ones reported in the anterior talofibular ligament (ICC 0.96, range 0.86–0.99) [31] and lumbar multifidus (ICC 0.62, range 0.45–0.77) [32] at rest. It is known that various factors influence the repeatability of ultrasound, including difficulties in maintaining a standardized testing position of the probe and joint, and inherent architecture, mechanical properties, size, and depth of the target tissues [33]. Our strategy to obtain satisfactory repeatability of ultrasonographic measurements is to use bony landmarks during scanning to identify target ligaments and PPMs.

In this study, only a limited number of participants with axial AS without significant loss of activity levels were recruited. Therefore, we are unable to exclude the possibility that morphomechanical properties of central ligaments or muscles differ between patients with suboptimal control of AS and those without. In addition, the exclusion criteria included BMI <30 kg/m^2, which limits our results to AS participants without significant obesity. This study also did not stratify the participants with AS based on disease stage, treatment, duration, or course with active/remissive status. In addition, our cohort might have been substantially heterogeneous. Future studies are recommended to recruit large populations of patients with AS and to compare the effects of medication on the morphomechanical properties of central ligaments or muscles.

Conclusion

We conclude that the ligaments and muscles involved in the stabilization of the iliolumbar and sacroiliac joints present increases in thickness, elastic modulus, and the presence of directional power Doppler signals in patients with AS relative to non-AS participants. These measurements are reliable and could serve as potential markers for the early diagnosis of AS and the monitoring of treatment effects on central deep soft tissues.

Conflict of interest: none

Acknowledgments: This study was financially supported by the National Science Council, Taiwan (NSC111-2314-B-002-153-). This study was also supported by National Taiwan University Hospital Yun-Lin Branch (grant number NTUHYL112.F007 to C-C Hung).

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