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ORIGINAL RESEARCH

DEUS Enthesitis Index (DEI): a new tool integrating ultrasound and clinical examination for enthesitis assessment in spondyloarthritis

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ABSTRACT

Objectives (1) To develop a composite score, the DEUS (Defining Enthesitis on Ultrasound in Spondyloarthritis) Enthesitis Index (DEI), which integrates ultrasound and clinical examination findings for enthesitis assessment in patients with spondyloarthritis (SpA); (2) to examine the relationships between DEI and clinical features in this population, compared to the clinical examination of the entheses alone.

Methods This was a cross-sectional, observational, multicentric study involving 20 rheumatology centres across 11 countries. Ultrasound and clinical examinations were performed bilaterally on the lower limb large entheses (ie, quadriceps tendon, proximal and distal patellar tendons, Achilles tendon and plantar fascia) in 413 patients with SpA, including 224 patients with axial SpA and 189 patients with psoriatic arthritis (PsA). A score of 1.0 for clinical enthesitis and 1.0 for ultrasound enthesitis was assigned for each of the 10 entheses evaluated. The total DEI score, which combines clinical and ultrasound findings, ranged from 0 to 20 per patient. Logistic and gamma regression models based on DEI were compared with those derived solely from clinical enthesitis assessment to evaluate their relative performance in explaining disease-related outcomes.

Results Among patients with SpA, the median DEI was 1.0 (IQR 0.0–3.0). DEI showed significant associations with SpA disease activity and severity indices in regression analyses, except for the Disease Activity in Psoriatic Arthritis score in patients with PsA. Compared with the clinical examination alone of the same entheses, DEI models exhibited a significantly better fit with C-reactive protein levels and ultrasound-detected structural damage at the enthesis (ie, enthesophytes and bone erosions). By contrast, the clinical examination alone models showed a significantly stronger fit with SpA disease activity indices and patient-reported outcomes compared with the DEI.

Conclusions DEI is a novel tool that integrates both ultrasound and clinical examination findings for enthesitis assessment, potentially ensuring a more reliable evaluation of this key domain in SpA.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Enthesitis, the inflammation at tendon or ligament attachment sites, is crucial in diagnosing and managing spondyloarthritis (SpA).
⇒ The clinical examination is the traditional method for assessing enthesitis; however, its sensitivity and specificity have been questioned by previous studies.

WHAT THIS STUDY ADDS

⇒ The DEUS (Defining Enthesitis on Ultrasound in Spondyloarthritis) Enthesitis Index (DEI) combines ultrasound and clinical examination findings, improving enthesitis assessment in SpA.
⇒ DEI models show a stronger fit with C-reactive protein and structural damage compared with the clinical examination alone of the same entheses.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ DEI could enhance clinical management of SpA by providing a more accurate measure of enthesitis.
⇒ This tool may guide clinicians in better evaluating disease activity and treatment response in patients with SpA.

INTRODUCTION

Spondyloarthritis (SpA), which includes axial SpA (axSpA) and psoriatic arthritis (PsA), constitutes a heterogeneous group of chronic inflammatory diseases characterised by shared clinical features, notably enthesitis (ie, inflammation at the sites where tendons, ligaments, or joint capsules insert into the bone).[1–3]

Indeed, enthesitis plays a pivotal role in the pathogenesis and clinical manifestations of SpA, representing a key component of classification criteria for axSpA and PsA.[4–6] According to the European Alliance of Associations for Rheumatology guidelines, in patients with PsA who show unequivocal signs of enthesitis and an inadequate response to non-steroidal anti-inflammatory drugs (NSAIDs) or local glucocorticoid injections, escalation to biologic disease-modifying

antirheumatic drug (DMARD) treatment should be considered.[7] Highlighting the significance of enthesitis in patients with SpA, recent clinical trials have also considered it as a secondary outcome for treatment response.[8]

The reliable assessment of enthesitis is challenging, mainly due to the limitations of clinical examination, such as its low specificity, which is the standard method for evaluating enthesitis in clinical practice and trials.[9] In recent years, interest has grown towards the use of imaging, and in particular ultrasound, for the evaluation of enthesitis in SpA.[10–12] Ultrasound has the ability to detect inflammatory changes at the enthesis, including entheseal thickening, hypoechoic areas and power Doppler (PD) signal, as well as structural damage findings, such as enthesophytes, calcifications and bone erosions. Several ultrasound scoring systems have been developed to assess enthesitis in SpA, including the Glasgow Ultrasound Enthesitis Scoring System,[13] the Madrid Sonographic Enthesis Index[14] and a recently proposed score from the Group for Research and Assessment of Psoriasis and Psoriatic Arthritis (GRAPPA),[15] among others.[16 17] Additionally, the Outcome Measures in Rheumatology (OMERACT) group has recently established a definition for ultrasound-detected enthesitis in SpA, along with criteria for its elementary ultrasound lesions and a semiquantitative scoring system for the evaluation of PD signal at the enthesis.[11 18] There is growing interest in using advanced ultrasound techniques, such as shear-wave elastography, to assess enthesitis in patients with SpA.[19]

A recent study conducted by our group, the multicentric DEUS (Defining Enthesitis on Ultrasound in Spondyloarthritis) study, demonstrated that ultrasound, unlike clinical examination, could differentiate between enthesitis related to SpA and 'mechanical' enthesitis in patients with osteoarthritis (OA) and fibromyalgia (FBM).[20] In that study, PD signal at the enthesis (an inflammatory feature) and bone erosions at the enthesis (indicative of structural damage) were the ultrasound findings most strongly associated with SpA. Notably, the insertion of the Achilles tendon emerged as the most discriminative entheseal site.[20]

Additionally, a subsequent paper of the DEUS study revealed a remarkable discrepancy between ultrasound and clinical examination in assessing enthesitis in patients with SpA, particularly at the Achilles tendon enthesis, which is traditionally regarded as a key site for the evaluation of enthesitis in patients with SpA.[21]

These studies highlight the challenges of relying solely on clinical examination for assessing enthesitis. Conversely, while ultrasound may offer greater accuracy than clinical examination, it alone does not provide a comprehensive view of the pathology or its impact on patient symptoms and functionality.

Therefore, we hypothesise that employing a tool that combines imaging (ie, ultrasound) with clinical examination findings could provide a more comprehensive assessment of enthesitis, thus potentially offering a better representation of disease activity in this domain.

Based on these premises, the main objectives of the current study were:

- To construct a new composite score, the DEUS Enthesitis Index (DEI), encompassing ultrasound and clinical evaluation findings for the assessment of enthesitis in patients with SpA.
- To examine the relationships between DEI and clinical features in this population, compared with the clinical examination of the entheses alone.

For completeness, the relationship between DEI and clinical features in the SpA population was also assessed in comparison to ultrasound examination of the entheses alone.

MATERIAL AND METHODS

Study design and participants

The DEUS study was an observational, cross-sectional, multicentric study involving 20 rheumatology centres across 11 countries. A detailed description of the DEUS study has been published previously.[20] Briefly, the DEUS study enrolled consecutive patients with SpA, including axSpA and PsA, based on established classification criteria.[4–6] A control group was included in the original work made by patients with OA and FBM (not used in the current analysis).

Participants (both axSpA and PsA) were excluded if they:

- Were younger than 18 years old.
- Had a history of major knee or ankle surgery or trauma.
- Engaged in intense physical activity in the 2 weeks preceding the clinical evaluation (≥5 hours per week of high-impact exercise that places significant mechanical stress on lower limb entheses, such as running, jumping or heavy weightlifting).
- Had a concomitant diagnosis of FBM according to the 2010 American College of Rheumatology Preliminary Diagnostic Criteria for Fibromyalgia and updated version.[22]

Clinical data collection

For all patients with SpA, the following clinical data were collected: age, sex, weight, height, body mass index, physical activity (frequency per week), cardiovascular disease (metabolic syndrome, diabetes, dyslipidaemia, hypertension), erythrocyte sedimentation rate, C-reactive protein (CRP), current DMARD therapy, use of NSAIDs or steroids, disease duration, previous episodes of enthesitis (diagnosed by a physician), presence of psoriasis or inflammatory bowel disease and HLA-B27 status (when clinically indicated).

In addition, the following disease activity indices were collected:

- Tender (0/68) and swollen (0/66) joint counts for both patients with axSpA and patients with PsA.

- Disease Activity in Psoriatic Arthritis (DAPSA) score for patients with PsA.[23]
- Leeds Enthesitis Index (LEI) for both patients with axSpA and patients with PsA.[24]
- Ankylosing Spondylitis Disease Activity Score (ASDAS), Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), Bath Ankylosing Spondylitis Functional Index and Bath Ankylosing Spondylitis Metrology Index for patients with axSpA.[25–28]
- Health Assessment Questionnaire Disability Index (HAQ-DI) and Visual Analogue Scale (VAS) global pain for both patients with axSpA and patients with PsA.[29]

Enthesis assessment and construction of DEI

The following lower limb entheses were included in the current study:

- Patellar insertion of the quadriceps tendon.
- Patellar (proximal) insertion of the patellar tendon.
- Tibial (distal) insertion of the patellar tendon.
- Calcaneal insertion of the Achilles tendon.
- Calcaneal insertion of the plantar fascia.

These entheses were evaluated on the same day both via ultrasound and physical examination by rheumatologists who were blinded to the patients' clinical data, including clinical examination of entheses.

Clinical enthesitis was diagnosed based on tenderness on pressure, mobilisation or contraction against resistance, with or without swelling at the enthesis.[30–32]

Ultrasound enthesitis was defined as either the presence of PD signal at the enthesis of grade ≥1 plus entheseal thickening and/or hypoechoic areas, or PD signal at the enthesis of grade >1, regardless of the presence of entheseal thickening or hypoechoic areas, as previously defined by our group.[20 33] For plantar fascia, the definition of 'active enthesitis' allowed the presence of entheseal thickening and hypoechoic areas (both had to be present), independent of PD signal, given the very low prevalence of the latter feature at this entheseal site. The elementary lesions of enthesitis (ie, PD signal, entheseal thickening, hypoechoic areas, enthesophytes and bone erosions) were defined according to OMERACT.[10 11]

Before the current study, the authors conducted an online exercise to assess both inter-rater and intrarater reliability regarding the agreement on OMERACT ultrasound elementary lesions of enthesitis.[34] Active discussions within the DEUS group were held to address image interpretation errors and enhance overall reliability throughout the study.

The details of the ultrasound machines used during the study have been reported in online supplemental table 1.

A score of 1.0 for clinical enthesitis and 1.0 for ultrasound enthesitis was assigned for each of the 10 entheses evaluated. The total score of DEI at the entheseal level could range from 0 to 2 (if both clinical enthesitis and DEUS active enthesitis were present) and from 0 to 20 at the patient level. A comparative score based solely on clinical enthesitis (without ultrasound findings) was also used, alongside an ultrasound score without clinical examination findings for comparison, with both scores ranging from 0 to 1 at the entheseal level and from 0 to 10 at the patient level. A representative visualisation of the DEI is provided in figure 1.

Statistical analysis

For categorical variables, frequencies and proportions were reported. Continuous variables were summarised as either means with SD or medians with IQR. Normality assumptions were verified using the Shapiro-Wilk test, graphical density plots and quantile–quantile plots. Homogeneity of variances was assessed with the F-test. The distributions of the DEI across axSpA and PsA populations were compared using Kolmogorov-Smirnov's test.

Simple, unadjusted logistic regression models were constructed to evaluate the association of DEI with the presence of enthesophytes and bone erosions at the enthesis on ultrasound examination in both patients with axSpA and patients with PsA. DEI was treated as the independent variable, while outcomes such as CRP levels, enthesophytes and bone erosions were dependent variables. Spearman's correlations between DEI and clinically relevant disease domains such as CRP levels, disease activity scores and patient-reported outcomes were performed. Specifically, ASDAS and BASDAI were used for patients with axSpA, DAPSA score for patients with PsA, LEI, HAQ-DI and VAS global pain for both patients with axSpA and patients with PsA. For logistic regression models, the linearity between continuous predictors and the logit of the outcome was assessed using interaction terms (Box-Tidwell test) and by plotting the fitted logit values against the predictors to visually inspect the relationship. Multicollinearity among predictors was evaluated by calculating the Variance Inflation Factor, with values below 5 considered acceptable. To evaluate the utility of DEI across various clinically relevant disease outcomes, we compared it against a clinical enthesitis only score and an ultrasound enthesitis only score. For each outcome, we fitted two models: one using DEI and another using the clinical enthesitis only score or ultrasound enthesitis only score as the predicting variable. Both models were adjusted for age and sex. For binary outcomes (namely ultrasound enthesophytes and bone erosions at the enthesis), logistic regression models were fitted. For continuous outcomes, such as CRP levels, HAQ-DI, ASDAS, BASDAI, DAPSA, LEI and VAS pain, univariable regression models were fitted using Gamma regression with a log link to account for the right-skewed distribution of the outcomes. DEI was also evaluated for skewness, and the relationship between DEI and the log-transformed outcome was assessed graphically by plotting fitted log values against the predictors. No transformations were applied to the DEI, as the linearity assumption on the log scale was visually confirmed. The performance of models using DEI and clinical enthesitis only score and ultrasound enthesitis only score was compared using the Akaike Information Criterion (AIC) and the Bayesian

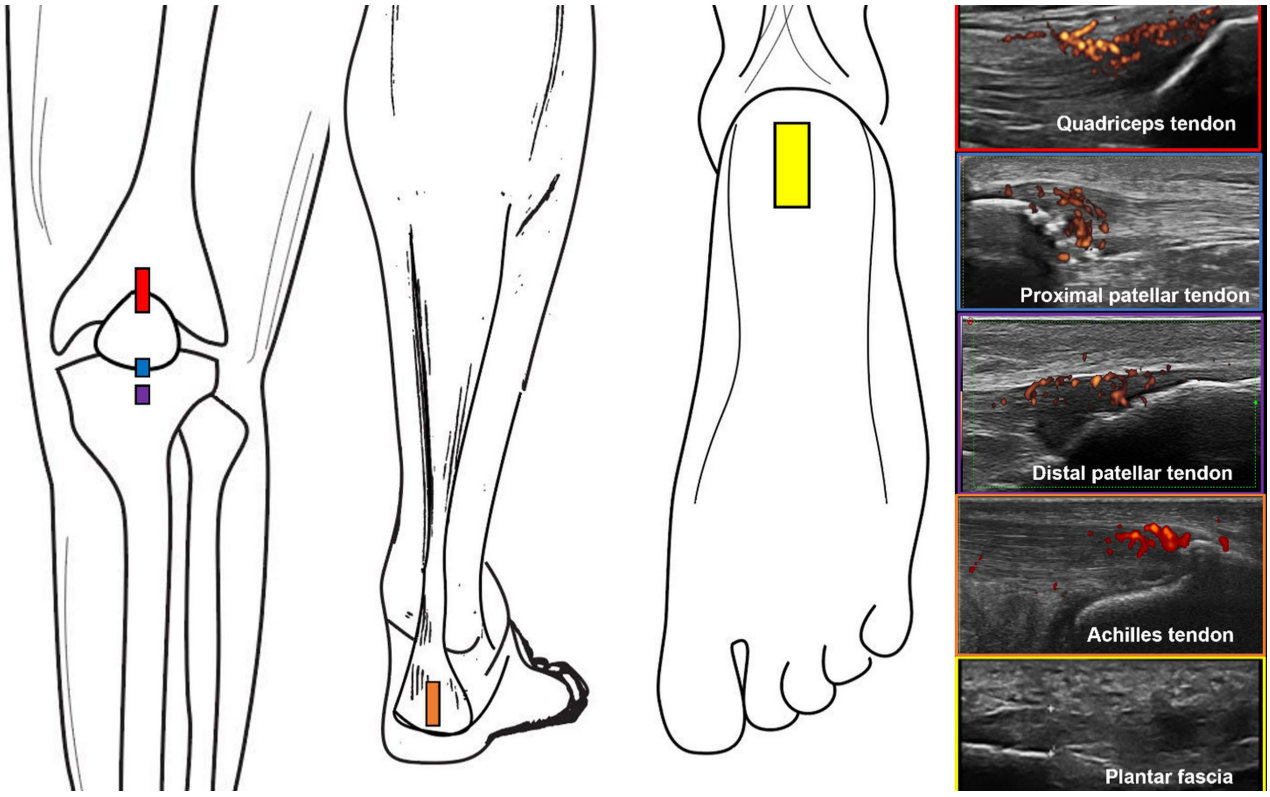


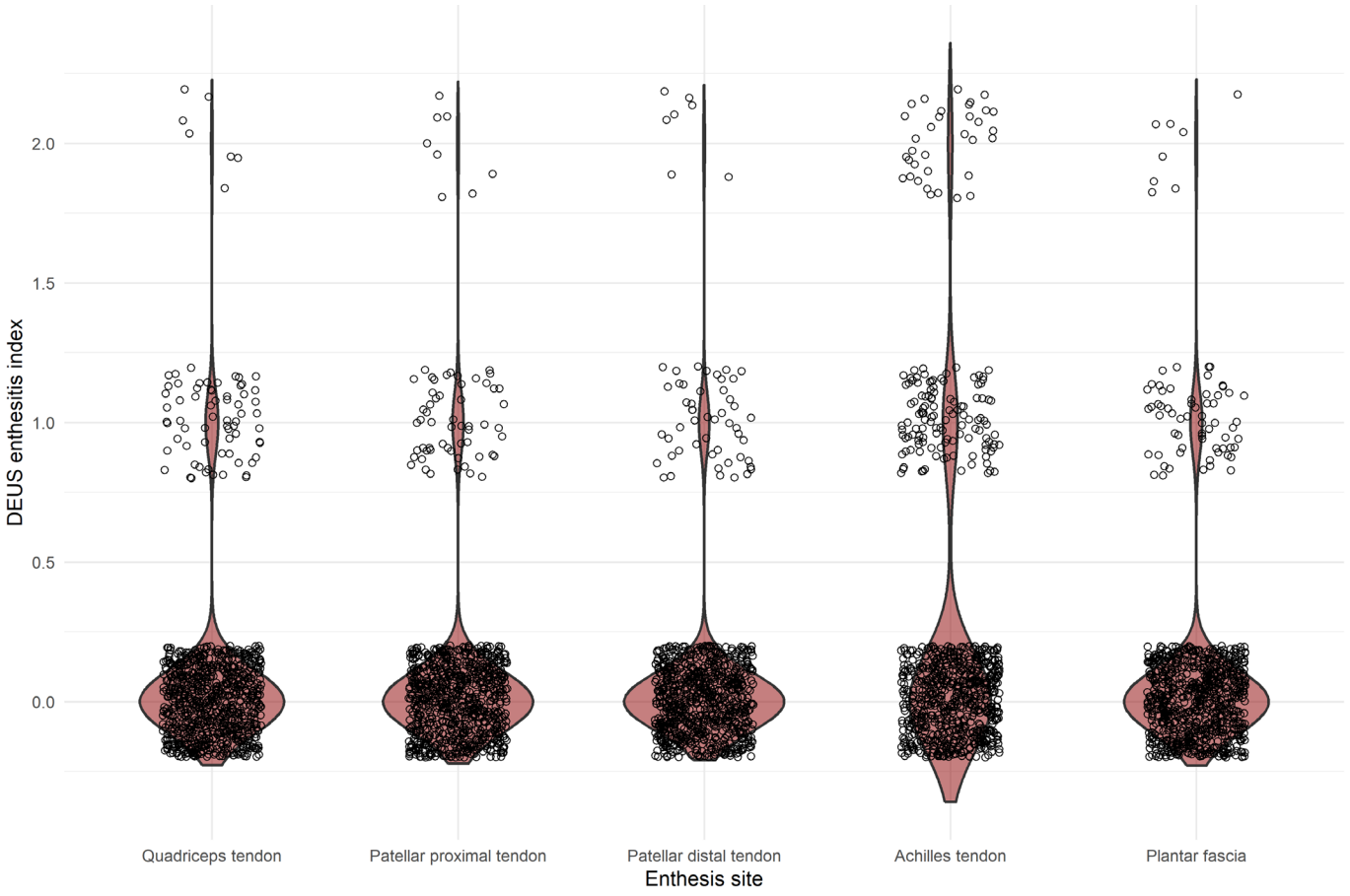
Figure 1 Image representation of the DEI. A score of 1.0 for clinical enthesitis and 1.0 for ultrasound enthesitis was assigned for each of the 10 entheses evaluated: quadriceps tendon (red), proximal patellar tendon (blue), distal patellar tendon (purple), Achilles tendon (orange) and plantar fascia (yellow). Ultrasound enthesitis was defined as either a power Doppler (PD) signal at the enthesis of grade ≥1 accompanied by entheseal thickening and/or hypoechoic areas, or a PD signal at the enthesis of grade >1, regardless of the presence of thickening or hypoechoic areas (reference n.[20]). For the plantar fascia, ultrasound enthesitis was also defined as the presence of entheseal thickening and hypoechoic areas regardless of the presence of PD signal. The total score of DEI at the entheseal level could range from 0 to 2 (if both clinical enthesitis and ultrasound enthesitis were present) and from 0 to 20 at the patient level. DEI, DEUS (Defining Enthesitis on Ultrasound in Spondyloarthritis) Enthesitis Index.

Information Criterion (BIC). Lower AIC and BIC values indicate better model fit, with a difference >2 considered evidence for the model with the smaller AIC.[35 36] These criteria allowed us to evaluate the relative performance of DEI and clinical enthesitis only score and ultrasound enthesitis only score across the different outcomes in a statistically robust manner. Further exploratory analyses were conducted using alternative composite indices. One index excluded the plantar fascia, as it did not differentiate between patients with SpA and controls in our previous study.[20] Another model defined active enthesitis based on entheseal thickening and/or hypoechoic areas, without the presence of PD signal. These analyses aimed to assess the fit of these indices and the clinical and demographic features of patients with SpA, in comparison to clinical and ultrasound examinations alone. All analyses were performed using R V.4.3.3 (R Core Team, 2024. R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The current study included 413 patients with SpA, comprising 224 patients with axSpA and 189 patients with PsA. Demographic features, clinical characteristics and treatment details of these patients are reported in online supplemental tables 2–4.

The median DEI values among patients with SpA at the patient level were 1.0 (IQR 0.0–3.0). The density distribution of DEI values in patients with SpA is illustrated in online supplemental figure 1. The prevalence and distribution of DEI values (with a breakdown of the clinical and ultrasound components) across different entheses in patients with SpA are reported in figure 2 (SpA) and figure 3 (divided by axSpA and PsA). As highlighted in these figures, higher DEI values were observed at the Achilles tendon enthesis compared with other entheseal sites in patients with SpA. Additionally, no significant difference in the density distribution of DEI values at the patient level was observed between patients with axSpA and patients with PsA (median 1.0 (IQR 0.0–2.0) vs 1.0 (IQR 0.0–3.0), respectively; p value=0.31), as shown in online supplemental figure 2. Table 1 reports significant correlations between DEI values and CRP levels, disease activity indices (i.e., LEI, ASDAS, BASDAI), patient's reported outcomes (i.e., HAQ, VAS global pain), and positive associations with ultrasound-detected structural damage at the enthesis (i.e., enthesophytes and bone



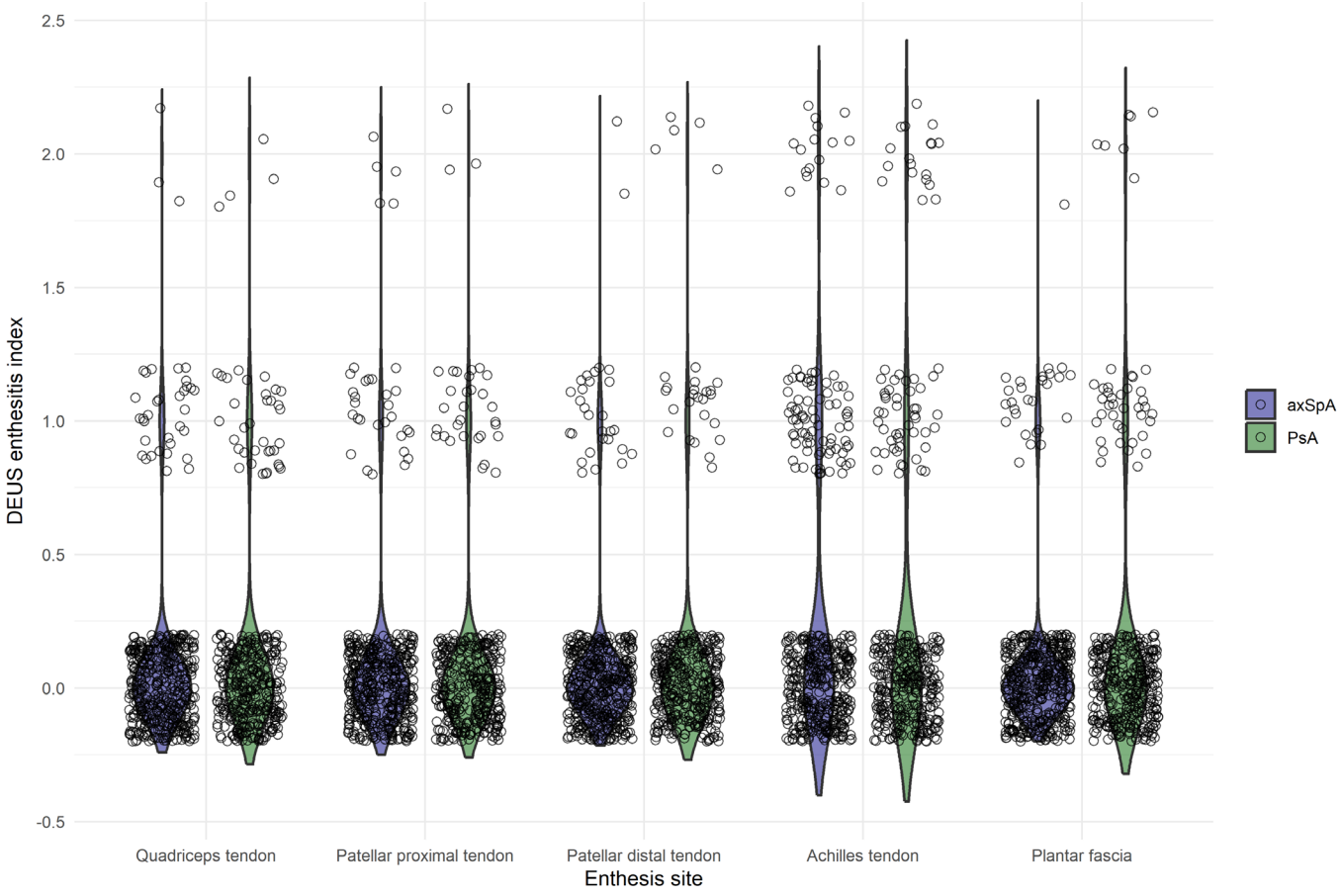
DEUS index value	Quadriceps tendon	Patellar proximal tendon	Patellar distal tendon	Achilles tendon	Plantar fascia
0.0	753/826	762/826	769/826	670/826	756/826
1.0 – Clinical enthesitis	40/826	39/826	24/826	97/826	57/826
1.0 – US enthesitis	26/826	17/826	26/826	25/826	5/826
2.0	7/826	8/826	7/826	34/826	8/826

Figure 2 Prevalence and distribution of DEI values (with a breakdown of ultrasound and clinical examination components) and the density distribution in patients with SpA (axSpA and PsA) at the entheseal level across different entheses. axSpA, axial spondyloarthritis; DEI, DEUS enthesitis index; DEUS, Defining Enthesitis on Ultrasound in Spondyloarthritis; PsA, psoriatic arthritis; SpA, spondyloarthritis; US, ultrasound.

erosions). No significant correlation was found between DEI values and DAPSA in PsA patients.

When comparing DEI models to clinical examination alone models, as shown in table 2, the models using DEI exhibit a better fit with CRP levels and ultrasound-detected structural damage at the enthesis (ie, enthesophytes and bone erosions). In contrast, models based solely on clinical examination alone showed a better fit with ASDAS, BASDAI, DAPSA, HAQ-DI, LEI and VAS global pain values. Furthermore, as shown in table 3, when compared with models based on ultrasound examination alone, the models using DEI exhibit a better fit with CRP levels and other clinical features, including ASDAS, BASDAI, DAPSA, HAQ-DI, LEI and VAS global pain values. In contrast, models based on ultrasound examination alone showed a better fit with ultrasound-detected bone erosions at the enthesis.

Further models were analysed, including the impact of excluding the plantar fascia, the impact of different definitions of 'active' enthesitis and their fit with the clinical and demographic features of patients with SpA, compared with clinical examination and ultrasound examination alone. The results are presented in online supplemental tables 5–8. In addition, the fit between the clinical-based model and ultrasound-based model across



	Quadriceps tendon		Patellar proximal tendon		Patellar distal tendon		Achilles tendon		Plantar fascia	
DEUS index value	AxSpA	PsA	AxSpA	PsA	AxSpA	PsA	AxSpA	PsA	AxSpA	PsA
0.0	413/448	340/378	416/448	346/378	419/448	350/378	356/448	314/378	421/448	335/378
1.0 – Clinical	22/448	18/378	20/448	19/378	17/448	7/378	62/448	35/378	26/448	31/378
1.0 – US	10/448	16/378	7/448	10/378	10/448	16/378	14/448	11/378	0/448	5/378
2.0	3/448	4/378	5/448	3/378	2/448	5/378	16/448	18/378	1/448	7/378

Figure 3 Prevalence and distribution of DEI values (with a breakdown of ultrasound and clinical examination components) and the density distribution in patients with SpA, categorised by axSpA and PsA, at the entheseal level across different entheses. Purple: patients with axSpA; Green: patients with PsA. axSpA, axial spondyloarthritis; DEI, DEUS enthesitis index; DEUS, Defining Enthesitis on Ultrasound in Spondyloarthritis; PsA, psoriatic arthritis; SpA, spondyloarthritis; US, ultrasound.

different domains of patients with SpA has been reported in online supplemental table 9.

DISCUSSION

To our knowledge, this is the first study to develop a tool that combines ultrasound and clinical evaluation findings to assess enthesitis in patients with SpA. Traditionally, enthesitis in patients with SpA has been primarily evaluated through clinical examination, using scoring systems such as the LEI, the Spondyloarthritis Research Consortium of Canada Enthesitis Index, the Maastricht Ankylosing Spondylitis Enthesitis Score, the University of California, San Francisco index and the Berlin index, widely used in clinical practice and research trials.[24 37–40] Clinical trials assessing drug efficacy for enthesitis typically rely on clinical examination findings like pain reduction; conversely, only a few studies incorporate ultrasound to assess treatment response.[8 41–44]

Studies have highlighted discrepancies between ultrasound and clinical examination findings in the assessment of enthesitis, suggesting limitations in relying solely on clinical examination to evaluate entheseal involvement in patients with SpA.[45–47] While clinical examination may not fully capture clinically relevant inflammation levels (eg, subclinical enthesitis), a recent study showed that ultrasound did not dimostrate 'active inflammation' in more than

Table 1 Correlation between the DEI values and clinical or serological characteristics of patients with SpA and unadjusted association between the DEI with ultrasound structural damage lesions

	DEI		
Outcome	**Rho***		**P value†**
CRP (axSpA and PsA)	0.117		0.018
ASDAS (axSpA)	0.386		<0.001
BASDAI (axSpA)	0.402		<0.001
DAPSA (PsA)	0.113		0.12
VAS global pain (axSpA and PsA)	0.303		<0.001
HAQ-DI (axSpA and PsA)	0.294		<0.001
LEI (axSpA and PsA)	0.568		<0.001
	OR	**95% CI**	**P value†**
US enthesophytes (axSpA and PsA)	1.58	1.34 to 1.94	<0.001
US bone erosions (axSpA and PsA)	1.35	1.19 to 1.54	<0.001

*Spearman's regression analysis.
†Bonferroni correction for multiple testing.
ASDAS, Ankylosing Spondylitis Disease Activity Score; axSpA, axial spondyloarthritis; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; CRP, C-reactive protein; DAPSA, Disease Activity in Psoriatic Arthritis; DEI, DEUS Enthesitis Index; DEUS, Defining Enthesitis on Ultrasound in Spondyloarthritis; HAQ-DI, Health Assessment Questionnaire Disability Index; LEI, Leeds Enthesitis Index; PsA, psoriatic arthritis; SpA, spondyloarthritis; US, ultrasound; VAS, Visual Analogue Scale.

two-thirds of patients with SpA who exhibited clinical signs of enthesitis.[21] This suggests a potential risk of overestimating enthesitis when relying solely on clinical examination.[21] Additionally, previous studies have demonstrated the higher specificity of ultrasound compared with clinical examination.[20 48 49] While clinical examination remains valuable for assessing pain and functional status, which are crucial for an integrated approach to patient management, its specificity may be limited in patients with conditions, such as chronic pain or 'mechanical' enthesitis, where tenderness can occur without active inflammation. Therefore, incorporating ultrasound findings, which offer greater specificity, enhances the accuracy of enthesitis assessment, potentially leading to more precise evaluation and monitoring of patients with SpA.[50 51]

Notably, recent studies have revealed the low specificity of certain ultrasound features (eg, entheseal thickening, hypoechoic areas, enthesophytes) for diagnosing SpA.[52] Addressing this challenge, we introduced a novel definition of 'active enthesitis' (ie, DEUS active enthesitis), which primarily relies on the presence of a PD signal at the enthesis (within 2 mm from the bone as per OMERACT definition), isolated (when moderate or higher grades are present) or in association with other inflammatory lesions, such as entheseal thickening and hypoechoic areas.[10 11 20] DEUS active enthesitis has demonstrated high discriminative value for SpA, although with a relatively low prevalence, and the strongest associations - among ultrasound lesions - with clinical features of disease activity and severity in a recent large multicentric study.[20] For these reasons, we opted to incorporate this ultrasound-based criterion for defining 'active' enthesitis in the current study. Indeed, in the current study, when

Table 2 Comparison between DEI and clinical enthesitis-based models across various disease outcomes in patients with SpA

Outcome	Model DEI AIC	Model clinical AIC	Model DEI BIC	Model clinical BIC	Delta AIC (clinical—DEI)	Delta BIC (clinical—DEI)	Delta AIC better model
CRP (axSpA and PsA)	1129.04	1132.63	1148.08	1153.66	7.59	5.58	DEI
ASDAS (axSpA)	778.56	773.88	795.68	791.01	−4.68	−4.67	Clinical
BASDAI (axSpA)	961.79	958.74	979.30	976.24	−3.05	−3.06	Clinical
DAPSA (PsA)	1405.85	1403.22	1422.29	1419.67	−2.63	−2.62	Clinical
VAS global pain (axSpA and PsA)	3859.86	3847.33	3879.95	3867.42	−12.53	−12.53	Clinical
HAQ-DI (axSpA and PsA)	−665.68	−667.82	−646.11	−648.26	−2.14	−2.15	Clinical
LEI *(axSpA and PsA)*	1181.89	1043.71	1201.96	1063.78	−138.18	−138.18	Clinical
US enthesophytes (axSpA and PsA)	334.60	355.79	350.65	371.88	21.19	21.23	DEI
US bone erosions (axSpA and PsA)	429.41	458.20	445.46	474.29	28.79	28.83	DEI

Models are adjusted for age and sex.
AIC, Akaike Information Criterion; ASDAS, Ankylosing Spondylitis Disease Activity Score; axSpA, axial spondyloarthritis; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BIC, Bayesian Information Criterion; CRP, C-reactive protein; DAPSA, Disease Activity in Psoriatic Arthritis; DEI, DEUS enthesitis index; DEUS, Defining Enthesitis on Ultrasound in Spondyloarthritis; HAQ-DI, Health Assessment Questionnaire Disability Index; LEI, Leeds Enthesitis Index; PsA, psoriatic arthritis; SpA, spondyloarthritis; US, ultrasound; VAS, Visual Analogue Scale.

Table 3 Comparison between DEI and ultrasound-based models across various disease outcomes in patients with SpA

Outcome	Model DEI AIC	Model US AIC	Model DEI BIC	Model US BIC	Delta AIC (US—DEI)	Delta BIC (US—DEI)	Delta AIC better model
CRP (axSpA and PsA)	1129.04	1142.27	1148.08	1162.30	13.23	12.22	DEI
ASDAS (axSpA)	778.56	793.04	795.68	810.16	14.48	14.48	DEI
BASDAI (axSpA)	961.79	971.67	979.30	989.18	9.88	9.88	DEI
DAPSA (PsA)	1405.85	1405.98	1422.29	1421.91	−0.13	−0.38	–
VAS global pain (axSpA and PsA)	3859.86	3884.38	3879.95	3904.46	24.52	24.51	DEI
HAQ-DI (axSpA and PsA)	−665.68	−656.77	−646.11	−637.20	8.91	8.91	DEI
LEI (axSpA and PsA)	1181.89	1328.75	1201.96	1348.22	146.86	146.26	DEI
US enthesophytes (axSpA and PsA)	334.60	332.81	350.65	348.91	−1.79	−1.74	–
US bone erosions (axSpA and PsA)	429.41	426.89	445.46	442.50	−2.52	−2.96	US

Models are adjusted for age and sex.
AIC, Akaike Information Criterion; ASDAS, Ankylosing Spondylitis Disease Activity Score; axSpA, axial spondyloarthritis; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BIC, Bayesian Information Criterion; CRP, C-reactive protein; DAPSA, Disease Activity in Psoriatic Arthritis; DEI, DEUS enthesitis index; DEUS, Defining Enthesitis on Ultrasound in Spondyloarthritis; HAQ-DI, Health Assessment Questionnaire Disability Index; LEI, Leeds Enthesitis Index; PsA, psoriatic arthritis; SpA, spondyloarthritis; US, ultrasound; VAS, Visual Analogue Scale.

other 'non-active' inflammatory lesions defined by the OMERACT criteria (such as entheseal thickening and hypoechoic areas) were used to define enthesitis instead of DEUS active enthesitis, the overall model performance was inferior (online supplemental tables 7 and 8). This was evidenced by a higher AIC and weaker associations with CRP (compared with the clinical examination alone model) and ultrasound-detected bone erosions (compared with the ultrasound examination alone model). Similarly, the model excluding the plantar fascia from DEI performed worse than the DEI model that included it, as illustrated in online supplemental tables 5 and 6.

It is important to note that variations in the definition of PD signal at the enthesis may occur depending on the ultrasound scoring system used. For example, the presence of a PD signal according to OMERACT is defined when present within 2 mm of the enthesis.[10 11] This differs from other scores, such as the GRAPPA scoring system, which may define the PD signal zone more broadly.[15] Further studies may be needed to evaluate the implications of these differences across various scoring systems.

In this study, DEI scores were notably higher at the Achilles tendon enthesis compared with other evaluated entheses (see figures 2 and 3), highlighting the significance of this entheseal site in assessing patients with SpA.[53] However, there were no substantial differences in DEI distribution between patients with axSpA and patients with PsA across various entheses (see figure 3). The relatively low DEI values in our cohort can be attributed to approximately half of the patients with SpA being in low disease activity or remission, with the majority receiving treatment (see online supplemental tables 2 and 3). Therefore, the relevance of DEI in a more clinically active population warrants further investigation. In addition, the prevalence of 'previous enthesitis' in our study appears lower than what is typically observed in clinical practice,[54] with reported rates of 35% in axSpA and 21% in PsA in the current study. This discrepancy can be attributed to the fact that enthesitis in our study was physician-diagnosed, which may lead to under-reporting, as physicians might not have systematically assessed for enthesitis in all patients, particularly if it was not the primary focus of care. For example, in patients with concomitant joint or axial disease, attention may have been directed toward dominant symptoms, resulting in less emphasis on diagnosing or documenting enthesitis, even if present. Indeed, in our study, the prevalence of clinical enthesitis (when systematically evaluated) on physical examination in patients with axSpA and patients with PsA was over 30%, which makes the overall prevalence of entheseal involvement in SpA consistent with what has been previously described in the literature.

DEI values showed significant correlations with various clinical parameters in patients with SpA, including CRP levels, clinical based disease activity indices (ie, ASDAS, BASDAI, LEI), patient-reported outcomes (ie, VAS global pain and HAQ-DI) and ultrasound-detected structural damage at the enthesis (ie, enthesophytes and bone erosions). These correlations suggest that DEI may capture aspects of both clinical and imaging-based enthesitis burden. Conversely, no correlation was found between DEI and DAPSA values, potentially highlighting the distinct domains of joint and entheseal involvement in SpA disease.[3] The relationship between entheses and joints in patients with SpA has been widely debated. As recently discussed by major associations such as GRAPPA, it remains unclear whether enthesitis is the primary driver of PsA and SpA, reflecting the ongoing debate between differing perspectives.[55] One theory suggests

that enthesitis triggers synovitis and musculoskeletal symptoms, a view supported by imaging advancements, cytokine studies and animal models. This perspective emphasises a strong link between enthesitis, osteitis and dactylitis, highlighting the role of local immunity at stress sites. Conversely, an alternative theory challenges the primacy of enthesitis, citing studies showing its absence in some early PsA cases, questioning its precedence over synovitis and noting differing treatment responses when these two domains are evaluated. Furthermore, the involvement of axial and peripheral entheses across the SpA spectrum may vary, and its relationship with clinical data in different SpA subtypes warrants further investigation.[56]

Compared with clinical examination only, the DEI demonstrated a better fit with CRP levels and ultrasound-detected structural damage at the enthesis, which are objective markers of inflammatory disease activity and severe entheseal involvement, respectively. In contrast, the clinical examination only model for the same entheses provided strong evidence for a better fit with SpA disease activity indices and VAS global pain scale, which are inherently more subjective. Furthermore, the results largely favoured the combined approach (ie, DEI) over ultrasound evaluation alone across multiple features in patients with SpA, indicating that this integrated tool may offer a more comprehensive assessment of enthesitis. However, it is important to underscore that our approach does not aim to establish the DEI as inherently superior to other enthesitis measures but rather explore the potential benefit of integrating these two modalities (clinical and ultrasound) into a single composite tool. The end goal is to create a more comprehensive measure that improves assessment accuracy by leveraging the strengths of both clinical and ultrasound examinations, rather than comparing their effectiveness in isolation.

Our findings suggest that bone erosions at the enthesis may represent a more objective measure of local inflammation compared with enthesophytes, given their stronger association with ultrasound-based models relying solely on the DEUS definition of entheseal 'active' inflammation. This is consistent with previous studies indicating that enthesophytes may arise not only from inflammatory processes but also in response to chronic mechanical stress or dysmetabolism, which can reduce their specificity for SpA-related entheseal inflammation.[20 52] Nevertheless, while the ultrasound-based model showed a trend for a better association with enthesophytes compared with DEI, this difference did not reach statistical significance. Future studies are needed to further investigate the clinical implications of different types of ultrasound findings of entheseal structural damage in patients with SpA, including their relationship with disease activity, severity, and other demographic and clinical factors.

Our novel tool, integrating ultrasound and clinical features into a single score for assessing disease activity within a specific clinical domain (ie, enthesitis), represents an absolute novelty in rheumatology. A previous study in rheumatoid arthritis (RA) has explored the additional value of ultrasound in established clinical disease activity measures, like the Disease Activity Score-28 joints, to improve the accuracy of disease activity assessment.[57] Previous attempts to demonstrate the superior value of ultrasound over clinical measurements in evaluating disease activity and treatment response, particularly in patients with RA, have often yielded inconclusive results.[58] As a result, clinical examination continues to be more widely adopted in rheumatology due to its practicality and the lack of need for specialised training or equipment.

We advocate for integrating ultrasound findings with clinical signs in the assessment of enthesitis, emphasising the crucial role of ultrasound in modern medical protocols, while acknowledging that clinical examination remains essential for evaluating this important domain of SpA. This combined approach can potentially offer significant advantages, enhancing diagnostic accuracy through the specificity of ultrasound and sensitivity of clinical examination. In addition, it might effectively reduce false positives and capture subtle cases of subclinical enthesitis, providing a comprehensive understanding of disease activity.

The main strength of this study lies in its novelty as the first to develop a tool combining ultrasound and clinical evaluation findings for the evaluation of enthesitis activity. Our study addresses a significant need in accurately assessing enthesitis in patients with SpA, which could potentially influence clinical practice and patient management, as well as the design of future clinical trials. The multicentric design of our study, which includes rheumatology centres worldwide and involves a large cohort of patients with axSpA and patients with PsA, along with the ultrasound and physical evaluation of over 4.000 entheses, enhances the generalisability and relevance of our results.

A major limitation of our study is its cross-sectional design, which precludes the ability to assess the sensitivity to change of the DEI. Future longitudinal studies in SpA populations with 'active' disease, particularly those starting treatment, will be essential for evaluating this aspect. Additionally, further investigation is needed to assess the prognostic value of the DEI in predicting worse disease outcomes, such as poor treatment response, structural damage development or functional limitations, especially in comparison with clinical-based enthesitis measurements like the LEI or others. Patients with PsA and axSpA and a concomitant diagnosis of FBM were excluded from the DEUS study. While this exclusion helps minimise confounding factors, it introduces a limitation by excluding a subset of patients for whom differentiating between FBM-related tenderness and SpA-related enthesitis is clinically relevant. This is particularly important, as enthesitis in patients with PsA with coexisting FBM can present significant diagnostic challenges.[59] It is crucial to emphasise that the DEI is not intended as a diagnostic method but rather as a comprehensive tool to evaluate entheseal disease activity and, potentially, monitor treatment response. Given this focus, the control group consisting of patients with OA and FBM part of the DEUS study was not

used in the current analysis, as their inclusion would not have contributed to assessing disease activity within SpA. Conversely, the exclusion of patients with PsA with FBM highlights the need for further studies to validate the DEI in populations with overlapping conditions, ensuring its applicability across a broader spectrum of patients. Another limitation of the study, and inherent to the nature of the entheseal disease domain, is the lack of a gold standard (eg, MRI or histology) for enthesitis assessment, which prevented formal specificity and sensitivity analyses. Future studies are needed to validate these findings. Furthermore, although an inter-rater reliability exercise on ultrasound-detected elementary enthesitis lesions was conducted among DEUS study participants prior to patient enrolment,[34] the reliability of this newly developed index, which combines ultrasound features with physical examination findings, as well as its feasibility in clinical practice and trials, including a formal analysis of the time required to perform it, still needs to be fully established. In addition, the ultrasound assessment relied on subjective criteria, and the absence of elastography, which provides a quantitative evaluation, further limits the findings. Finally, another limitation of this study is that only large lower limb entheses were included, excluding both large upper limb entheses (eg, lateral epicondyle, supraspinatus) and smaller entheses, such as those in the hands.[60] We believe further research is warranted to explore whether this integrated approach, combining clinical and ultrasound findings, could be extended to these additional sites.

CONCLUSIONS

The DEI is a novel tool designed to assess enthesitis activity in SpA. This index uniquely combines ultrasound-detected inflammation at the enthesis with clinical signs of enthesitis into a single comprehensive score. This integrated approach aims to offer a more comprehensive evaluation of enthesitis in patients with SpA and to provide a reliable assessment and monitoring of disease activity in this critical domain. In addition, the integration of imaging and clinical findings sets a precedent for developing comprehensive assessment tools in other domains of rheumatology.

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