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Original article

The utility of magnetic resonance imaging lesion combinations in the sacroiliac joints for diagnosing patients with axial spondyloarthritis. A prospective study of 204 participants including post-partum women, patients with disc herniation, cleaning staff, runners and healthy persons

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Abstract

Objectives. To investigate the diagnostic utility of different combinations of SI joint MRI lesions for differentiating patients with axial SpA (axSpA) from other conditions with and without buttock/pelvic pain.

Methods. A prospective cross-sectional study included patients with axSpA ($n = 41$), patients with lumbar disc herniation ($n = 25$), women with ($n = 46$) and without ($n = 14$) post-partum (birth within 4–16 months) buttock/pelvic pain and cleaning assistants ($n = 26$), long-distance runners ($n = 23$) and healthy men ($n = 29$) without pain. Two independent readers assessed SI joint MRI lesions according to the Spondyloarthritis Research Consortium of Canada MRI definitions and pre-defined MRI lesion combinations with bone marrow oedema (BME) and fat lesions (FAT), respectively. Statistical analyses included the proportion of participants with scores above certain thresholds, sensitivity, specificity, positive and negative predictive values and likelihood ratios.

Results. BME adjacent to the joint space (BME@joint space) was most frequent in axSpA (63.4%), followed by women with post-partum pain (43.5%), but was present in nearly all groups. BME adjacent to fat lesions (BME@FAT) and BME adjacent to erosions (BME@erosion) were only present in axSpA patients and in women with post-partum pain, but scores ≥ 3 and ≥ 4, respectively, were only seen in axSpA patients. FAT@erosion was exclusively recorded in axSpA patients. FAT@joint space and FAT@sclerosis were present in most groups, but with higher scores in the axSpA group.

Conclusion. BME@joint space and FAT@joint space were frequent in axSpA but also in other conditions, reducing the diagnostic utility. FAT@erosion, and BME@FAT, BME@erosion and FAT@sclerosis above certain thresholds, were exclusively seen in axSpA patients and may thus have diagnostic utility in the differentiation of axSpA from other conditions.

Key words: axial spondyloarthritis, magnetic resonance imaging, inflammation, post-partum women, sacroiliac joints

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CLINICAL SCIENCE

Rheumatology key messages

- MRI bone marrow oedema is not exclusively seen in axSpA, emphasizing the need to improve diagnostic accuracy.
- This is the first study investigating the utility of MRI lesion combinations for diagnosing axSpA.
- Assessment of MRI lesion combinations may improve the utility of MRI for diagnosing axSpA.

Introduction

Bone marrow oedema (BME) on MRI of the sacroiliac (SI) joints comprises one of the two cornerstones in the Assessment of Spondyloarthritis International Society (ASAS) classification criteria for axial SpA (axSpA) [1–3]. However, a number of studies have shown that BME in the SI joints is frequently present in conditions other than axSpA, such as non-specific back pain [4, 5], during pregnancy and post-partum [5–8] and in healthy persons [4], including athletes [6, 9] and military recruits [10]. To enhance the diagnostic accuracy of the axSpA diagnosis there has been an increasing focus on interpreting both active and structural MRI lesions, separately and in combination [11]. Studies of the diagnostic utility of structural SI joint MRI lesions such as SI joint erosion [12–14], fat lesions [12, 14, 15], sclerosis [5, 14] and ankylosis [13] have shown that ankylosis is primarily seen in patients with late disease, while fat lesions and erosions [4, 14] may have diagnostic utility in patients at an earlier disease stage.

In this prospective study, we hypothesized that certain combinations of MRI lesions, such as BME and fat lesions (FAT) in relation to structural MRI lesions in the SI joints, improve the utility of MRI for diagnosis of axSpA *vs* other groups that may have MRI signs of sacroiliitis for other reasons, such as post-partum women, patients with disc herniation, cleaning staff, long-distance runners and healthy persons. Therefore the aim was to investigate the diagnostic utility of the presence of BME and FAT adjacent to each other, adjacent to the joint space and adjacent to MRI structural lesions (FAT, erosion, sclerosis and ankylosis) to differentiate patients with axSpA from other conditions.

Methods

Subjects

The MASH study (Scientific investigation of MRI and biochemical markers in patients with axial spondyloarthritis, back pain of other reasons, subjects with strain on the sacroiliac joints and healthy subjects) was a prospective cross-sectional study conducted at Rigshospitalet Glostrup, in the Capital Region of Copenhagen, from 2013 to 2016. The study was approved by the local ethical committee (approval number H-17034960) and conducted according to the Declaration of Helsinki V and Danish law. All participants provided written informed consent before study inclusion.

The study included 204 participants comprising patients with axSpA ($n = 41$), lumbar disc herniation ($n = 25$) and women with post-partum buttock/pelvic pain ($n = 46$) and groups of healthy persons consisting of women without post-partum buttock/pelvic pain ($n = 14$) and persons with hard physical work, defined as hospital cleaning staff ($n = 26$), long-distance runners ($n = 23$) and healthy men ($n = 29$). Post-hoc, we defined a subgroup of women who had previously given birth from the disc herniation, cleaning staff and long-distance runner groups ($n = 38$).

Inclusion criteria

Patients with axSpA fulfilled the ASAS criteria for axSpA [1] and inflammatory back pain [16] and patients with lumbar disc herniation had symptoms, clinical and MRI findings consistent with nerve root compression. Both groups had symptoms $\geq$2 months and pain (BASDAI for axSpA patients) and physician global scores $\geq$2 (0–10). Women with post-partum pain had persistent buttock/pelvic pain $\geq$2 (0–10) after pregnancy and/or vaginal birth, with a symptom duration of at least 4 month and $<$16 months since last childbirth, whereas post-partum women without pain had a normal pregnancy and vaginal birth within the same time frame. A control group of healthy participants comprised cleaning staff who had worked $\geq$30 h/week for $\geq$2 months, long-distance runners who had been running $\geq$30 km/week for $\geq$2 months and healthy men. Supplementary Table S1, available at *Rheumatology* online, provides detailed information on inclusion and exclusion criteria and recruitment of study participants.

Exclusion criteria

For axSpA patients, prior treatment with TNF-α inhibitor was not allowed and no patients (axSpA and disc herniation) were allowed to initiate or change the dose of NSAIDs within 14 days prior to study inclusion. The exclusion criteria for all participants except for axSpA patients were any history of or hereditary dispositions to axSpA and SpA-associated diseases or clinical suspicion of an inflammatory, infectious or malignant cause for the back pain. Post-partum women were not allowed to have been hospitalized for back pain before their last pregnancy or to have been examined or treated by a physician for back pain within 3 years before the last pregnancy. Post-partum women without pain, female

cleaning assistants and runners were not allowed to have buttock/pelvic pain lasting >1 week from 4 months after the last childbirth.

Recruitment strategy

Patients with axSpA and disc herniation were recruited in the outpatient clinic of the Center of Rheumatology and Spine Diseases, Rigshospitalet Glostrup. Women with post-partum pain were recruited at a physiotherapy clinic in Copenhagen. Cleaning staff was recruited at Rigshospitalet Glostrup. The runners were recruited at running events in Copenhagen. Finally, women without post-partum pain and healthy men were recruited by advertisement and among the staff at Rigshospitalet Glostrup.

Patient evaluation

Demographics and clinical characteristics for all participants were acquired using a questionnaire and past medical history was collected by a physician. All participants were assessed for meeting the ASAS classification criteria for axSpA. Blood samples were analysed for serum CRP and HLA-B27 and MRI of the SI Joints was performed.

MRI methodology

The SI joint MRIs were performed at Rigshospitalet Glostrup on a 1.5 T Siemens Avanto scanner, version Syngo MR B17 with Numaris/4 software. The images obtained included a semicoronal short tau inversion recovery sequence with repetition time (TR) 4000 ms, inversion time (TI) 160 ms, echo time (TE) 37 ms, slice thickness 4 mm, gap 0.4 mm, field of view 26 × 26 cm and matrix size 205 × 256 and a semicoronal T1-weighted sequence with TR 660 ms, TE 11 ms, slice thickness 4 mm, gap 0.3 mm, field of view 23 × 23 cm and matrix size 320 × 256. The MRIs were anonymized and evaluated independently and in random order by two experienced readers (a radiologist and a rheumatologist with extensive MRI SI joint reading experience) who were blinded to clinical, biochemical and other imaging data. The entire cartilaginous compartment of the SI joint was covered by nine MRI slices. Each SI joint in each slice was systematically assessed for inflammatory and structural lesions according to the lesion definitions of the Spondyloarthritis Research Consortium of Canada (SPARCC) SI Joint Inflammation Index [17] and SPARCC Sacroiliac Structural Score (SSS) [18] and MORPHO definitions [1, 12]. MRI sclerosis was defined as a hypointense signal on both MRI sequences extending ≥5 mm perpendicular to the joint space. In each of the nine slices both SI joints were assessed separately for the presence of nine pre-defined combinations of MRI lesions: BME located adjacent to joint space (BME@joint space), BME adjacent to FAT (BME@FAT), BME adjacent to sclerosis (BME@sclerosis), BME adjacent to erosion (BME@erosion) and BME adjacent to ankylosis (BME@ankylosis), and similarly, FAT adjacent to joint space (FAT@joint space), sclerosis (FAT@sclerosis), erosion (FAT@erosion) and ankylosis (FAT@ankylosis). For each of the nine slices, data were entered in a database by use of a schematic supporting simultaneous MRI evaluation and data recording. When a certain lesion combination was present, a score of 1 per slice per joint was given. Finally, a total 'nine-slices lesion combination score' for each of the pre-defined lesion combinations was calculated, resulting in a total score range of 0–18 per patient per lesion combination type.

Statistical analysis

Data were analysed by descriptive statistics and non-parametric tests and a *P*-value ≤0.05 was considered to be statistically significant. Intraclass correlation coefficient (ICC) was used to assess the interreader agreement on MRI lesions based on a two-way random effects single-measure model for absolute agreement. Values from 0.0 to 0.2 were considered poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good and 0.81–1.00 very good agreement, respectively [19]. Sensitivity, specificity, positive and negative predictive values (PPV and NPV) and likelihood ratios were used to determine the diagnostic utility of MRI lesion combinations for axSpA. The primary analysis was based on reader agreement ('concordant reads') on the presence of the individual lesion combinations. Statistical analyses were performed in SPSS version 22.0 (IBM, Armonk, NY, USA).

Results

Demographic, clinical and biochemical characteristics

Table 1 provides the demographic, clinical and biochemical characteristics of the participants stratified according to participant group. The participants overall comprised 41.2% males, had a mean age of 33.2 years (range 19–45) and 22% were HLA-B27 positive. Participants with pain had a mean symptom duration of 3.7 years (range 0.2–24) and a mean low back pain visual analogue scale (VAS) score of 2.8 (range 0–10).

MRI SI joint lesion scores

The lesion scores as the mean of the two readers for the individual groups of participants are shown in Supplementary Table S2, available at *Rheumatology* online. The interreader reliability was good or very good, except for sclerosis. BME, FAT and erosion (mean 6.5, 8.0 and 3.8, respectively) showed statistically significantly higher scores in patients with axSpA as compared with the other groups, followed by women with post-partum pain (mean 2.9, 0.7 and 0.5, respectively), although present in nearly all groups. Ankylosis was only recorded in the axSpA group.

Table 1 Demographic, clinical and biochemical characteristics of the different groups of study participants

Characteristics	AxSpA	Women with post-partum pain	Women without post-partum pain	Disc herniation	Cleaning staff	Long-distance runners	Healthy men	Women with one or more childbirths from the disc herniation, cleaning staff and runner groups[a]
Participants, *n*	41	46	14	25	26	23	29	38
Age, years	30.9 (6.4)/ 30.0 (19–44)	32.6 (3.3)/ 32.5 (26–41)*	33.1 (4.1)/ 32.5 (27–41)	35.2 (5.7)/ 37 (21–43)**	39.1 (4.6)/ 39 (28–45)***	32.7 (6.2)/ 32 (22–43)	30.9 (6.4)/ 30 (20–45)	38.7 (4.4)/ 39.0 (27–45)***
Sex, male, *n* (%)	26 (63.4)	0***	0***	11.0 (44.0)	0***	18 (78.3)	29 (100)***	0***
Childbirths, if female	1.7 (0.8)/ 2 (0–2)	1.5 (0.8)/ 1 (1–4)	1.9 (0.8)/ 2 (1–3)	1.6 (0.9)/ 2 (0–3)	2.54 (1.1)/ 3 (0–5)	0.5 (1.0)/ 0 (0–2)	NA/NA	2.4 (0.9)/ 2 (1–5)
Time since last childbirth, if female	4.9 (4.6)/ 4.7 (0.8–9.3)	0.7 (0.3)/ 0.7 (0.3–1.3)**	0.8 (0.3)/ 0.9 (0.3–1.1)*	9.1 (7.0)/ 6.6 (2.0–21.5)	10.5 (6.3)/ 10.3 (1.7–22.3)	5.7/5.7 (5.7–5.7)	NA	9.7 (6.4)/ 10.0 (1.7–22.3)
Symptom duration, years	8.4 (5.6)/ 8.4 (1.2–23.8)	1.0 (0.8)/ (0.3–6.0)***	NA	1.0 (0.9)/ 0.7 (0.2–3.6)***	NA	NA	NA	NA
Low back pain VAS (0–10)	3.8 (2.8)/ 3.7 (0–10.0)	5.5 (2.4)/ 6.0 (0–9.8)**	0.4 (0.7)/ 0 (0–1.9)***	5.5 (2.4)/ 6.2 (0.3–9.6)*	0.8 (1.8)/ 0 (0–6.8)***	0.2 (0.5)/ 0 (0–1.5)***	0.1 (0.3)/ 0 (0–1.2)***	2.4 (3.2)/ 0 (0–9.6)**
HLA-B27 positive, *n* (%)	33 (80.5)	5 (10.9)***	1 (7.1)***	0***	0***	1 (4.3)***	4 (13.8)***	0***
CRP >3 mg/l, *n* (%)	24 (58.5)	8 (17.4)***	3 (21.4)**	5 (20.0)**	4 (15.4)**	4 (17.4)**	1 (3.4)***	7 (18.4)***

Values presented as mean (S.D.)/median (minimum–maximum) unless stated otherwise. Mann–Whitney test was applied and all tests are patients with axSpA compared with the other groups. [a]The mean time since last delivery was 9.7 years (range 1.7–22.3); 10 (26.3%) had their last delivery <5 years ago, 10 (26.3%) 5–10 years ago and 18 (47.4%) >10 years ago. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 2 MRI interreader reliability and mean relation scores for BME and FAT, stratified by participant group

Characteristics		AxSpA	Women with post-partum pain	Women without post-partum pain	Disc herniation	Cleaning staff	Long-distance runners	Healthy men	Women with one or more childbirths from disc herniation, cleaning staff and runner groups	Interreader ICC (95% CI)
Participants, *n*		41	46	14	25	26	23	29	38	204
BME@	Joint space	5.0 (5.0)/ 4.0 (0–15.5)	2.1 (2.8)/ 0.5 (0–13)**	1.0 (1.6)/ 0 (0–5.5)**	0.3 (0.6)/ 0 (0–2)***	0.2 (0.6)/ 0 (0–2.5)***	0.2 (0.5)/ 0 (0–1.5)***	0.2 (0.4)/ 0 (0–1.5)***	0.2 (0.6)/ 0.2 (0–2.5)***	0.89 (0.86, 0.92)
	FAT	1.2 (2.1)/ 0 (0–10)	0.1 (0.5)/ 0 (0–3.5)***	0.0 (0.1)/ 0 (0–0.5)*	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0.60 (0.50, 0.69)
	Sclerosis	0.8 (1.9)/ 0 (0–10)	1.7 (3.0)/ 0 (0–13)	0.7 (1.2)/ 0 (0–3.5)	0 (0.1)/ 0 (0–0.5)**	0.2 (0.7)/ 0 (0–3.5)*	0.0 (0.1)/ 0 (0–0.5)*	0.0 (0.2)/ 0 (0–1)**	0.1 (0.6)/ 0 (0–3.5)*	0.81 (0.76, 0.86)
	Erosion	1.6 (3.0)/ 0.5 (0–14)	0.2 (1.0)/ 0 (0–6.5)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0.1 (0.3)/ 0 (0–1.5)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0.74 (0.66, 0.79)
	Ankylosis	0.1 (0.2)/ (0–1)	0 (0)/ 0 (0–0)*	0 (0)/ 0 (0–0)	0 (0)/ 0 (0–0)	0 (0)/ 0 (0–0)	0 (0)/ 0 (0–0)	0 (0)/ 0 (0–0)	0 (0)/ 0 (0–0)*	0.28 (0.15, 0.41)
FAT@	Joint space	6.1 (5.3)/ 5.5 (0–17.5)	0.3 (1.4)/ 0 (0–8.5)***	0.5 (1.5)/ 0 (0–5.5)***	0.3 (0.8)/ 0 (0–3)***	0 (0)/ 0 (0–0)***	0.5 (1.5)/ 0 (0–6)***	0.8 (2.8)/ 0 (0–13)***	0.08 (0.41)/ 0 (0–2.5)***	0.89 (0.86, 0.92)
	Sclerosis	0.6 (1.2)/ 0 (0–5.5)	0.1 (0.3)/ 0 (0–1.5)***	0.1 (0.3)/ 0 (0–1)	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0.2)/ 0 (0–1)***	0.1 (0.6)/ 0 (0–3)***	0 (0)/ 0 (0–0)***	0.57 (0.48, 0.66)
	Erosion	1.9 (2.7)/ 0 (0–8.0)	0.0 (0.1)/ 0 (0–1)***	0 (0)/ 0 (0–0)**	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0.47 (0.35, 0.57)
	Ankylosis	1.7 (3.8)/ 0 (0–16)	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)*	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)**	0 (0)/ 0 (0–0)***	0 (0)/ 0 (0–0)***	0.89 (0.85, 0.91)

Values presented as mean (S.D.)/median (minimum–maximum) unless stated otherwise. ICCs are single measures with 95% CIs. MRI scores are mean scores of two readers and correspond to the number of MRI SI joints with a lesion in nine slices, providing a total score range of 0–18. Mann–Whitney test was applied; all tests are patients with axSpA compared with other groups. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

BME and FAT lesion combination scores

The scores for BME and FAT in relation to joint space and different structural lesions as the mean for the two readers are provided in Table 2, as is the interreader reliability (ICC) for the two readers. BME@joint space and BME@sclerosis were present in all groups. However, while the BME@joint space score was statistically significantly higher in the axSpA group, numerically higher scores of BME@sclerosis were found in women with post-partum pain. BME@FAT was only present in the axSpA group and in women with and without post-partum pain, while BME@erosion was mostly seen in the axSpA group and women with post-partum pain. BME@ankylosis was exclusively recorded in the axSpA group. For BME lesion combination scores, the interreader reliability was good to very good, except for BME@ankylosis, which was very rare. FAT@joint space and FAT@sclerosis were present in most groups, but at statistically significantly higher levels in the axSpA group. FAT@erosion and

FAT@ankylosis were exclusively recorded in the axSpA group. For FAT lesion combination scores, the interreader reliability was moderate to very good.

MRI cut-off levels for BME and FAT lesion combination scores

Table 3 displays the proportion of participants in each group with concordant lesion combination scores for BME and FAT above different cut-off levels (i.e. both readers agree on a score above a certain threshold). Except for long-distance runners, all groups had BME@joint space at a cut-off level $\geq$1, although much more frequently in the axSpA group (63%) followed by women with (44%) and without (21%) post-partum pain. Substantially lower frequencies were observed in the latter two groups with increasing thresholds. BME@FAT and BME@erosion were only present in axSpA patients and in women with post-partum pain, but at cut-off scores $\geq$3 and $\geq$4, respectively, only in axSpA patients (5%/4%). BME@sclerosis was most frequent in women with post-partum pain (28%) and was even present at a cut-off score $\geq$10 followed by the axSpA group (17%) and women without post-partum pain (14%). BME@ankylosis was only, albeit rarely, recorded in the axSpA group. FAT@joint space at a cut-off score $\geq$1 was present in nearly all groups, however, it was most frequent in the axSpA group (68%), followed by the group of healthy men (10%). At a cut-off score $\geq$10, FAT@joint space was still present in only these two groups (22% and 3%, respectively). FAT@sclerosis was present in the axSpA group, even at a cut-off score $\geq$5, and in women without post-partum pain and healthy men, however, not above cut-off scores $\geq$1 and $\geq$2, respectively. FAT@erosion and FAT@ankylosis were only recorded in the axSpA group.

MRI findings in post-partum women with disc herniation, cleaning staff and long-distance runners

A post-hoc analysis was performed on a subgroup of 38 women who had previously given birth from the disc herniation, cleaning staff and long-distance runner groups [mean time since last delivery 9.7 years (range 1.7–22.3)]. Patient characteristics are presented in Table 1. The concordant reads for BME lesion combination scores (Table 3) showed that three (8%) had BME@joint space and one (3%) had BME@sclerosis, however, none at cut-off levels $\geq$3 and $\geq$5, respectively. None had BME@FAT, BME@erosion or BME@ankylosis. The lesion combination scores for FAT (Table 3) showed that only one (3%) had FAT@joint space and none had FAT@sclerosis, FAT@erosion or FAT@ankylosis.

Diagnostic utility of SI joint MRI lesion combinations in axSpA

The sensitivities, specificities, PPV, NPV and likelihood ratios of different MRI lesion combinations at different cut-off levels for the axSpA diagnosis when compared with control subjects are shown in Tables 4 and 5 and in Supplementary Tables S3a and S3b, available at *Rheumatology* online. For BME lesion combinations, the specificities/PPVs were overall highest for BME@FAT (0.98–1.00/0.83–1.00) and BME@erosion (0.96–1.00/0.82–1.00) and lowest for BME@joint space. For FAT lesion combinations, the specificities and PPVs were highest for FAT@erosion and FAT@ankylosis, with specificities and PPVs consistently $>$0.97. The positive likelihood ratios (LR^+) (Table 5) for comparisons with all control subjects were good for BME@FAT and BME@erosion, even at low thresholds, and for BME@joint space and FAT@joint space at high thresholds. For FAT@erosion, FAT@ankylosis and BME@ankylosis, and high thresholds of BME@FAT and BME@erosion, the LR^+ could not be calculated since these findings were only observed in axSpA patients. For both BME and FAT combinations, the overall pattern was that, with increasing cut-off levels, specificity and PPV increased, while sensitivity and NPV decreased.

Discussion

In this prospective study we investigated the utility of MRI BME and MRI FAT adjacent to different types of MRI structures and lesions (i.e. lesion combinations) in the entire cartilaginous compartment of the SI joints to separate patients with axSpA from other conditions. Our main findings were that FAT@erosion—and BME@FAT, BME@erosion and FAT@sclerosis above certain thresholds—were exclusively seen in axSpA patients, which may potentially be very helpful in the differentiation of axSpA from other conditions (see Fig. 1 for representative MRI findings in the different groups).

Our findings document that while BME adjacent to joint space and in combination with other structural lesions are present in conditions other than axSpA, especially in post-partum women, FAT adjacent to other

Table 3 Proportion of participants with lesion combinations at different cut-off scores based on concordant reads[a]

Characteristics		AxSpA	Women with post-partum pain	Women without post-partum pain	Disc herniation	Cleaning staff	Long-distance runners	Healthy men	Women with one or more childbirths from disc herniation, cleaning staff and runner groups
Number of participants		41	46	14	25	26	23	29	38
BME@joint space	≥1	26 (63.4)	20 (43.5)	3 (21.4)	2 (8.0)	2 (7.7)	0	1 (3.4)	3 (7.9)
	≥2	23 (56.1)	17 (37.0)	1 (7.1)	1 (4.0)	1 (3.8)	0	0	2 (5.3)
	≥3	23 (56.1)	13 (28.3)	1 (7.1)	0	0	0	0	0
	≥4	22 (53.7)	7 (15.2)	1 (7.1)	0	0	0	0	0
	≥5	19 (46.3)	4 (8.7)	1 (7.1)	0	0	0	0	0
	≥10	7 (17.1)	1 (2.2)	0	0	0	0	0	0
BME@FAT	≥1	7 (17.1)	1 (2.2)	0	0	0	0	0	0
	≥2	5 (12.2)	1 (2.2)	0	0	0	0	0	0
	≥3	2 (4.9)	0	0	0	0	0	0	0
	≥4	2 (4.9)	0	0	0	0	0	0	0
	≥5	2 (4.9)	0	0	0	0	0	0	0
	≥10	0	0	0	0	0	0	0	0
BME@sclerosis	≥1	7 (17.1)	13 (28.3)	2 (14.3)	0	1 (3.8)	0	0	1 (2.6)
	≥2	5 (12.2)	9 (19.6)	2 (14.3)	0	1 (3.8)	0	0	1 (2.6)
	≥3	2 (4.9)	6 (13.0)	1 (7.1)	0	1 (3.8)	0	0	1 (2.6)
	≥4	1 (2.4)	6 (13.0)	0	0	0	0	0	1 (2.6)
	≥5	1 (2.4)	6 (13.0)	0	0	0	0	0	0
	≥10	0	1 (2.2)	0	0	0	0	0	0
BME@erosion	≥1	11 (26.8)	2 (4.3)	0	0	0	0	0	0
	≥2	9 (22.0)	2 (4.3)	0	0	0	0	0	0
	≥3	7 (17.1)	1 (2.2)	0	0	0	0	0	0
	≥4	4 (9.8)	0	0	0	0	0	0	0
	≥5	4 (9.8)	0	0	0	0	0	0	0
	≥10	1 (2.4)	0	0	0	0	0	0	0
BME@ankylosis	≥1	1 (2.4)	0	0	0	0	0	0	0
	≥2	0	0	0	0	0	0	0	0
FAT@joint space	≥1	28 (68.3)	2 (4.3)	1 (7.1)	2 (8.0)	0	1 (4.3)	3 (10.3)	1 (2.6)
	≥2	25 (61.0)	2 (4.3)	1 (7.1)	2 (8.0)	0	1 (4.3)	2 (6.9)	1 (2.6)
	≥3	22 (53.7)	2 (4.3)	1 (7.1)	0	0	1 (4.3)	2 (6.9)	0
	≥4	20 (48.8)	2 (4.3)	1 (7.1)	0	0	1 (4.3)	2 (6.9)	0
	≥5	18 (43.9)	1 (2.2)	1 (7.1)	0	0	1 (4.3)	2 (6.9)	0
	≥10	9 (22.0)	0	0	0	0	0	1 (3.4)	0
FAT@ sclerosis	≥1	3 (7.3)	0	1 (7.1)	0	0	0	1 (3.4)	0
	≥2	3 (7.3)	0	0	0	0	0	1 (3.4)	0
	≥3	2 (4.9)	0	0	0	0	0	0	0
	≥4	1 (2.4)	0	0	0	0	0	0	0
	≥5	1 (2.4)	0	0	0	0	0	0	0
	≥10	0	0	0	0	0	0	0	0
FAT@erosion	≥1	11 (26.8)	0	0	0	0	0	0	0
	≥2	9 (22.0)	0	0	0	0	0	0	0
	≥3	7 (17.1)	0	0	0	0	0	0	0
	≥4	5 (12.2)	0	0	0	0	0	0	0
	≥5	3 (7.3)	0	0	0	0	0	0	0
	≥10	0	0	0	0	0	0	0	0
FAT@ankylosis	≥1	6 (14.6)	0	0	0	0	0	0	0
	≥2	6 (14.6)	0	0	0	0	0	0	0
	≥3	5 (12.2)	0	0	0	0	0	0	0
	≥4	5 (12.2)	0	0	0	0	0	0	0
	≥5	5 (12.2)	0	0	0	0	0	0	0
	≥10	3 (7.3)	0	0	0	0	0	0	0

Values presented as *n* (%) of patients with a score above a certain level. [a]Participants with a score above the cut-off level by both readers are registered.

Table 4 Sensitivity, specificity and predictive values of lesion combinations at certain cut-off levels for the axSpA diagnosis

Characteristics	AxSpA *vs* women with post-partum pain				AxSpA *vs* women without post-partum pain				AxSpA *vs* disc herniation				AxSpA *vs* all healthy subjects pooled[a]				AxSpA *vs* women with one or more childbirths from disc herniation, cleaning staff and runner groups			
	n = 41 *vs n* = 46				*n* = 41 *vs n* = 14				*n* = 41 *vs n* = 25				*n* = 41 *vs n* = 92				*n* = 41 *vs n* = 38			
	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV
BME@joint space																				
≥1	0.63	0.57	0.57	0.63	0.63	0.79	0.90	0.42	0.63	0.92	0.93	0.61	0.63	0.91	0.76	0.85	0.63	0.92	0.90	0.70
≥2	0.56	0.63	0.58	0.62	0.56	0.93	0.96	0.42	0.56	0.96	0.96	0.57	0.56	0.97	0.88	0.83	0.56	0.95	0.92	0.67
≥3	0.56	0.72	0.64	0.65	0.56	0.93	0.96	0.42	0.56	1.00	1.00	0.58	0.56	0.99	0.96	0.83	0.56	1.00	1.00	0.68
≥4	0.54	0.85	0.76	0.67	0.54	0.93	0.96	0.41	0.54	1.00	1.00	0.57	0.54	0.99	0.96	0.83	0.54	1.00	1.00	0.67
≥5	0.46	0.91	0.83	0.66	0.46	0.93	0.95	0.37	0.46	1.00	1.00	0.53	0.46	0.99	0.95	0.81	0.46	1.00	1.00	0.63
≥10	0.17	0.98	0.88	0.57	0.17	1.00	1.00	0.29	0.17	1.00	1.00	0.42	0.17	1.00	1.00	0.73	0.17	1.00	1.00	0.53
BME@FAT																				
≥1	0.17	0.98	0.88	0.57	0.17	1.00	1.00	0.29	0.17	1.00	1.00	0.42	0.17	1.00	1.00	0.73	0.17	1.00	1.00	0.53
≥2	0.12	0.98	0.83	0.56	0.12	1.00	1.00	0.28	0.12	1.00	1.00	0.41	0.12	1.00	1.00	0.72	0.12	1.00	1.00	0.51
≥3	0.05	1.00	1.00	0.54	0.05	1.00	1.00	0.26	0.05	1.00	1.00	0.39	0.05	1.00	1.00	0.70	0.05	1.00	1.00	0.49
≥4	0.05	1.00	1.00	0.54	0.05	1.00	1.00	0.26	0.05	1.00	1.00	0.39	0.05	1.00	1.00	0.70	0.05	1.00	1.00	0.49
≥5	0.05	1.00	1.00	0.54	0.05	1.00	1.00	0.26	0.05	1.00	1.00	0.39	0.05	1.00	1.00	0.70	0.05	1.00	1.00	0.49
≥10	0.00	1.00	NA	0.53	0.00	1.00	NA	0.25	0.00	1.00	NA	0.38	0.00	1.00	NA	0.69	0.00	1.00	NA	0.48
BME@sclerosis																				
≥1	0.17	0.72	0.35	0.49	0.17	0.86	0.78	0.26	0.17	1.00	1.00	0.42	0.17	0.97	0.70	0.72	0.17	0.97	0.88	0.52
≥2	0.12	0.80	0.36	0.51	0.12	0.86	0.71	0.25	0.12	1.00	1.00	0.41	0.12	0.97	0.63	0.71	0.12	0.97	0.83	0.51
≥3	0.05	0.87	0.25	0.51	0.05	0.93	0.67	0.25	0.05	1.00	1.00	0.39	0.05	0.98	0.50	0.70	0.05	0.97	0.67	0.49
≥4	0.02	0.87	0.14	0.50	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	0.97	0.50	0.48
≥5	0.02	0.87	0.14	0.50	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	1.00	1.00	0.49
≥10	0.00	0.98	0.00	0.52	0.00	1.00	NA	0.25	0.00	1.00	NA	0.38	0.00	1.00	NA	0.69	0.00	1.00	NA	0.48
BME@erosion																				
≥1	0.27	0.96	0.85	0.59	0.27	1.00	1.00	0.32	0.27	1.00	1.00	0.45	0.27	1.00	1.00	0.75	0.27	1.00	1.00	0.56
≥2	0.22	0.96	0.82	0.58	0.22	1.00	1.00	0.30	0.22	1.00	1.00	0.44	0.22	1.00	1.00	0.74	0.22	1.00	1.00	0.54
≥3	0.17	0.98	0.88	0.57	0.17	1.00	1.00	0.29	0.17	1.00	1.00	0.42	0.17	1.00	1.00	0.73	0.17	1.00	1.00	0.53
≥4	0.10	1.00	1.00	0.55	0.10	1.00	1.00	0.27	0.10	1.00	1.00	0.40	0.10	1.00	1.00	0.71	0.10	1.00	1.00	0.51
≥5	0.10	1.00	1.00	0.55	0.10	1.00	1.00	0.27	0.10	1.00	1.00	0.40	0.10	1.00	1.00	0.71	0.10	1.00	1.00	0.51
≥10	0.02	1.00	1.00	0.53	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	1.00	1.00	0.49
BME@ankylosis																				
≥1	0.02	1.00	1.00	0.53	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	1.00	1.00	0.49
≥2	0.02	1.00	NA	0.53	0.00	1.00	NA	0.25	0.00	1.00	NA	0.38	0.00	1.00	NA	0.69	0.00	1.00	NA	0.48

(continued)

Table 4 Continued

Characteristics	AxSpA *vs* women with post-partum pain				AxSpA *vs* women without post-partum pain				AxSpA *vs* disc herniation				AxSpA *vs* all healthy subjects pooled[a]				AxSpA *vs* women with one or more childbirths from disc herniation, cleaning staff and runner groups			
	n = 41 *vs n* = 46				*n* = 41 *vs n* = 14				*n* = 41 *vs n* = 25				*n* = 41 *vs n* = 92				*n* = 41 *vs n* = 38			
	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV
FAT@joint space																				
≥1	0.68	0.96	0.93	0.77	0.68	0.93	0.97	0.50	0.68	0.92	0.93	0.64	0.68	0.92	0.80	0.87	0.68	0.97	0.97	0.74
≥2	0.61	0.96	0.93	0.73	0.61	0.93	0.96	0.45	0.61	0.92	0.93	0.59	0.61	0.93	0.81	0.84	0.61	0.97	0.96	0.70
≥3	0.54	0.96	0.92	0.70	0.54	0.93	0.96	0.41	0.54	1.00	1.00	0.57	0.54	0.96	0.85	0.82	0.54	1.00	1.00	0.67
≥4	0.49	0.96	0.91	0.68	0.49	0.93	0.95	0.38	0.49	1.00	1.00	0.54	0.49	0.96	0.83	0.81	0.49	1.00	1.00	0.64
≥5	0.44	0.98	0.95	0.66	0.44	0.93	0.95	0.36	0.44	1.00	1.00	0.52	0.44	0.96	0.82	0.79	0.44	1.00	1.00	0.62
≥10	0.22	1.00	1.00	0.59	0.22	1.00	1.00	0.30	0.22	1.00	1.00	0.44	0.22	0.99	0.90	0.74	0.22	1.00	1.00	0.54
FAT@sclerosis																				
≥1	0.07	1.00	1.00	0.55	0.07	0.93	0.75	0.25	0.07	1.00	1.00	0.40	0.07	0.98	0.60	0.70	0.07	1.00	1.00	0.50
≥2	0.07	1.00	1.00	0.55	0.07	1.00	1.00	0.27	0.07	1.00	1.00	0.40	0.07	0.99	0.75	0.71	0.07	1.00	1.00	0.50
≥3	0.05	1.00	1.00	0.54	0.05	1.00	1.00	0.26	0.05	1.00	1.00	0.39	0.05	1.00	1.00	0.70	0.05	1.00	1.00	0.49
≥4	0.02	1.00	1.00	0.53	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	1.00	1.00	0.49
≥5	0.02	1.00	1.00	0.53	0.02	1.00	1.00	0.26	0.02	1.00	1.00	0.38	0.02	1.00	1.00	0.70	0.02	1.00	1.00	0.49
≥10	0.00	1.00	NA	0.53	0.00	1.00	NA	0.25	0.00	1.00	NA	0.38	0.00	1.00	NA	0.69	0.00	1.00	NA	0.48
FAT@erosion																				
≥1	0.27	1.00	1.00	0.61	0.27	1.00	1.00	0.32	0.27	1.00	1.00	0.45	0.27	1.00	1.00	0.75	0.27	1.00	1.00	0.56
≥2	0.22	1.00	1.00	0.59	0.22	1.00	1.00	0.30	0.22	1.00	1.00	0.44	0.22	1.00	1.00	0.74	0.22	1.00	1.00	0.54
≥3	0.17	1.00	1.00	0.58	0.17	1.00	1.00	0.29	0.17	1.00	1.00	0.42	0.17	1.00	1.00	0.73	0.17	1.00	1.00	0.53
≥4	0.12	1.00	1.00	0.56	0.12	1.00	1.00	0.28	0.12	1.00	1.00	0.41	0.12	1.00	1.00	0.72	0.12	1.00	1.00	0.51
≥5	0.07	1.00	1.00	0.55	0.07	1.00	1.00	0.27	0.07	1.00	1.00	0.40	0.07	1.00	1.00	0.71	0.07	1.00	1.00	0.50
≥10	0.00	1.00	NA	0.53	0.00	1.00	NA	0.25	0.00	1.00	NA	0.38	0.00	1.00	NA	0.69	0.00	1.00	NA	0.48
FAT@ankylosis																				
≥1	0.15	1.00	1.00	0.57	0.15	1.00	1.00	0.29	0.15	1.00	1.00	0.42	0.15	1.00	1.00	0.72	0.15	1.00	1.00	0.52
≥2	0.15	1.00	1.00	0.57	0.15	1.00	1.00	0.29	0.15	1.00	1.00	0.42	0.15	1.00	1.00	0.72	0.15	1.00	1.00	0.52
≥3	0.12	1.00	1.00	0.56	0.12	1.00	1.00	0.28	0.12	1.00	1.00	0.41	0.12	1.00	1.00	0.72	0.12	1.00	1.00	0.51
≥4	0.12	1.00	1.00	0.56	0.12	1.00	1.00	0.28	0.12	1.00	1.00	0.41	0.12	1.00	1.00	0.72	0.12	1.00	1.00	0.51
≥5	0.12	1.00	1.00	0.56	0.12	1.00	1.00	0.28	0.12	1.00	1.00	0.41	0.12	1.00	1.00	0.72	0.12	1.00	1.00	0.51
≥10	0.07	1.00	1.00	0.55	0.07	1.00	1.00	0.27	0.07	1.00	1.00	0.40	0.07	1.00	1.00	0.71	0.07	1.00	1.00	0.50

Participants with a score above the cut-off level by both readers (concordant reads) are registered. [a]Women without post-partum pain. Cleaning staff, long-distance runners and healthy men pooled. Likelihood ratios for these comparisons are presented on Supplementary Table S3a, available at *Rheumatology* online, while Supplementary Table S3b, available at *Rheumatology* online, contains the results for cleaning staff, long-distance runners and healthy men. Sens: sensitivity; Spec: specificity.

TABLE 5 Sensitivity, specificity, PPV, NPV, LR^+ and LR^- of lesion combinations at certain cut-off levels for the axSpA diagnosis

Characteristics		axSpA (n = 41)	All control subjects (n = 163)	AxSpA *vs* all control subjects[a] (n = 41 *vs* n = 163)					
				Sensitivity	Specificity	PPV	NPV	LR^+	LR^-
BME@joint space									
	≥1	26 (63.4)	28 (17.2)	0.63	0.39	0.48	0.55	1.04	0.93
	≥2	23 (56.1)	20 (12.3)	0.56	0.57	0.53	0.59	1.29	0.78
	≥3	23 (56.1)	14 (8.6)	0.56	0.70	0.62	0.64	1.84	0.63
	≥4	22 (53.7)	8 (4.9)	0.54	0.83	0.73	0.67	3.09	0.56
	≥5	19 (46.3)	5 (3.1)	0.46	0.89	0.79	0.65	4.26	0.60
	≥10	7 (17.1)	1 (0.6)	0.17	0.98	0.88	0.57	7.85	0.85
BME@FAT									
	≥1	7 (17.1)	1 (0.6)	0.17	0.98	0.88	0.57	7.85	0.85
	≥2	5 (12.2)	1 (0.6)	0.12	0.98	0.83	0.56	5.61	0.90
	≥3	2 (4.9)	0	0.05	1.00	1.00	0.54	NA[b]	0.95
	≥4	2 (4.9)	0	0.05	1.00	1.00	0.54	NA[b]	0.95
	≥5	2 (4.9)	0	0.05	1.00	1.00	0.54	NA[b]	0.95
	≥10	0	0	0.00	1.00	NA	0.53	NA[b]	1.00
BME@sclerosis									
	≥1	7 (17.1)	16 (9.8)	0.17	0.65	0.30	0.47	0.49	1.27
	≥2	5 (12.2)	12 (7.4)	0.12	0.74	0.29	0.49	0.47	1.19
	≥3	2 (4.9)	8 (4.9)	0.05	0.83	0.20	0.49	0.28	1.15
	≥4	1 (2.4)	6 (3.7)	0.02	0.87	0.14	0.50	0.19	1.12
	≥5	1 (2.4)	6 (3.7)	0.02	0.87	0.14	0.50	0.19	1.12
	≥10	0	1 (0.6)	0.00	0.98	0.00	0.52	0.00	1.02
BME@erosion									
	≥1	11 (26.8)	2 (1.2)	0.27	0.96	0.85	0.59	6.17	0.76
	≥2	9 (22.0)	2 (1.2)	0.22	0.96	0.82	0.58	5.05	0.82
	≥3	7 (17.1)	1 (0.6)	0.17	0.98	0.88	0.57	7.85	0.85
	≥4	4 (9.8)	0	0.10	1.00	1.00	0.55	NA[b]	0.90
	≥5	4 (9.8)	0	0.10	1.00	1.00	0.55	NA[b]	0.90
	≥10	1 (2.4)	0	0.02	1.00	1.00	0.53	NA[b]	0.98
BME@ankylosis									
	≥1	1 (2.4)	0	0.02	0	1.00	0.53	NA[b]	0.98
	≥2	0	0	0.00	NA	NA	0.53	NA[b]	1.00
FAT@joint space									
	≥1	28 (68.3)	9 (5.5)	0.68	0.80	0.76	0.74	3.49	0.39
	≥2	25 (61.0)	8 (4.9)	0.61	0.83	0.76	0.70	3.51	0.47
	≥3	22 (53.7)	6 (3.7)	0.54	0.87	0.79	0.68	4.11	0.53
	≥4	20 (48.8)	6 (3.7)	0.49	0.87	0.77	0.66	3.74	0.59
	≥5	18 (43.9)	5 (3.1)	0.44	0.89	0.78	0.64	4.04	0.63
	≥10	9 (22.0)	1 (0.6)	0.22	0.98	0.90	0.58	10.10	0.80
FAT@sclerosis									
	≥1	3 (7.3)	2 (1.2)	0.07	0.96	0.60	0.54	1.68	0.97
	≥2	3 (7.3)	1 (0.6)	0.07	0.98	0.75	0.54	3.37	0.95
	≥3	2 (4.9)	0	0.05	1.00	1.00	0.54	NA[b]	0.95
	≥4	1 (2.4)	0	0.02	1.00	1.00	0.53	NA[b]	0.98
	≥5	1 (2.4)	0	0.02	1.00	1.00	0.53	NA[b]	0.98
	≥10	0	0	0.00	1.00	NA	0.53	NA[b]	1.00
FAT@erosion									
	≥1	11 (26.8)	0	0.27	1.00	1.00	0.61	NA[b]	0.73
	≥2	9 (22.0)	0	0.22	1.00	1.00	0.59	NA[b]	0.78
	≥3	7 (17.1)	0	0.17	1.00	1.00	0.58	NA[b]	0.83
	≥4	5 (12.2)	0	0.12	1.00	1.00	0.56	NA[b]	0.88
	≥5	3 (7.3)	0	0.07	1.00	1.00	0.55	NA[b]	0.93
	≥10	0	0	0.00	1.00	NA	0.53	NA[b]	1.00
FAT@ankylosis									
	≥1	6 (14.6)	0	0.15	1.00	1.00	0.57	NA[b]	0.85
	≥2	6 (14.6)	0	0.15	1.00	1.00	0.57	NA[b]	0.85
	≥3	5 (12.2)	0	0.12	1.00	1.00	0.56	NA[b]	0.88

(continued)

TABLE 5 Continued

Characteristics	axSpA (n = 41)	All control subjects (n = 163)	AxSpA *vs* all control subjects[a] (n = 41 *vs* n = 163)					
			Sensitivity	Specificity	PPV	NPV	LR^+	LR^-
≥4	5 (12.2)	0	0.12	1.00	1.00	0.56	NA[b]	0.88
≥5	5 (12.2)	0	0.12	1.00	1.00	0.56	NA[b]	0.88
≥10	3 (7.3)	0	0.07	1.00	1.00	0.55	NA[b]	0.93

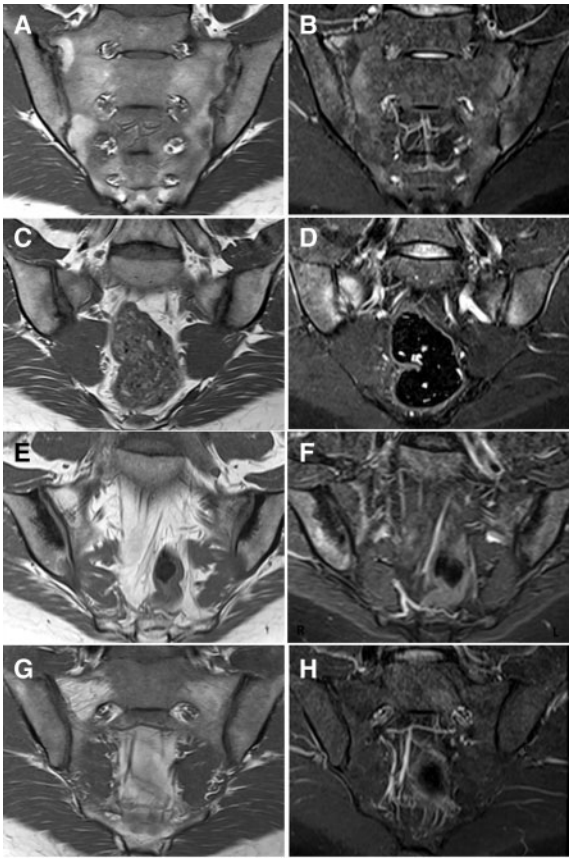
Values presented as n (%) of patients with a score above a certain level reported by both readers (concordant reads). [a]All control subjects pooled. [b]LR^+ could not be calculated since these findings were not observed in control groups.

structural lesions is very uncommon except in axSpA. Furthermore, the fact that in the subgroup of 38 mothers [last pregnancy 1.7–22.3 years ago (mean 9.7)] we only found three (8%) and one (3%) who had BME@joint space and FAT@joint space, respectively, suggests that BME lesion combinations found in the post-partum groups represent early MRI lesions that diminish over time without being replaced by fat infiltration, but further studies are needed to support this observation. However, the differences between these 38 mothers, of which we have no knowledge of history of buttock/pelvic pain in relation to pregnancy or post-partum, and the population of women with established post-partum pain in this study must be acknowledged. The discrimination of axSpA in post-partum women still constitutes a differential diagnostic challenge, since in these women BME was frequently present in relation to joint space, and especially in relation to sclerosis, even at high cut-off levels in women with post-partum pain. The observed iliac sclerosis in post-partum women is also known as osteitis condensans ilii. BME was absent only in relation to ankylosis.

The presence of MRI BME is essential in the ASAS classification criteria for axSpA while MRI structural/chronic lesions are only considered if there is at least some BME [2]. However, previous studies have shown that BME lacks specificity, since sacroiliitis according to the ASAS MRI definitions also is prevalent in persons with conditions other than axSpA, such as patients with non-specific back pain [4, 5], post-partum women [5, 6], athletes [6, 9], military recruits [10] and healthy persons [4]. These findings warrant assessment of the differential diagnostic utility of including other types of MRI lesions such as fat lesion, sclerosis, erosion and ankylosis, and/or lesion combinations as in current study, thus potentially widening the imaging criteria for axSpA. A comparison of patients with axSpA to patients with non-specific back pain and healthy persons in the MORPHO study found that structural lesions (e.g. fat lesions and erosion) were frequently present on SI joint MRIs of patients with axSpA [12, 15], that erosion was relatively specific to axSpA and that adding erosion to the ASAS MRI definitions would increase sensitivity from 67% to 81% while maintaining specificity at 88% [4]. In comparison, we found BME and structural lesions, including FAT and erosion, but excluding ankylosis, in nearly all participant groups, although to a lesser extent than in axSpA. Also, the MORPHO study evaluated the presence of individual MRI lesions and not the direct combination of lesions as in the current study. In the SPondyloArthritis Caught Early cohort, the optimal cut-offs of SI joint MRI structural lesions to ensure high specificity (≥95%) was investigated [14]. They found that a cut-off of three or more fatty lesions and three or more erosions provided ≤5% false positives. None of these studies investigates the impact of lesion combinations, such as BME@erosion and FAT@erosion.

A recent prospective multicentre study comparing SI joint MRIs of 30 healthy women in early (within 7 days) post-partum to 30 age-matched axSpA women found that while erosions were uncommon (10%), fatty bone marrow replacement, backfill and ankylosis were not seen in the post-partum group and higher sclerosis scores were observed in the axSpA group (5.3 *vs* 1.6) [7]. A retrospective cross-sectional study of 93 pelvic and hip MRIs of pregnant and ≥6 months post-partum women found prevalent peri-partum SI joint BME and subchondral sclerosis but no evident erosions or fatty replacement of marrow [8]. In comparison with these two studies, we not only observed erosions and FAT in addition to BME in women with and without post-partum pain, but also higher sclerosis scores compared with axSpA. These differences in findings may be attributable to the different lesion definitions and/or scoring methods applied or in follow-up time from labour. Another retrospective, cross-sectional study of pelvic MRI in a large asymptomatic non-rheumatological population found that fat lesions adjacent to joint space were very common and increased with age (50.6% at age <45 years *vs* 94.4% at age ≥75 years) [20]. In accordance with the latter, we found fat lesions in nearly all participant groups, except in cleaning assistants, but it was not seen adjacent to structural lesions in such participant groups. The occurrence of FAT@joint space in healthy men remains unexplained but may be related to work conditions or physical activity. A cross-sectional study of 157 subjects found that a distinct border or homogeneity of fat infiltration on SI joint MRI showed small to moderate diagnostic utility in non-radiographic axSpA, but was strongly associated with concomitant BME or erosion [15]. To our knowledge, BME lesion

Fig. 1 MRI of the SI joints



(**A**–**B**) MRI of a 19-year-old male patient with axSpA. At the upper right sacrum several lesion combinations are seen: FAT at an erosion (FAT@erosion) and at the joint space (FAT@joint space), BME at the joint space (BME@joint space) and BME at FAT (BME@FAT). At the left sacrum there are two examples of FAT at erosion (FAT@erosion) and of BME@joint space. At the lower sacrum on both sides there are FAT@joint space. (**C**–**D**) MRI of a 36-year-old woman with pelvic/buttock pain 4 months post-partum. At the right SI joint, BME@joint space and BME@erosion are observed, and at the left SI joint there are BME@joint space and probably also BME@erosion, since the joint cavity seems wider than anticipated. (**E–F**) MRI of a 35-year-old woman with pelvic/buttock pain 5 months post-partum. At the right SI joint the lesion combinations BME@FAT, BME@sclerosis and FAT@joint space are seen. At the left SI joint there are BME@joint space and BME@sclerosis. (**G–H**) MRI of a healthy 40-year-old male runner. At the right SI joint, FAT@joint space is seen. At the left SI joint there is a hyperintense signal in the bone marrow of the sacrum on the T1-weigthed image considered to be physiological fat, as there is no distinct border or sufficiently homogeneous signal intensity across the lesion. All images are semicoronal MR images of the SI joints, with T1-weighted images in the left column and corresponding STIR images in the right column. STIR: short tau inversion recovery.

combinations and FAT lesion combinations have not been systematically investigated previously.

The strengths of this study are the prospective design, the different participant groups, including women with and without post-partum pain, selected based on well-defined inclusion criteria, the standardized MRI protocol covering the entire cartilaginous compartment of the SI joints, the blinded reads by two independent, experienced observers and the large sample size, although the axSpA group was limited to 41 patients. This may potentially influence our results. Since we have not performed follow-up MRIs, the limitations include the lack of knowledge on the natural evolution of the MRI findings observed in the non-axSpA participants, particularly the post-partum women, since they were included within 4–16 months after giving birth.

In conclusion, BME@joint space and FAT@joint space were frequent in axSpA but also in other conditions, reducing the diagnostic utility, especially at lower thresholds, whereas it was better at higher thresholds. BME@sclerosis was most frequent in women with post-partum pain. FAT@erosion and FAT@ankylosis—and BME@FAT, BME@erosion and FAT@sclerosis above certain thresholds—were exclusively seen in patients with axSpA. Assessment of lesion combinations may thus improve the diagnostic utility of MRI for differentiating axSpA from other conditions.

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Supplementary data

Supplementary data are available at *Rheumatology* online.

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