Associations Of Abnormalities Detected On Mri And Radiography With Hand Pain And Function In A Population-Based Older Adult Cohort.

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Abstract

Objective To describe associations between hand abnormalities on MRI or radiographs (X-ray) and pain and function in a cross-sectional study of community-based older adults.

Methods Distal and proximal interphalangeal index finger joints (n=221) were examined using MRI, X-ray, and hand examination. Hand pain, function, and stiffness were assessed using Australian/Canadian hand osteoarthritis index (AUSCAN) questionnaire. Grip strength was assessed using dynamometer. Models were adjusted for age, sex, and other MRI or X-ray abnormalities.

Results Absence of collateral ligament (CLs) on MRI (relative risk; RR=3.15 (95% confidence interval 1.33, 7.50), and joint space narrowing (JSN) on X-ray (RR=2.96 (1.33, 6.58)) was associated with having a painful joint after adjustment for confounders. JSN was also associated with tender joints (RR=2.19 (1.01, 4.76)). Effusion-synovitis was associated with better AUSCAN pain scores (OR=0.51 (0.28, 0.94)) and JSN with worse AUSCAN pain scores (odds ratio; OR=1.67 (1.13, 2.48)). Absent CLs were also associated with stiffer joints (OR=3.12 (1.26, 7.70)) and weaker grip strength (β=-1.69 (-2.95, -0.43)) independent of pain and other features; JSN was also associated with weaker grip strength (β=-0.87 (-1.62, -0.14)). No other MRI or X-ray abnormalities were associated with pain or function independent of age, sex or pain.

Conclusion Most MRI abnormalities were not associated with pain and function cross-sectionally. Absent CLs and JSN were associated with painful joints and weak grip strength independent of pain and other imaging features. JSN was also associated with tender joints and absent CLs with stiff joints. Unexpectedly, effusions were associated with reduced odds of pain.

Introduction

Hand pain is extremely common in older adults [1, 2], and interferes with physical hand function [3, 4]. Although radiography is routinely used to image hands, radiographic hand abnormalities are only weakly associated with pain and physical function limitation [5-8], and do not predict worsening of hand pain and function limitation [9, 10]. MRI has advantages over conventional radiography as it gives three-dimensional, multiplanar visualisation of all joint components and soft tissue changes, whereas conventional radiography (X-rays) provides a single image in two-dimension of bony changes and joint space width only.

Magnetic resonance imaging (MRI) is widely used to image knees, hips and spine osteoarthritis (OA) in both clinical and research settings [11], but have rarely been used to image hands in hand osteoarthritis studies. Abnormal features of knee and hip joints seen on MRI such as bone marrow lesions (BMLs) and effusion-synovitis are associated with pain [12, 13], poor physical function [14], structural progression or joint replacement [15], but there is limited data on associations between abnormal features seen on hand

MRIs, and pain and function limitations [16, 17]. The previous study demonstrated that bone marrow lesions (BMLs), synovitis, bone remodelling, and erosions were independently associated with joint tenderness, but not pain or function; while osteophytes were correlated with grip strength independent of age, sex, and other MRI abnormalities in people with hand OA (HOA) [16]. The previous studies were conducted in people with OA, and no study has yet assessed the association in general older adult population.

Therefore, we aimed to describe cross-sectional associations between abnormalities present on MRI (effusion-synovitis, absence of collateral ligament (CL), BMLs, erosion, and osteophytes) or radiographs (osteophytes and joint space narrowing) with painful and tender joints, pain, physical function limitations, stiffness, and grip strength in a cohort of community dwelling older adults.

Methods

Participants

The Tasmanian older adult cohort (TASOAC) study is a prospective, population-based study which aimed to identify factors associated with development and progression of osteoarthritis and osteoporosis in older adults. Participants aged 50 and 80 years were recruited from the electoral roll in Southern Tasmania in 2002 using sex stratified random sampling (response rate 57%). Participants were excluded if they lived in a nursing home or reported contraindications to MRI. Hand data (hand examination (n=520), MRI (n=221), and X-ray (n=201)) was only collected at the 10-year follow-up (2013 to 2015); therefore, analyses in this manuscript consists of cross-sectional data from the 10-year follow-up only (n=221).

All research was conducted in compliance with the Declaration of Helsinki and was approved by the Southern Tasmanian Health and Medical Human Research Ethics Committee. All subjects gave informed written consent.

Hand examination

Bilateral clinical examination of the 15 joints of both hands were performed in all participants attending Phase 4 by one trained assessor (CB). Presence or absence of tenderness, soft tissue swelling, hard tissue enlargement (nodules) and deformity were assessed using American College of Rheumatology (ACR) criteria for HOA [18]. Tenderness was assessed by the examiner exerting pressure onto the joint using thumb and index finger sufficient to produce whitening of the examiners nail bed [19]. Joint pain in

individual joints in the target hand was determined by asking participants if they had pain (yes/no) in each joint in the preceding seven days. Each patient's dominant hand (target hand) was imaged using radiographs and MRI. If the participant had contraindications to MRI on the dominant hand, the contralateral hand was examined. Clinically defined HOA was diagnosed according to ACR criteria [18] using data from the clinical hand examination. Intra-observer reliability was assessed on 10 participants with at least a one-week interval between the readings using kappa-statistic [20]. The results were fair to substantial; k=0.376 (95% CI 0.061,0.690) for left hand deformity, k=0.495 (0.211, 0.779) for left hand tenderness, k=0.606 (0.467, 0.746) for left hand nodules, k=0.668 (0.537, 0.799) for right hand nodules, and k=0.688 (0.431, 0.946) for right hand deformity. Swollen and tender joints in the right hand, and swollen joints in the left hand had too little variability to enable kappa to be calculated.

Hand pain, stiffness, physical function limitation, and total AUSCAN score.

Pain was assessed as presence or absence of pain in a specific joint (proximal (PIP) or distal interphalangeal (DIP)) during clinical assessment, and hand pain (both hands) during the last 48 hours using Australian/Canadian hand osteoarthritis (AUSCAN) questionnaire [21] on 100mm visual analog scale (VAS) score. Hand stiffness and physical function were also assessed using the AUSCAN questionnaire; a 15 item questionnaire (5 for pain, 1 for (morning) stiffness, and 9 for physical function), which is a valid, reliable, and responsive measure for HOA [21].

AUSCAN subscales (hand pain, physical function limitation, and stiffness) scores and total AUSCAN scores are bounded by zero and non-normally distributed with a large number of zeros, therefore AUSCAN pain, stiffness, physical function limitation, and total AUSCAN scores were categorised into groups as none, below the median scores (mild to moderate), and above the median scores (moderate to severe). These equate to the following scores: pain score 0 (none), 1-51 (mild pain), and 52-500 (moderate to severe pain); stiffness score 0 (none), 1-12 (mild stiffness), and 13-100 (moderate to severe stiffness); physical function limitation score 0 (none), 1-73 (mild function limitation), and 74-900 (moderate to severe function limitation); total AUSCAN 0 (none), 1-111 (mild total disability), and 112-1500 (moderate to severe total disability).

Magnetic resonance imaging (MRI)

Distal interphalangeal (DIP) and proximal interphalangeal (PIP) joints of the index finger of the target hand were imaged using a 1.5T whole-body magnetic resonance unit (Siemens, Espree) using five sequences (supplementary Figure 1) with physical hand assessment and micro-computed tomography

scans. One reader (SNL) assessed effusion-synovitis, absence of collateral ligaments (CLs), bone marrow lesions (BMLs), erosion, and osteophytes on T2-MRI sequences according to the Oslo Hand Osteoarthritis MRI score [22]. We did not use gadolinium contrast, and thus we cannot distinguish between effusion and synovitis. Therefore, we modified the scoring system to suit our MR images as follows:

Effusion-synovitis and CLs were scored as present or absent in either radius or ulnar (effusion-synovitis 1 = present, 0 = absent; CL absence/discontinuity present=0, absent=1). BMLs, erosions, and osteophytes were classified on a 0–3 scale at the distal and proximal of interphalangeal joints, (0=none, 1=mild, 2=moderate, 3=severe). SNL re-scored 40 randomly selected MRI scans after 2 weeks and assessed intra-reader reliability using kappa and weighted kappa. Intra-rater agreements were moderate to almost perfect [20] as shown in supplementary Table 1. Variability in DIP effusion, DIP and PIP absence of collateral ligament, and PIP osteophytes was too small to calculate kappa.

Conventional radiography

The target hand was also imaged using radiographs (X-ray). A single exposure anteroposterior radiograph of the hand was performed according to a standardised protocol [23]. JSN and osteophytes of the DIP and PIP index finger joints were independently assessed by 2 readers (KS and GJ). Severity of osteophytes and JSN were assessed using Osteoarthritis Research Society International (OARSI) atlas [23] using a 0-3 scale (0=normal, 1=mild change, 2=moderate change, 3=severe change). Intra-observer reliability was excellent for both osteophytes and JSN scores, assessed one week apart (n=45) [8].

Other factors

BMI was calculated as weight (kg)/height $(m)^2$ using weight measured to the nearest 0.1kg (with shoes, socks and bulky clothing removed) by calibrated electronic scales, and height measured to the nearest 0.1cm (without shoes, socks and headwear) by stadiometer. Grip strength was measured using an adult bulb dynamometer (0-30 psi) (North Coast^{TM}) with the patient sitting with shoulders in a neutral position and the elbow in 90 degrees of flexion, the maximum value out of two attempts was used. In this study, we used grip strength measurements of the hand that had been imaged by MRI. Assessment of Quality of Life (AQoL-4D [24]) data from Phase 4 was used to assess participants quality of life over several domains. We used AQoL expressed as utility score, as such it is an index of the strength of a person's preference for a health state, with scores ranging from 0.00 (Dimension Worst Health State) to 1.00 (Dimension Best Health State). Any pain medication used were recorded in self-reported questionnaire from the list of medications they were taking (medication name, dose, and frequency).

Statistical analyses

Associations with binary outcomes (presence of painful and tender joints) were assessed using log binomial regressions. Associations with categorical outcomes (categorical AUSCAN pain, physical function limitation, stiffness, and total AUSCAN score) were assessed using adjacent category ordinal logistic regressions. Associations with linear outcomes (grip strength) were assessed using linear regression. Models were adjusted for age and sex, and then further adjusted for pain (for function and grip strength outcomes) and then for all other MRI abnormalities or X-ray features to enable assessment of confounders (age, sex, other MRI or X-ray features) and mediator (hand pain score on AUSCAN). All models had inverse probability weighting applied to adjust for study participants who were lost to follow-up. We conducted sensitivity analysis to examine whether pain medication use was a confounder. Further adjustment of all our presented models for any use of pain medication did not change the effect sizes by more than 10%, therefore data not shown. All statistical analyses were performed using Stata 15 SE (Stata-Corp, College Station, Texas, USA). The significant p-value was set at the value of less than 0.05 (two-tailed).

Results

Table 1 presents the characteristic of participants split by categorical AUSCAN pain scores. Greater proportions of participants with moderate to severe AUSCAN pain scores had weaker grip strength, met the ACR hand OA criteria, poorer quality of life, more joints which were painful and tender on clinical assessment, more joints with absent CLs on MRI, and greater JSN grade on X-ray compared to those with mild or no pain. Unexpectedly, effusion-synovitis was less common in those with moderate or mild pain. Half of participants with pain on AUSCAN were women compared to a third those with no pain.

There were no differences in the age, BMI, total MRI abnormalities mean score, presence of BML, erosion, and MRI and X-rays detected osteophytes amongst pain score groups.

Painful and tender joints on clinical examination and AUSCAN pain

Table 2 shows significant associations between absence of CLs and JSN and presence of painful joints after adjustment for age and sex and all other MRI features. JSN was also independently associated with higher risk of tender joints. Other MRI and X-ray features were not associated with either painful or tender joints. (Table 2). Further adjustment of the association between absence of CLs and painful joint for JSN on radiographs did not change effect sizes (RR=2.75 (1.08, 7.00)), indicating this effect was independent

of JSN; however the reverse was not true (further adjustment of associations between JSN and painful joints for absent CLs (RR=2.24 (0.83, 6.03)).

Table 3 shows that presence of effusion-synovitis was associated with increased odds of moving to a lower category of pain score (as assessed by AUSCAN pain score), after adjusting for age and sex and all other MRI abnormalities. Sensitivity analysis shows one or both DIP and PIP joints were associated with pain, with a threshold effect at one joint (data not shown). JSN was associated with increased odds of moving to a higher category of AUSCAN pain score, after adjustment for age and sex and other X-ray abnormalities (Table 3). Further adjusting the association between presence of effusion on MRI and AUSCAN pain for radiographic JSN did not significantly change the effect size (OR=0.50 (0.25 to 0.98)), and vice versa (JSN OR=1.68 (1.12 to 2.51)).

No other abnormalities were associated with AUSCAN pain score (Table 3).

Physical function limitation, stiffness, and grip strength

No abnormalities were associated with AUSCAN physical function limitation independent of AUSCAN pain and other imaging features (Table 3). Absent CLs is the only correlate of stiffness, independent of pain and other imaging features (Table 3). Absence of CLs and JSN were associated with weaker grip strength after adjustment for age, sex, pain, and all other MRI features (Table 4). Further adjustment of the association between absence of CLs and grip strength for JSN on radiographs did not change effect sizes (b=-1.63 (-3.08 to -0.18)), indicating this effect was independent of JSN; however not the reverse (further adjustment of associations between JSN and painful joints for absent CLs (JSN b=-0.68 (-1.42 to 0.06)).

Total AUSCAN score

JSN is the only correlate of total AUSCAN score independent of age, sex and other imaging features (Supplementary Table 2).

Discussion

These results show that abnormal imaging features seen on hand MRI are common in older adults, both with and without pain. Absence of CLs were associated with greater risk of having a painful joint, stiffer hand with lower grip strength, while effusions were associated with lower risk of hand pain independent of other factors. However, presence of other abnormalities present on MRI and number of MRI abnormalities were not associated with joint pain, tenderness, or physical function limitation, stiffness, or grip strength independent of pain. JSN (on X-ray) was independently associated with joint pain, tenderness, and weaker grip strength. Overall, this demonstrates that absent CLs on MRI and JSN on hand radiographs are important correlates of hand pain in older adults.

Prevalence estimates of most abnormalities were comparable to estimates from existing literature, which is predominantly from cohorts of patients with HOA. Prevalence of effusion-synovitis was similar to two previous cohort of HOA patients (54% to 98%) [17, 25] but greater than reported by Haugen et al. (13%), who used a different imaging method (contrast enhanced MRI to detect active synovitis (vs effusion-synovitis)) [26]. Similarly, prevalence of osteophytes on MRI was comparable with previous studies (34% to 75%) [25, 26]. However, radiographic osteophytes were more common in our cohort than in the other two cohort studies (range 12% to 33%) [6, 27], but these studies included younger people over a wider age range than our study sample. Prevalence of erosions was similar to previous estimates 48%, [16] but absent CL were rarer than estimates from cohorts of patients with HOA (range of 38% to 53%) [22, 28]. Prevalence of JSN was higher in our cohort (37%) than in a previous cohort study (12% to 17 %) [27], but this may be attributable to use of different scoring systems (OARSI vs Kellgren and Lawrence).

This study is the first to report statistically significant associations between absence of CLs and painful hand joints, stiffer hands, and weak grip strength. Associations between absent CLs and increased pain is plausible as collateral ligaments have rich pain innervation in animal models and human knee joints, thus damaged collateral ligament may causes joint instability and pain during movement [29]. Ligament injury predicts radiographic knee OA, pain, and function limitations over 12 years [30] and ligament tear is a risk factor in knee OA in young adults [31]. Thus, our data is consistent with data in knees, but not the only available data in hand joints: Haugen et al. found that absence of collateral ligaments was not correlated with AUSCAN pain and function limitation and grip strength [16], but reasons for the discrepancy are unclear.

Effusion-synovitis was common in our cohort, and effusion-synovitis of the knee joints are typically associated with knee pain [12, 32-34]. However, to the best of our knowledge, we are the first to show that presence of effusion-synovitis in the one hand joint is associated with lower AUSCAN hand pain scores.

Ideally, presence of synovitis should be differentiated from effusion using contrast-enhanced MRI assessment, however, we elected not to do this as we did not consider that the increased risk of side effects from contrast agents was ethically justifiable in a research cohort. Thus, our findings need to be replicated in a cohort with contrast enhanced imaging.

Our study is the first to describe associations between MRI and radiograph detected abnormalities and stiffness. Absent CLs was the only significant correlate of stiffness.

We found no associations between osteophytes on MRI or X-ray and any outcome, whereas Kortekaas et al., found dose-dependent associations between osteophytes on X-ray with painful hand joints [35] and Haugen et al reported that osteophytes detected on MRI were the only independent correlates of low grip strength [16]. Reasons for these discrepancies are unclear. Additionally, we did not find associations between number of abnormalities on MRI and any clinical outcome, consistent with the literature [16].

Effusion-synovitis and JSN are two different and independent pathologies in the association with hand pain on AUSCAN. Associations between JSN and AUSCAN pain were independent of effusion-synovitis on MRI. However, associations between radiographic JSN and painful joints and grip strength were not independent of absent CLs on MRI, suggesting that absent CLs is a mediator in this association. Overall, absent CLs has a greater effect on the presence of pain and grip strength compared to JSN.

Overall, hand pain was associated with reduced hand function and grip strength in this data, which is consistent with the literature [35] [8]. When examining the associations between abnormal imaging features and physical function or grip strength, we adjusted for pain in order to assess whether these associations were independent. Of the imaging features seen on MRI, none were associated with physical function independent of age, sex and pain. Only absent CLs on MRI were associated with grip strength independent of age, sex, and pain. Since these associations are biologically plausible and consistent both across functional outcomes, and with similar reports in the knee [36, 37], this has the potential to be clinically relevant. JSN was also associated with reduced grip strength independent of pain, but smaller effect size than absence of CL. It is also independently associated with painful and tender joints, and AUSCAN pain score, consistent with previous studies [35, 38, 39]. This is plausible because normal cartilage is aneural, whilst abnormal cartilage is not [40, 41]. Additionally, thinning cartilage could increase the effect of localised loading to the innervated subchondral bone [42], but given that hand X-ray abnormalities do not predict worsening of clinical outcomes (as outlined in the introduction), these cross-sectional associations between JSN and pain and grip strength may not have strong clinical relevance.

This study utilised three different ways of measuring pain (joint pain on palpation and tender joints during clinical assessment, and whole hand pain measured by AUSCAN questionnaire). We showed that painful joints on clinical examination and AUSCAN pain are more sensitive in measuring pain than tenderness. This might be due to poor reliability of tender joint assessment along with it being highly assessor dependent [43]. Therefore, future studies should include site-specific joint pain and whole hand pain measurement as outcomes. This study also assessed associations between osteophytes measured on both MRI and X-ray and clinical outcomes. Strength of associations were greater with presence of osteophytes on MRI and clinical outcomes, but osteophytes were not significantly associated with clinical outcomes regardless of imaging modality.

Strengths of this study include using standardised radiograph and MRI hand osteoarthritis atlases and the population-based source of the data; which enables findings to be generalised to older adults in the community. We also included three different pain measurements which improves confidence in the findings.

Limitations include loss to follow up within the TASOAC cohort: data used for this study (collected at the ten year follow up) is a subset of the original cohort that had MRI and X-ray images taken, who were younger, had lower BMI, and fewer females at baseline than those who did not complete the 10 year follow up (n=875) (data not shown), but absolute differences were small. However, to account for these differences, we have inverse probability weighted the data; therefore, the results remain generalisable to older people. Other potential limitations include the small number of joints assessed - DIP and PIP of the index finger on one hand, rather than assessment of a whole hand, meaning that the prevalence of abnormalities and associations with pain and function could differ between these two joints and other hand joints. However, previous studies show that index finger DIP joints have the highest prevalence of symptomatic HOA, and index finger PIP joints have similar prevalence of symptomatic HOA to the other finger joints [4, 44]. Therefore, the prevalence should be similar or slightly overestimated than if we assessed the whole hand. We were unable to assess the effect of not assessing all hand joints on associations between hand pain and function. Thumb base OA may be a larger contributor to poor function than the fingers we assessed, and had we assessed imaging abnormalities in the thumb, we may have found different associations. Also, we were unable to assess presence of BMLs at the collateral ligament enthesis, and effusion-synovitis was scored as present or absent in this study due to available image quality and without using gadolinium contrast medium. Thus, we cannot provide the prevalence of BMLs at the collateral ligament enthesis, and we may underestimate the effect size of the association between inflammation (detected by effusion-synovitis in this study), and hand pain and symptoms.

In conclusion, most MRI abnormalities were not associated with pain and function cross-sectionally. Absent CLs and JSN were associated with painful joints and weak grip strength independent of pain and other imaging features. JSN was also associated with tender joint and absent CLs with stiff joints. Unexpectedly, effusions were associated with reduced odds of pain. Longitudinal population-based cohort studies are needed to confirm these findings.

Declarations

Ethics approval and consent to participate

All research conducted was in compliance with the Declaration of Helsinki and was approved by the Southern Tasmanian Health and Medical Human Research Ethics Committee. All subjects gave informed written consent.

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author's contributions

All authors were involved in drafting the article or revising it for important intellectual content. All authors have approved the final manuscript. Laura L. Laslett (laura.laslett@utas.edu.au) takes responsibility for the integrity of the work as a whole, from inception to finished article.

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Competing interest statement

The authors declare no competing interest.

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Tables

Table 1. Characteristic of participants, by AUSCAN pain score (n=221).

	No pain AUSCAN pain score =0 n=94		Mild pain AUSCAN pain score =1-50 n=65		Moderate – severe pain AUSCAN pain score >51-500 n=62	
Age	72.3 (6.4)		71.3 (6.4)		73.1 (7.2)	
Female (%)	32		52		55	
BMI (kg/m^2)	27.9 (4.3)		27.3 (4.5)		28 (4.1)	
Grip Strength (psi)	12.2 (3.4)		11.6 (3.8)		9 (3.6)	
Hand OA (ACR criteria)	39.4		69.2		91.9	
Total MRI abnormalities mean score (1-22)	4.5 (2.8)		5.0 (3.1)		5.8 (3.9)	
AQoL utility score	0.8 (0.19)		0.78 (0.16)		0.66 (0.19)	
	%	No. of joints (0-2)	%	No. of joints (0-2)	%	No. of joints (0-2)
Clinical Assessment						
Painful joints	0	0 (0)	2	0 (0.1)	33	0.4 (0.6)
Tender joints	1	0 (0.1)	5	0.1 (0.3)	28	0.3 (0.6)
MRI assessment						
Effusion-synovitis	95	1.4 (0.6)	91	1.4 (0.7)	85	1.4 (0.7)
Absence of collateral ligament	4	0 (0.2)	2	0 (0.1)	13	0.1 (0.4)
BML	60	0.8 (0.7)	63	0.9 (0.8)	69	0.9 (0.7)
Erosion	38	0.5 (0.7)	34	0.5 (0.7)	45	0.6 (0.8)
Osteophytes	69	0.8 (0.6)	82	1 (0.6)	81	1 (0.6)
No. of MRI abnormalities	100	2.7 (1.13)	98	2.7 (1.1)	98	3 (1.2)
Radiographic assessment						
Osteophytes	67	0.9 (0.7)	73	1 (0.7)	71	1 (0.8)
JSN	28	0.3 (0.5)	35	0.4 (0.6)	50	0.6 (0.7)

Mean (standard deviation) except for percentage.

Clinical, MRI, and radiographic assessment are presence of the features at either distal or proximal interphalangeal joint of the same MRI target hand.

n, number; BMI, body mass index; AUSCAN, Australian/Canadian hand osteoarthritis index; MRI, magnetic resonance imaging; ACR, American College of Rheumatology; AQoL, Assessment of Quality of Life; CL, collateral ligament; BML, bone marrow lesions; JSN, joint space narrowing.

Table 2. Associations of MRI/X-ray abnormalities and painful or tender index finger joints on clinical examination.

Adjusted for	Presence of painful joint		Presence of tender joint	
	age and sex RR (95% CI)	+ all other MRI/X-ray abnormalities RR (95% CI)	age and sex RR (95% CI)	+ all other MRI/X-ray abnormalities RR (95% CI)
MRI abnormalities...				
Effusion	0.82 (0.21, 3.25)	0.60 (0.15, 2.46)	0.66 (0.20, 2.20)	0.59 (0.15, 2.33)
Absence of CL	**5.22 (2.47, 11.04)**	**3.15 (1.33, 7.50)**	0.80 (0.12, 5.25)	0.65 (0.08, 5.13)
BML	3.10 (0.91, 10.55)	1.16 (0.21, 6.45)	1.01 (0.95, 1.07)	1.15 (0.31, 4.18)
Erosion	**3.40 (1.42, 8.15)**	2.34 (0.65, 8.43)	1.01 (0.95, 1.07)	1.31 (0.42, 4.05)
Osteophytes	6.13 (0.88, 42.94)	3.33 (0.42, 26.16)	1.44 (0.40, 5.24)	1.20 (0.27, 5.34)
No. of MRI abnormalities	3.36 (0.78, 14.50)	-	1.04 (0.43, 2.54)	-
X-ray abnormalities...				
Osteophytes	0.88 (0.36, 2.16)	0.71 (0.31, 1.65)	1.00 (0.38, 2.63)	0.86 (0.35, 2.12)
JSN	**2.83 (1.23, 6.49)**	**2.96 (1.33, 6.58)**	2.15 (0.95, 4.87)	**2.19 (1.01, 4.76)**

Associations were assessed using log binomial regression with inverse probability weighting.

No. of MRI abnormalities were dichotomised at the median (3).

MRI, magnetic resonance imaging; RR, relative risk; CI, confidence interval; CL, collateral ligament; BML, bone marrow lesions; JSN, joint space narrowing.

Bold denotes a statistically significant result.

Table 3. Associations of MRI/X-ray abnormalities at index finger and AUSCAN pain, function limitation, and stiffness.

	AUSCAN pain		AUSCAN physical function limitation			AUSCAN stiffness		
l for	age and sex OR (95% CI)	+ all other MRI/X-ray abnormalities OR (95% CI)	age and sex OR (95% CI)	+ AUSCAN pain OR (95% CI)	+ all other MRI/X-ray abnormalities OR (95% CI)	age and sex OR (95% CI)	+ AUSCAN pain OR (95% CI)	+ all other MRI/X-ray abnormalities OR (95% CI)
normalities...								
on	**0.50 (0.27, 0.93)**	**0.51 (0.28, 0.94)**	0.61 (0.34, 1.11)	1.21 (0.59, 2.51)	1.32 (0.60, 2.89)	**0.53 (0.31, 0.92)**	0.76 (0.41, 1.40)	0.85 (0.45, 1.58)
ce of	1.96 (0.91, 4.20)	1.81 (0.84, 3.91)	**2.73 (1.00, 7.43)**	2.61 (0.91, 7.46)	3.42 (0.99, 11.83)	**3.44 (1.60, 7.42)**	**3.33 (1.47, 7.51)**	**3.12 (1.26, 7.70)**
	1.14 (0.73, 1.78)	1.25 (0.75, 2.08)	0.90 (0.61, 1.31)	0.71 (0.45, 1.12)	0.86 (0.49, 1.50)	**1.47 (1.00, 2.15)**	1.55 (0.95, 2.51)	1.28 (0.74, 2.22)
on	1.12 (0.78, 1.60)	0.96 (0.60, 1.53)	0.81 (0.55, 1.20)	**0.62 (0.39, 0.99)**	0.57 (0.32, 1.03)	1.35 (0.93, 1.94)	1.34 (0.88, 2.06)	1.00 (0.60, 1.66)
	1.27 (0.84, 1.93)	1.19 (0.77, 1.86)	1.21 (0.78, 1.88)	1.12 (0.69, 1.84)	1.22 (0.70, 2.15)	1.47 (0.96, 2.26)	1.65 (0.96, 2.82)	1.47 (0.82, 2.66)
hytes								
MRI	1.13 (0.80, 1.61)	-	0.78 (0.53, 1.13)	0.68 (0.43, 1.06)	-	1.28 (0.89, 1.85)	1.35 (0.86, 2.11)	-
alities								
normalities...								
phytes	0.98 (0.65, 1.48)	0.84 (0.55, 1.30)	1.00 (0.62, 1.61)	1.13 (0.62, 2.07)	1.03 (0.54, 1.99)	1.14 (0.74, 1.76)	1.24 (0.72, 2.11)	1.25 (0.64, 2.46)
	1.60 (1.09, 2.35)	**1.67 (1.13, 2.48)**	**1.67 (1.10, 2.52)**	1.50 (0.88, 2.54)	1.51 (0.84, 2.72)	1.38 (0.94, 2.03)	1.14 (0.73, 1.80)	1.46 (0.77, 2.77)

Associations were assessed using ordinal logistic regression with inverse probability weighting.

AUSCAN scales were categorised as none, below, and above median.

No. of MRI abnormalities were dichotomised at the median (3).

AUSCAN, Australian/Canadian hand osteoarthritis index; OR, odds ratio; CI, confidence interval; MRI, magnetic resonance imaging; RR, relative risk; CI, confidence interval; CL, collateral ligament; BML, bone marrow lesions; JSN, joint space narrowing.

Bold denotes a statistically significant result.

Table 4. Associations of presence of MRI/X-ray abnormalities at the index finger joints and grip strength.

Adjusted for	Grip strength (0-30psi)		
	age and sex β (95% CI)	+ AUSCAN pain β (95% CI)	+ all MRI/-ray abnormalities β (95% CI)
MRI abnormalities...			
Effusion	0.95 (-0.58, 2.48)	0.48 (-0.93, 1.89)	0.47 (-0.94, 1.89)
Absence of CL	**-2.04 (-3.20, -0.88)**	**-1.56 (-2.79, -0.34)**	**-1.69 (-2.95, -0.43)**
BML	-0.10 (-0.89, 0.69)	-0.03 (-0.76, 0.70)	-0.02 (-0.92, 0.87)
Erosion	-0.14 (-0.85, 0.57)	-0.04 (-0.69, 0.61)	0.08 (-0.66, 0.82)
Osteophytes	0.48 (-0.31, 1.27)	0.48 (-0.25, 1.22)	0.66 (-0.16, 1.48)
No. of MRI abnormalities	-0.04 (-0.83, 0.75)	0.01 (-0.72, 0.73)	-
X-ray abnormalities...			
Osteophytes	-0.20 (-0.99, 0.59)	-0.21 (-0.95, 0.53)	0.03 (-0.77, 0.84)
JSN	**-1.08 (-1.82, -0.34)**	**-0.87 (-1.54, -0.19)**	**-0.87 (-1.61, -0.14)**

Associations were assessed using linear regression with inverse probability weighting.

Number of MRI abnormalities were dichotomised at the median (3).

MRI, magnetic resonance imaging; β, beta-coefficient; CI, confidence interval; CL, collateral ligament; BML, bone marrow lesions; JSN, joint space narrowing.

Bold denotes a statistically significant result.

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