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The Association Between Different Trajectories of Low Back Pain and Degenerative Imaging Findings in Young Adult Participants within The Raine Study

RRH: **Low Back Pain and Imaging Findings**

Anne Smith PhD[1], Mark Hancock PhD[2], Susan O'Hanlon MB BS FRANZCR[3,4], Michael Krieser MB BS FRANZCR[3,4], Peter O'Sullivan PhD[1], Flavia Cicuttini PhD[4], Leon Straker PhD[1], Brendan Adler MB BS FRANZCR[6], Yuanyuan Wang PhD[5], Jaro Karppinen PhD[7,8], Dino Samartzis PhD[9], Darren Beales PhD[1], Pieter Coenen PhD[10], Peter Kent PhD[1,11]

[1]School of Physiotherapy and Exercise Science, Curtin University, Perth, Australia

[2]Faculty of Medicine and Health Sciences, Macquarie University, Sydney, Australia

[3]Envision Medical Imaging, Perth, Australia

[4]Fiona Stanley Hospital, Perth, Australia

[5]School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia

[6]Envision Medical Imaging, Perth, Australia

[7]Medical Research Center Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland; [8]Rehabilitation Services of South Karelia Social and Health Care District, Lappeenranta, Finland

[9]Department of Orthopaedic Surgery, RUSH University, USA

[10]Amsterdam UMC, Vrije Universiteit, Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Amsterdam, The Netherlands

[11]Center for Muscle and Joint Health, University of Southern Denmark, Odense, Denmark

Corresponding author:

Anne Smith

School of Physiotherapy and Exercise Science, Curtin University, GPO Box U1987, Perth WA 6945, Australia

Email: Anne.Smith@curtin.edu.au; Ph: +61 8 421572987

Abstract

Study Design: case-control study

Objective: Investigate the association between lumbar spine MRI findings and 5-year trajectories of low back pain (LBP) in young Australian adults.

Summary of Background Data: The association between lumbar spine imaging findings and LBP remains unclear due to important limitations of previous research, such as a lack of clearly defined LBP phenotypes and inadequate controlling for age, which may substantially affect the association.

Methods: Seventy-eight 'case' participants with a previously identified 'consistent high disabling LBP' trajectory from age 17 to 22 years and 78 'control' participants from a trajectory with consistently low LBP over the same time period, matched for sex, body mass index, physical activity levels and work physical demands, were identified from Gen2 Raine Study participants. At age 27, participants underwent a standardised lumbar MRI scan, from which specific MRI phenotypes were identified. Primary analyses used unconditional logistic regression, adjusting for covariates used in the matching process, to investigate the relationship between presence of each imaging finding and being a case or control. Secondary analyses explored those relationships based on the number of spinal levels with each MRI finding.

Results: The odds for being a case compared to a control were higher in those with disc degeneration (Pfirrmann grade $\geq$3; OR=3.21, 95%CI:1.60-6.44; p=0.001) or those with a herniation (OR=1.90, 95%CI:0.96-3.74; p=.065). We also found that the association became substantially stronger when either disc degeneration or herniation was present at 2 or more spinal levels (OR=5.56, 95%CI:1.97-15.70; p=0.001, and OR=5.85, 95%CI:1.54-22.25; p=.009, respectively). The other investigated MRI findings were not associated with greater odds of being a case.

Conclusion: Lumbar disc degeneration and herniation may be important contributors to disabling LBP in young adults. Further investigation of their potential prognostic and causal roles is indicated.

Level of Evidence: 4

Keywords: low back pain, diagnosis, magnetic resonance imaging, disc degeneration

Mini Abstract:

This study investigated the association between lumbar spine MRI findings and 5-year trajectories of low back pain in young Australian adults. Young adults with disc degeneration or herniation were more likely to have a 5-year trajectory of consistently high disabling low back pain.

The manuscript submitted does not contain information about medical device(s)/drug(s).

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Background

Low back pain (LBP) is the leading cause of global disability, yet little is known about the underlying causes or pain generators.[1] Most patients with LBP are considered to have non-specific LBP, indicating that a pathoanatomical or nociceptive source cannot be identified. Critics of the term non-specific LBP argue that the term does not acknowledge the potential contribution of biologic factors or guide clinical management, and may contribute to lack of progress in reducing the burden of LBP.[2]

Magnetic resonance imaging (MRI) can detect structural spinal abnormalities that are potential sources of back pain. However, the clinical importance of these findings remains unclear due to relatively few studies, variable findings between studies and methodological limitations of the existing research.[3,4] A key limitation of many previous studies is the definition of LBP, which varies substantially. Given LBP is typically a long-term fluctuating condition,[5] how LBP is defined and the timing of the measures could be critical to the strength of any potential relationship between imaging findings and LBP. The experience of LBP over a sustained period, rather than at a single timepoint, may be a more valid/important way to define a 'case' but is prone to recall bias. Another key limitation of previous studies is the confounding influence of age as lumbar spine imaging findings become more common with each decade.[6] Thus, examining the relationship between lumbar spine imaging findings and LBP in younger people, when imaging findings are less common, provides the opportunity to determine if a relationship exists independent of age-related changes in older people.

The Raine Study (www.rainestudy.org.au) repeatedly collected detailed information on LBP, and these data have been used to identify individuals with different trajectories of LBP.[7] This provides a unique opportunity to investigate the relationship between lumbar MRI findings

and LBP in young adults with well-defined LBP phenotypes, thus accounting for significant limitation in prior research in this area. Therefore, the objective of this study was to investigate the association between selected lumbar spine MRI findings and previous LBP, defined using 5-year LBP trajectories in young adults.

Methods

Participants

This case-control study identified Gen2 participants from the Raine Study,[8] an ongoing intergenerational study of 2868 (Gen2) offspring born to 2900 women (Gen1) enrolled before the 18th gestational week between 1989-91. Full details of the Raine Study Gen2 in terms of design, measures, follow-up, attrition and representativeness are described elsewhere.[8] The current ongoing Gen2 cohort remain representative of the Western Australian population of a similar age in terms of education, occupation and income levels.[8]

Definition of cases and controls

A previous investigations in the Raine Study identified 4 distinct clusters of Gen2 participants with different trajectories of LBP and its impact from questionnaire data collected between 17 and 22 years of age, using latent class analysis.[7] In that previous study, pain was assessed on three occasions, at 17, 20 and 22 years of age, by the Nordic musculoskeletal questionnaire[9] modified to ask about pain in the last month. Impact was assessed using data on seeking care, taking medication, missing work or school, and modifying physical activity and activities of daily living. Participants were assigned to one of four trajectory groups, described as ' consistently low prevalence of LBP and impact' (53%), 'decreasing prevalence and impact' (15%),' increasing prevalence and impact' (22%) and 'consistently high prevalence and impact' (10%).[7] The current study recruited Gen2 participants at 27 years of age on a case control basis, by sampling 'case' participants from the group with 'consistently high prevalence and impact of LBP' and matched 'control' participants from the group with 'a consistently low prevalence and impact of LBP'. Thus, the study performed a cross-sectional analysis of differences in MRI parameters between two groups of participants at the age of 27, one with and one without a history of high prevalence and impact of LBP over the age of 17-22. The maximum number of participants was constrained to 78 in each group due to funding limitations for MRI scans. Figure 1 outlines the flow of the procedure for the identification of participants for this study.

Procedures

Five potential controls from the 661 participants from the trajectory of a consistently low prevalence of LBP and impact were identified for each of the 124 Gen2 Raine Study participants with a previously identified trajectory of a consistently high prevalence of LBP and its impact.[7] Propensity scores for case-control status were generated from sex, age, body mass index (BMI), self-reported moderate-vigorous physical activity levels (IPAQ short

form), and work physical demands,[10] measured at the time of the Gen2 22-year follow-up (Stata/IC 15.0 *pscore*) . We then used k-nearest neighbour matching (Stata/IC 15.0 *psmatch)* to identify 5 of the best matching participants to be approached to participate in the study as a control for each case.[11] A research assistant was provided with a list of the 124 cases in randomly order, with their 5 potential matched controls, ordered by proximity of matching. Case participants were contacted by telephone sequentially from the randomly ordered list to ascertain their willingness to undergo lumbar MRI and were screened for contraindications to MRI scanning. If they agreed to participate, the 5 potential matched controls were contacted in order of proximity of matching, until a consenting matched control was identified. All participants were screened for contraindications to MRI, and provided informed written consent.

Participants underwent lumbar MRI scanning between February and November 2018. In the week prior to, or at the time of, their MRI scan appointment, participants completed an online questionnaire, which collected 3 widely recommended measures related to current LBP. These were average pain intensity in the last week (Numerical Pain Rating Scale 0-10),[12] pain-related disability (Roland Morris Disability Index (RMDQ), 0-24 with 24 representing high disability)[13] and 'personal impact of LBP' (8-50 scale), as recommended by the NIH task force report on research standards for LBP.[14] The outcome combines 9 items from the Patient Reported Outcome Measurement Information System (PROMIS-10) short form and covers the domains of pain intensity, pain interference with normal activities and functional status.

Lumbar spine imaging

The lumbar spine of all participants was imaged on a single occasion in a 1.5 Tesla clinical MR scanner (Skyra, Siemens Healthineers). Participants underwent sagittal and axial T1- and T2-weighted sequences of the lumbar spine with optimised parameters used in standard MRI protocols as follows: 1) sagittal T1 images (FOV 280mm, TR 767msec, TE 9.5 msec, res 0.729 x 0.729mm, slice thickness 4mm), (2) sagittal T2 images (FOV 280mm, TR 2900msec, TE 90msec, res 0.729 x 0.729 mm, slice thickness 4mm) (3) axial T2 image (FOV 190mm, TR 3420msec, TE 94msec, res 0.594 x 0.594mm, slice thickness 4mm) (4) sagittal TIRM (FOV 280mm, TR 3500msec, TE 38msec, res 0.875 x 0.875mm, slice thickness 4mm).

MRI findings were reported separately for each lumbar spine level from (T12-L1 to L5-S1). Measures included disc degeneration, disc space narrowing, Modic changes, high intensity zone (HIZ) lesions, disc herniation/protrusion, lumbar stenosis, osteophytes, nerve root compromise, facet joint arthrosis, spondylolisthesis, bone marrow oedema and fat infiltration of multifidus (Table 1). A radiologist blinded to case/control status and questionnaire outcomes performed the grading guided by detailed instructions for reporting on each finding. A second radiologist, using the same reporting instructions, graded 91 randomly selected MRIs for the purpose of estimating inter-rater reliability. Table 1 reports the method of initial scoring for each MRI finding and the derived measures used in analyses.

Statistical analysis

Inter-Rater Reliability

Reliability analyses were conducted per spinal level on MRI variables with an average prevalence >15% in the total case-control sample. To accommodate the use of multiple levels (maximum of 6) per individual, overall bias-corrected 95% confidence intervals for inter-rater kappa values were calculated using a bootstrap technique with 1000 samples each, with 91 MRI examinations taken with replacement from the image records at the individual-level.

Case control differences

Summary statistics for matching variables are presented for cases and controls. Pain, disability and impact measures, collected at time of MRI, were compared between cases and controls using chi-squared test for binary variables or Mann-Whitney U test for both ordinal and continuous variables, due to the skewed distribution.

The relationship between MRI parameters and case vs control status was statistically investigated where the prevalence of the MRI parameter pooled over the case and control groups was >15% or tabulated only when less than 15%. For those MRI parameters that were compared statistically, primary analysis was performed using unconditional (ordinary) logistic regression adjusting for covariates used in the matching process, as recommended as best practice for studies of matched pairs.[15] Conditional matched logistic regression was also performed as a sensitivity analysis. First, we investigated the relationship between the presence of each MRI finding and being a case or control. We then investigated the relationship between the number of spinal levels with each MRI finding and being a case or control. Odds ratios (ORs) and associated 95% confidence intervals (CIs) and p-values are presented for all analyses.

Power

We were able to identify 78 pairs of cases and a corresponding, suitable matched control who were willing to consent to participate in the study and undergo MRI scanning. With 78 pairs, we had 80% power to detect ORs of $\geq$2.5 for single MRI findings with a 35% prevalence. For MRI findings with prevalence lower than 35% we discuss OR estimates and their associated 95% CIs, as to whether they are potentially informative, even where p>0.05.

Results

Of the 124 Gen2 Raine Study participants with a previously identified trajectory of a consistently high prevalence of LBP and its impact, 108 were randomly approached to undergo an MRI for the study. Of the 108 approached, 78 (62.9%) participated in the study, 19 (17.6%) resided interstate and were thus unavailable, 2 (1.9%) were pregnant, and 9 (8.3%) declined participation, for reasons unrecorded. Of the 661 Gen2 Raine Study participants with a previously identified trajectory of a consistently low prevalence of LBP

and its impact, 96 were randomly approached to undergo MRI, and of these 78 (81.3%) participated in the study, 5 (5.2%) resided interstate and were thus unavailable, 2 (2.1%) were pregnant, and 11 (11.4%) declined participation. Cases and controls were comparable on all 5 matching variables (Table 2). The proportion of participants with current LBP, and the severity of current LBP, RMDQ and PROMIS were all clinically and statistically significantly higher in cases than controls at the time of MRI (Table 2).

Inter-rater reliability kappa values were 0.855 (95%CI:0.753-0.926) for presence of Pfirrmann grade 3 or more, 0.588 (95%CI:0.450-0.710) for presence of disc herniation, 0.362 (95%CI:0.189-0.523) for presence of HIZ and 0.239 (95%CI:0.037-0.351) for presence of facet joint arthrosis.

Odds for being a case versus control were significantly higher in the presence of $\geq$ Grade 3 lumbar disc degeneration at any spinal level (OR=3.21, 95%CI:1.60-6.44, p=.001, Table 3). Odds ratios were larger if $\geq$ Grade 3 lumbar disc degeneration was present at 2 or more spinal levels (OR=5.56, 95%CI:1.97-15.70, p=.001, Table 3) and not as large when disc degeneration was present at only one spinal level (OR=2.31, 95%CI:1.03-5.16, p=.042, Table 3).

Odds for being a case versus control did not differ in the presence of HIZ at any spinal level (OR=1.21, 95%CI:0.60-2.44, p=.595, Table 3), nor when the number of levels with HIZ was considered.

Odds for being a case versus control were higher in the presence of disc herniation at any level (OR=1.90, 95%CI:0.96-3.74, p=.065, Table 3), and this was more so in the presence of disc herniation at 2 or more levels (OR=5.85, 95%CI:1.54 – 22.25, p=.009).

Odds for being a case versus control did not differ in the presence of facet joint arthrosis at any spinal level (OR=0.83, 95%CI:0.40-1.69, p=.600, Table 3), nor when the number of levels with facet joint arthrosis was considered.

For all MRI parameters, conditional matched logistic regression results were in agreement with the findings of the primary analysis (Table 3).

Prevalence of MRI features with pooled prevalence at less than 15% are presented for cases and controls in Table 4. No MRI parameter with low prevalence appeared to be substantially more common in the cases than the controls based on observation of prevalence values in each group.

Discussion

Main findings:

This study found that some lumbar MRI findings were substantially more common in young adults with a well-documented history of consistent LBP and impact, when compared to

matched young adults who consistently did not report LBP. Specifically, the odds for being a case compared to a control were higher in those with disc degeneration grade ≥3 (OR=3.21, 95%CI:1.60-6.44) or those with a herniation (OR=1.90, 95%CI:0.96-3.74). We also found that the association became substantially stronger when either disc degeneration or herniation was present at 2 or more spinal levels (OR=5.56, 95%CI:1.97-15.70 and OR=5.85, 95%CI:1.54 – 22.25 respectively). The other investigated MRI findings were not associated with greater odds of being a case.

Comparison to previous studies

Our findings in 27-year-old people align with a recent systematic review[16] that investigated the prevalence of lumbar MRI finding in adults <50 years old with and without LBP. They reported that disc degeneration, extrusion, protrusion, Modic type 1 changes, and spondylolysis were more common in those with LBP. For disc degeneration they reported an odds ratio of 2.24 (95%CI:1.21– 4.15) compared to our OR of 3.21 (95%CI:1.60-6.44). They reported substantial heterogeneity across studies (I^2=89%) which is likely due to the different definitions of pain and different thresholds used for disc degeneration across individual studies. It may also reflect the variability in age of participants across the included studies. The authors used meta-regression to investigate if the relationship between disc degeneration and LBP was different based on age but were unable to draw any solid conclusions due to limited power. Our somewhat stronger relationship may be a result of including only young adults, and/or our definition of case vs control which was based on repeated measures over 5 years. In our study we defined herniation as protrusion, extrusion, or sequestration, while in the Brinjikji review[16] they reported separately for disc extrusion and protrusion. Despite this our findings are similar, although the ORs reported for extrusion (4.38; 95%CI:1.98 –9.68) are higher than we found for all herniations (OR=1.90, 95%CI:0.96-3.74). Similar to our study, Brinjikji et al[16] did not find a significant association between any Modic change (aggregated regardless of type) or high intensity zone and LBP. We did not formally test the association between Modic changes and LBP as the prevalence was <15% but the raw data do not suggest an important relationship (Table 4). Brinjikji et al[16] do report a positive association between Modic Type 1 and LBP (OR=4.01; 95%CI:1.10–14.55) but we had inadequate prevalence of Type 1 changes to investigate this relationship.

The study by Takatalo et al[17] is arguably the most similar study to ours. They included a sample of a birth cohort of 21-year-old young adults and investigated the relationship between disc degeneration and clusters of patients based on pain and functional limitation at ages of 18, 19 and 21. Similarly to our study they found a positive relationship between disc degeneration grade 3 and high LBP severity cluster, when compared to minor pain cluster (OR= 1.88; 95%CI:1.02–3.48). They also investigated a higher threshold of grade 4 disc degeneration and found a slightly stronger relationship (OR= 2.77; 95%CI:1.38–5.57). An important difference between the study by Takatalo et al[17] and our study is that we selected propensity score “matched controls” based on sex, age, body mass index, self-reported physical activity levels, and work physical demands.

Strengths, Limitations and Future Directions

A strength of our study is the inclusion of a representative sample of young adults with a well-defined back pain phenotype over a 5-year period, and closely matched controls. The imaging acquisition process and reporting were standardised, and inter-rater reliability was confirmed on 91 participants. Sensitivity analyses confirmed the main findings.

A limitation of our study is that we investigated the relationship between imaging findings and previous LBP experience. Future research is needed as to whether the existence of imaging findings, such as disc degeneration and disc herniation, predict future LBP or response to specific interventions. Until imaging findings are shown to predict future LBP or response to intervention, their clinical importance remains uncertain. Currently very few such studies have been conducted[3,4] and this is an important area for future research. Our sample size was larger than most previous studies,[16] however, the prevalence for several imaging findings were low (<15%), so we were unable to draw confident conclusions about the association of these variables with LBP.

Conclusions

This study of young adults found MRI reported disc degeneration and disc herniation are associated with a history of disabling LBP over a 5-year period. In addition, these relationships were stronger when the MRI finding was present at 2 or more lumbar levels. These findings suggest that lumbar disc degeneration and herniation may be important contributors to LBP; however, a causal association cannot be confirmed. The clinical importance of these findings needs to be confirmed in future studies examining whether these MRI findings are able to predict important clinical outcomes or response to specific interventions.

Key Points:

- The association between lumbar spine imaging findings and low back pain remains unclear due to important limitations of previous research
- We investigated the association between lumbar spine MRI findings and 5-year trajectories of low back pain in young Australian adults
- Young adults with disc degeneration or herniation were more likely to have a 5-year trajectory of consistently high disabling low back pain
- The presence of disc degeneration or herniation at 2 or more levels strengthened the relationship with a 5-year trajectory of consistently high disabling low back pain

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Figure legends

Figure 1: Flow chart of the procedure for the identification of study participants

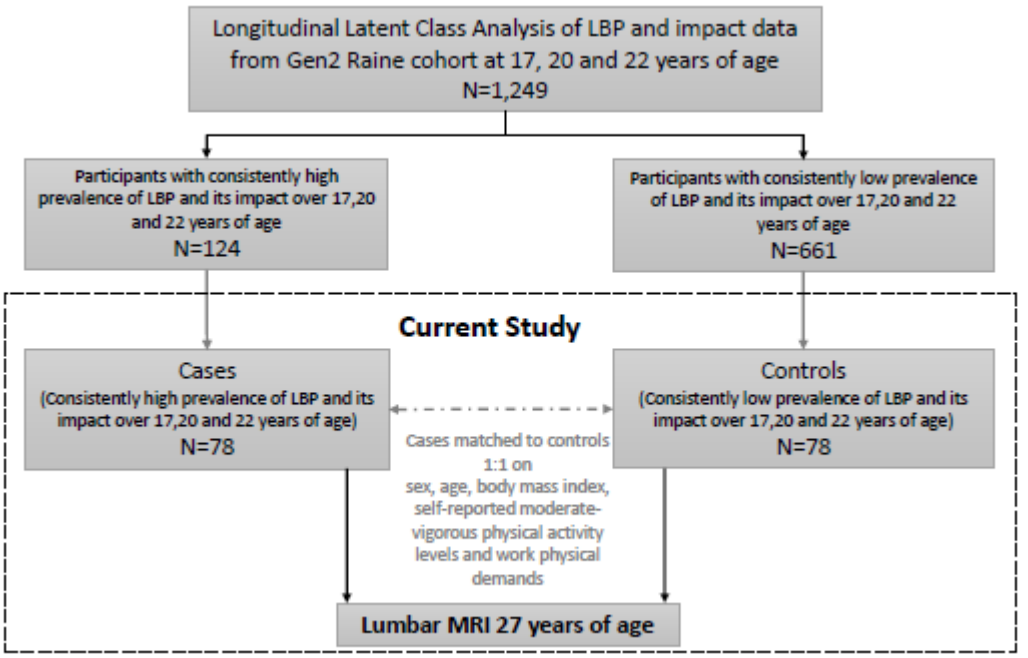

Table 1: MRI measures, method of scoring at each spinal level, and derived summary variables

MRI measure	Method of initial scoring	Level of data
Lumbar intervertebral joint/disc pathology		
Lumbar disc degeneration	Pfirrmann classification[18] Ordinal (1-5 scale)	Grade 3 or more at any spinal level (Y/N)
Modic changes (vertebral bone marrow lesions)	As per task force recommendations[19]	Presence of any (1, 2 or 3) Modic change at any spinal level (Y/N) Presence of Type 1 Modic change at any spinal level (Y/N)
Disc herniation	As per task force recommendations[19]	Presence of disc herniation at any level (focal protrusion, extrusion, or sequestration) (Y/N) Presence of an extrusion or sequestration at any level (Y/N)
High intensity zone (HIZ) lesions	As per task force recommendations[19]	Presence of HIZ at any level (Y/N)
Osteophytes		Presence at any level (Y/N)
Central stenosis Foraminal stenosis		Presence of any central stenosis at any level (Y/N) Presence of any foraminal stenosis at any level (Y/N)
Nerve root		Any nerve root compromise (Y/N)

compromise		
Posterior vertebral column pathology		
Facet joint degeneration	As per Carrino et al[20]	Present of any facet joint arthrosis at any level (Y/N)
Spondylo- listhesis	As per Carrino et al[20]	Spondylolisthesis present at any level (Y/N)
Bone marrow oedema (pars)		Present at any level (Y/N)
Muscle pathology		
Fat infiltration in the multifidus muscle	Ordinal 0: less than 10% fat, 1: 10-50%, 2: more than 50%[21]	Fat infiltration at any level (Y/N)
General evaluation		
Scoliosis	Present/absent, location of apex, convexity, dysplasia, vertebral height reduction	Presence (Y/N)
Transitional vertebra		Presence (Y/N)

Table 2: Sample Demographics and Pain Characteristics

Demographic and Current LBP measures	Scoring	Controls (n=78)	Cases (n=78)	
Age (yrs)	Mean, SD	27.3 (0.1)	27.3 (0.1)	
Time from Age 22 year assessment to MRI (yrs)	Mean, SD	5.2 (0.5)	5.2 (0.5)	
Sex	N (%) females	56 (71.8%)	56 (71.8%)	
Other Matching variables (collected at Age 22 years)				
BMI	Mean, SD	24.4 (5.1)	24.9 (5.1)	
Moderate-Vigorous PA	From IPAQ; Deciles of total time	5 (6)	5 (5)	
	median (IQR), min-max	0-9	0-9	
Work demand	Sedentary	17 (21.8%)	14 (20.5%)	
	Standing	37 (47.4%)	35 (44.9%)	
	Physical	20 (26.6%)	23 (29.5%)	
	Heavy manual	4 (5.1%)	4 (5.1%)	
LBP measures collected at time of MRI[a]				**Difference**
LBP in the last week	N (%) scoring 3 or more on NRS for average LBP in the last week	12 (15.6%)	49 (62.8%)	p<.0001[b]
LBP (average in last week), (0-10)	NRS: median (IQR), min-max	0 (2) 0-6	3 (3) 0-8	p<.0001[c]
Roland Morris Disability Index (0-24)	median (IQR), min-max	0 (1) 0-24	3 (6) 0-20	p<.0001[c]
PROMIS impact (8-50)	median (IQR), min-max	8 (2) 8-29	14 (7) 8-33	p<.0001[c]

[a]One Control participant did not complete online questionnaire at time of MRI, imputed mean of Controls for LBP measures [b]chi-squared test, [c]Mann-Whitney U test

Table 3: Prevalence of MRI parameters for Cases and Controls, and Odds Ratios for Case versus Control status based on each MRI parameter (for those parameters where prevalence pooled over both groups was greater than 15%)

MRI parameter	Controls (n=78)	Cases (n=78)	Primary Analysis[a]: OR (95%CI), p-value	Sensitivity Analysis[b]: OR (95%CI), p-value
Lumbar disc degeneration: Grade 3 or more at any spinal level (Yes/No)				
	21 (26.9%)	41 (52.6%)	3.21 (1.60 – 6.44), p=.001	2.67 (1.37 – 5.18), p=.004
Lumbar disc degeneration: Count of levels with Grade 3 or more				
0	57 (73.1%)	37 (47.4%)	REF	REF
1	15 (19.2%)	21 (26.9%)	2.31 (1.03 – 5.16), p=.042	2.16 (0.99 – 4.71), p=.054
≥2[c]	6 (7.7%)	14 (18.0%)	5.56 (1.97 – 15.70), p=.001	5.14 (1.89 – 13.98), p=.001
3	0	6 (13.7%)	N/A[c]	NA[c]
High intensity zone (HIZ): Presence of HIZ at any level (Yes/No)				
	21 (26.9%)	24 (30.8%)	1.21 (0.60 – 2.44), p=.595	1.21 (0.6 – 2.46), p=.591
High intensity zone (HIZ): Count of levels with HIZ				
0	57 (73.1%)	54 (69.2%)	REF	REF
1	16 (20.5%)	18 (23.1%)	1.16 (0.53 – 2.54), p=.707	1.19 (0.58 – 2.43), p=.638
2	5 (6.4%)	6 (7.7%)	1.37 (0.39 – 4.84), p=.627	1.37 (0.39 – 4.84), p=.588
Disc herniation (focal protrusion, extrusion, or sequestration): presence at any level (Yes/No)				
	23 (29.5%)	34 (43.6%)	1.90 (0.96-3.74), p=.065	1.85 (0.94 – 3.63), p=.075
Disc herniation (focal protrusion, extrusion, or sequestration): Count of levels				
0	55 (70.5%)	44 (56.4%)	REF	REF

MRI parameter	Controls (n=78)	Cases (n=78)	Primary Analysis[a]: OR (95%CI), p-value	Sensitivity Analysis[b]: OR (95%CI), p-value
1	20 (25.6%)	21 (26.9%)	1.31 (0.61 – 2.78), p=.489	1.36 (0.65 – 2.84), p=.418
≥2[c]	3 (3.9%)	10 (12.8%)	5.85 (1.54 – 22.25), p=.009	6.77 (1.47 – 31.28), p=.014
3	0	3 (3.9%)	N/A[c]	N/A[c]
Facet joint arthrosis: Presence at any level (Yes/No)				
	23 (29.5%)	21 (26.9%)	0.83 (0.40 - 1.69), p=.600	0.88 (0.43 – 1.79), p=.715
Facet joint arthrosis: Count of levels with arthrosis				
0	55 (70.5%)	57 (73.1%)	REF	REF
1	20 (25.6%)	18 (23.1%)	0.80 (0.37 – 1.71), p=.556	0.87 (0.42 – 1.81), p=.708
≥2[c]	2 (2.6%)	2 (2.6%)	1.03 (0.19 – 5.44), p=.976	0.93 (0.18 -4.82), p=.933
3	1 (1.3%)	1 (1.3%)	N/A[c]	N/A[c]

[a]Unconditional (Ordinary) logistic regression model, adjusting for matching variables only (sex, age, body mass index (BMI), self-reported moderate-vigorous physical activity levels, and work physical demands), [b]conditional matched logistic regression, [c]count categories 2 and 3 combined for analysis due to sparse data for counts of 3 levels, N/A= not applicable as analysis not conducted due to sparse data

Table 4: Prevalence of MRI parameters in cases and controls, for those parameters where prevalence pooled over both groups was less than 15%

MRI parameter (Yes/No)	Controls (n=78)	Cases (n=78)
Nerve root compromise:	9 (11.5%)	13 (16.7%)
Presence at any spinal level		
Modic change any type:	7 (9.0%)	5 (6.4%)
Presence at any spinal level		
Modic Type 1 change:	5 (6.4%)	0
Presence at any spinal level		
Disc extrusion or sequestration: Presence at any spinal level	1 (1.3%)	5 (6.4%)
Central stenosis:	0	1(1.3%)
Presence at any spinal level		
Foraminal stenosis:	0	0
Presence at any spinal level		
Osteophytes:	4 (5.1%)	4 (5.1%)
Presence at any spinal level		
Spondylolisthesis:	5 (6.4%)	4 (5.1%)
Presence at any spinal level		
Bone Marrow oedema:	0	1 (1.3%)
Presence at any spinal level		
Fat infiltration:	4 (5.1%)	3 (3.9%)
Presence at any spinal level		
Scoliosis:	2 (2.6%)	2 (2.6%)
Presence		
Transitional Vertebrae:	1 (1.3%)	0
Presence		