

1 **Presence and Extent of Severe Facet Joint Osteoarthritis Are Associated with Back**  
2 **Pain in Older Adults**

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34 **ABSTRACT**

35 **Objective:** To determine whether the presence and extent of severe lumbar facet joint  
36 osteoarthritis (OA) is associated with back pain in older adults, accounting for disc height  
37 narrowing and other covariates.

38 **Design:** 252 older adults from the Framingham Offspring Cohort (mean age 67 years)  
39 were studied. Participants received standardized CT assessments of lumbar facet joint OA  
40 and disc height narrowing at the L2-S1 interspaces using 4-grade semi-quantitative  
41 scales. Severe facet joint OA was defined according to the presence and/or degree of joint  
42 space narrowing, osteophytosis, articular process hypertrophy, articular erosions,  
43 subchondral cysts, and intraarticular vacuum phenomenon. Severe disc height narrowing  
44 was defined as marked narrowing with endplates almost in contact. Back pain was  
45 defined as participant report of pain on most days or all days in the past 12 months. We  
46 used multivariable logistic regression to examine associations between severe facet joint  
47 OA and back pain, adjusting for key covariates including disc height narrowing,  
48 sociodemographics, anthropometrics, and health factors.

49 **Results:** Severe facet joint OA was more common in participants with back pain than  
50 those without (63.2% vs. 46.7%; $p=0.03$ ). In multivariable analyses, presence of any  
51 severe facet joint OA remained significantly associated with back pain (odds  
52 ratio[OR]2.15 (95% confidence interval [CI]1.13-4.08). Each additional joint with severe  
53 OA conferred greater odds of back pain (OR per joint 1.20 (95% CI;1.02-1.41).

54 **Conclusions:** The presence and extent of severe facet joint OA on CT imaging is  
55 associated with back pain in community-based older adults, independent of  
56 sociodemographics, health factors, and disc height narrowing.

57 Key Words: zygapophyseal; lumbar; arthritis, intervertebral disc, spondylosis

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59

60 **INTRODUCTION**

61

62 Back pain is a common reason prompting older adults to seek medical care, and a  
63 leading cause of disability in developed countries [1-5]. The spinal facet  
64 (*'zygapophyseal'*) joints are a widely treated source of back pain, and rates of  
65 nonoperative yet invasive percutaneous facet joint procedures in older adults have  
66 increased more than 4-fold over the past decade[6]. Facet joint osteoarthritis (OA) is  
67 often presumed to be the cause of pain in some older adults with facet-mediated pain  
68 confirmed by anesthetic blocks[7]. Nevertheless, some patients with facet joint OA may  
69 have no back pain at all, and patients without facet joint OA may have substantial back  
70 pain[8-10]. This discordance between the appearance of facet joint OA on imaging and  
71 the symptom of pain is analogous to the high prevalence of asymptomatic radiographic  
72 findings observed in the setting of knee OA[11, 12].

73 Cross-sectional imaging using CT or MRI is necessary for complete evaluation of  
74 facet joint morphology in multiple planes, including the axial plane. Remarkably few  
75 population-based studies have examined relationships between facet joint OA on cross-  
76 sectional spinal imaging and the presence of back pain[8-10] (Table 1), and no studies  
77 have found significant associations. However, characteristics of these earlier works may  
78 explain why relevant associations between facet joint OA and back pain might not have  
79 been detected. Prior studies used either mild or moderate facet joint OA at any spinal  
80 level as the threshold for defining prevalent facet joint OA. It is possible that more  
81 advanced (severe) facet joint OA would be more strongly associated with back pain, such  
82 as is seen in the context of knee OA[11]. Also, prior studies did not examine the number

83 of levels affected by severe facet joint OA, ignoring this important aspect of disease  
84 burden. Furthermore, earlier studies examined younger and middle-aged samples. This  
85 largely excludes older adults, in whom advanced facet joint OA on imaging as well as  
86 facet-mediated pain is most prevalent[13, 14], and in whom facet joint interventions are  
87 most commonly performed[6]. Last, some prior studies have not utilized well-described  
88 and reliable scales for facet joint OA[8, 9].

89 <<Table 1>>

90 We attempted to overcome these limitations by conducting a study to examine  
91 associations between lumbar facet joint OA on imaging and back pain in a sample  
92 representative of community-based older US adults. The aim of this study was to  
93 determine whether definitions of facet joint OA incorporating the presence and extent of  
94 severe facet joint OA are associated with back pain in older adults, with and without  
95 adjustment for other sociodemographic factors, clinical factors, and disc height  
96 narrowing.

97

98

99     **METHODS**

100

101     **Participants:** This study was an ancillary investigation to the Framingham Heart Study,  
102     and was approved by the Institutional Review Board of New England Baptist Hospital.  
103     The Offspring cohort of the Framingham Heart Study was initiated in 1971 as a  
104     prospective epidemiologic study of 5124 young adults [15]. 1418 individuals from the  
105     Offspring cohort underwent computed tomography (CT) scanning as part of the  
106     multidetector CT (MDCT) substudy of Framingham, which has been described elsewhere  
107     <sup>[16, 17]</sup>. Two hundred and seventy-two participants randomly selected from the MDCT  
108     cohort study received standardized CT assessments of facet joint OA as part of this  
109     ancillary study (Figure 1). Of this subgroup, 252 participants also attended Framingham  
110     Examination 8, and comprised our study sample. This represents a separate study sample  
111     from that reported in an earlier publication on facet joint OA by our research group [10].  
112     Whereas the earlier study examined participants from both the Offspring and Generation  
113     3 cohorts of Framingham, the present study sample is drawn from the Offspring cohort  
114     only, enriching the sample for older adults. Furthermore, the present study includes  
115     separate CT assessments conducted by different readers, and different pain assessments.  
116     In addition, our *a priori* analytic approach is distinct from that taken in our earlier work  
117     in that it examines the presence and extent of severe facet joint OA, rather than the  
118     finding of any moderate FJ facet joint OA.

119

<< Figure 1 >>

120

121 **Assessment of Facet Joint Osteoarthritis:** All CT imaging assessments were performed  
122 using eFilm Workstation (Version 2.0.0) software, with blinding to sociodemographic  
123 and health-related factors, and pain information. Facet joint OA was graded at both the  
124 left and the right side at the spinal levels L2-L3, L3-L4, L4-L5, and L5-S1. We applied  
125 the Framingham Scale for grading of facet joint OA, a semi-quantitative measure we  
126 designed for these research purposes, based on earlier scales by Pathria et al.[19] and  
127 Weishaupt et al.[20] The Framingham Scale grades facet joint OA according to the  
128 degree of pathoanatomic change in the separate subcategories of joint space narrowing,  
129 osteophytosis, articular process hypertrophy, sclerosis, subarticular erosion, subchondral  
130 cystic change, and presence of vacuum phenomenon (Appendix 1). Because we were  
131 specifically focused on examining associations with severe or advanced facet joint OA,  
132 we considered the presence of severe facet joint OA to be at least grade IV facet joint OA  
133 in either the left or right facet joints at one or more lumbar spinal levels L2-S1 (Appendix  
134 1). We defined the extent of severe facet joint OA as the number of joints with severe  
135 facet joint OA at the lumbar spinal levels L2-S1 (range 0-8). **The Framingham CT scans**  
136 **did not consistently include the L1-L2 level, and this level therefore was not read as part**  
137 **of these structured assessments.**

138

139 **Assessment of Disk Height Narrowing:** Disc height narrowing was graded at spinal  
140 levels L2-L3, L3-L4, L4-L5, and L5-S1, using grading criteria developed for research  
141 purposes by Videman et al., that have been used previously in studies of spinal  
142 degeneration on MRI[21-23]. Using sagittal CT reformatting, the midsagittal plane was  
143 identified at each level, and measurements of disc height narrowing were made at the



144 midpoint of the anteroposterior diameter of the disk. This method was intended to  
145 account for degenerative scoliosis, which is common in older adults and may influence  
146 interpretations of disc height. These measurements were then used in applying the  
147 grading system of Videman: disc height narrowing was graded as ‘normal’ (disc height  
148 greater than level immediately superior), ‘mild’ (disc height equal to level immediately  
149 superior), ‘moderate’ (disc height narrowed as compared to level immediately superior),  
150 and ‘severe’ (endplates almost in contact)[24]. In instances where the reference level  
151 exhibited apparent disc height narrowing, the first ‘normal’ interspace superior to the  
152 index level was used as a reference. Since there is greater variability in disc height at the  
153 L5-S1 level as compared to L4-L5 [25], L5-S1 was graded based on reader experience,  
154 but was generally considered normal if comparable to, or slightly narrowed, as compared  
155 to L4-L5. Further details of the disc grading methods employed are provided  
156 elsewhere[24].

157

158 **Quality and Reliability of CT Assessments:** CT assessments of facet joint OA and disc  
159 height narrowing were performed by a board-certified, fellowship-trained nonoperative  
160 spine care specialist (PS), who was trained by a musculoskeletal radiologist (AG).  
161 Assessments of facet joint OA and disc height narrowing were performed at separate  
162 periods in time (i.e. disc height narrowing assessments were completed for all  
163 participants in the sample prior to the start of facet joint OA assessments), and  
164 participants were blinded to the results of these assessments. A reference atlas for each  
165 degenerative parameter was used throughout the reading process. The spine specialist  
166 reader calibrated to the standard of the radiologist prior to the start of formal reads using

167 training sets of CT scans, and inter-observer reliability was calculated between the  
168 radiologist and spine specialist at the start of the reading process. All CT scans were  
169 interpreted by the spine specialist in a blinded fashion. Recalibration of the spine  
170 specialist was repeated during the reading process, either by direct interactions with the  
171 radiologist, or by review of images previously interpreted by the radiologist. To evaluate  
172 for reader-drift, reliability was reassessed periodically. Inter-observer reliability using the  
173 weighted  $\kappa$  statistic ranged between 0.68 and 0.84 for facet joint OA, and 0.70 and 0.84  
174 for disc height narrowing, representing moderate to excellent reproducibility.

175

176 **Assessment of Back Pain:** All participants in the Framingham Offspring cohort  
177 underwent a standardized interview as part of the recurring Framingham clinical  
178 examinations. Participants were asked the question, ‘Have you had back pain in the past  
179 12 months?’ Response categories included ‘no back pain’, or back pain on ‘a few days’,  
180 ‘some days’, ‘most of the days’, or ‘all days’. Because most individuals reported having  
181 at least some back pain, and we were interested in associations with frequent or persistent  
182 back pain specifically, individuals who reported having back pain on ‘all days’ or ‘most  
183 of the days’ were considered to have frequent back pain, and individuals who reported  
184 having no back pain, back pain on ‘a few days’, or ‘some days’ were considered to be  
185 without frequent back pain. Back pain and covariate data were taken from the  
186 Framingham examination that best coincided with the timing of the CT scan  
187 (Examination 8); this examination was conducted an average of 20 months after the CT  
188 scan (range: -1 to 58 months).

189

190 **Covariates:** Covariates examined in this study included those of particular relevance to  
191 older adults at or beyond retirement age[26-28]. Data were collected on participant age  
192 calculated according to birth date, and participant-reported sex, race, ethnicity, and  
193 **educational** background. Participants reported on current employment or volunteering  
194 activities, retirement from primary occupation or career, marital status, and whether or  
195 not they currently lived alone. Height and weight were measured at each clinical  
196 examination, and body mass index (BMI) was calculated as weight (kg) divided by height  
197 (meters<sup>2</sup>). Participants who reported smoked regularly within the past year were defined  
198 as current smokers.

199

#### 200 **Statistical analysis:**

201 We characterized the sample using descriptive statistics. We compared  
202 sociodemographics, health-related factors, and prevalence of facet joint OA and disc height  
203 narrowing between participants with and without frequent back pain, using the Student's t-  
204 test for continuous variables or the chi-square test for categorical variables. We used **a series**  
205 **of** logistic regression models to determine **unadjusted** associations between **single**  
206 independent variables, including facet joint OA, and the outcome of frequent back pain. We  
207 examined correlations between independent variables using Spearman correlation  
208 coefficients. Next, we created a 'core' **multivariable logistic regression** model that included  
209 those sociodemographic and health-related factors that demonstrated at least a statistical  
210 trend towards an association with frequent back pain in the **unadjusted** regression **models** ( $p$   
211  $\leq 0.15$ ). We then added the variables of any severe facet joint OA and any severe disc height  
212 narrowing to the core **multivariable** model. We then repeated this process, treating the facet

213 joint OA and disc height narrowing variables as the number of joints with severe OA or the  
214 number of disc levels with severe narrowing, rather than as dichotomous variables. We also  
215 conducted secondary multivariable analyses choosing covariates based on conceptual  
216 importance, adjusting for the factors of age, sex, BMI, and education. All analyses were  
217 performed using SPSS software, version 20.0.0) (IBM Corporation, Armonk, NY).

218

## 219 RESULTS

220 Two hundred and fifty-two participants comprised the study sample (Table 2).  
221 The mean age of participants was  $67.4 \pm 9.1$  years and approximately half of participants  
222 were female. Reflecting the demographics of Framingham, Massachusetts at the time of the  
223 Offspring cohort's inception, almost all participants were of white race and of non-Latino  
224 ethnicity. Roughly half of the sample were neither working nor volunteering, or had retired  
225 from their primary career occupation, reflecting the older age of the study sample. The study  
226 sample was slightly older than the main MDCT cohort (67.4 vs. 65.9 years;  $p=0.02$ ), but  
227 otherwise without significant differences with respect to sociodemographic factors or back  
228 pain (data not shown).

229

<< Table 2 >>

230 Table 3 presents a comparison of individuals with and without frequent back pain.  
231 Individuals with back pain were significantly older than those without (69.6 vs. 66.7 years;  
232  $p=0.03$ ); this association was driven mainly by a higher prevalence of back pain in those  
233 adults age  $\geq 75$  years. Self-report of neither working nor volunteering currently, and  
234 retirement from usual occupation, were significantly associated with a higher prevalence of  
235 back pain, and individuals with back pain were also somewhat more likely to live alone.

236 Other sociodemographic and health factors, including higher BMI, were not associated with  
237 back pain. The presence of moderate facet joint OA was not associated with back pain, but  
238 both the presence of any severe facet joint OA (46.7% vs. 63.2%; p=0.03), and the number of  
239 joints with severe facet joint OA (p=0.006), were significantly associated with back pain.  
240 No associations were seen between disc height narrowing and back pain, regardless of the  
241 severity or extent of disc height narrowing.

242 <<suggested position of Table 3>>

243 Table 4 presents odds ratios (ORs) and 95% confidence intervals (95% CI) for  
244 associations between predictor variables and frequent LBP. Retirement and  
245 working/volunteering status were highly intercorrelated, and therefore only retirement status  
246 was included in the multivariable analyses. In the core multivariable model including the  
247 sociodemographic factors of age  $\geq 75$ , retirement, and living alone, retirement showed a weak  
248 and non-significant trend towards an association with back pain (odds ratio [OR] 1.82 [95%  
249 confidence interval [95% CI] 0.95-3.48]), but other variables showed no independent  
250 association with back pain (data not shown). When the variables of any severe facet joint OA  
251 and any severe disc height narrowing were added to the core model, the presence of any  
252 severe facet joint OA was significantly and independently associated with back pain (OR  
253 2.15 [95% CI 1.13-4.08]), but no association was seen for disc height narrowing. When the  
254 variables of number of joints with severe facet joint OA and number of spinal levels with  
255 severe disc height narrowing were added to the core model, the number of joints with severe  
256 OA was significantly and independently associated with back pain (OR 1.22 [95% CI 1.04-  
257 1.42]), but no such association was seen for number of spinal levels with severe disc height  
258 narrowing. In secondary multivariable analyses, when adjusting for factors based on

259 conceptual importance alone (age, sex, BMI, and education), any severe facet joint OA (OR  
260 1.96 [95% CI 1.01-3.77]), and number of joints with severe OA (OR 1.21 [95% CI 1.03-  
261 1.42]), were significantly associated with back pain, although the corresponding measures for  
262 disc height narrowing were not. Last, in sensitivity analyses to examine the effects of  
263 imprecise temporal concordance between the date of the CT scans and the clinical  
264 examination (during which back pain frequency in the prior 12 months was assessed), we  
265 found no material differences in the association between facet joint OA and back pain when  
266 including the covariate of time delay between CT scan and clinical examination, or when  
267 restricting the analyses to those participants with less than a 20 month (mean) delay between  
268 the CT scan and the clinical examination (data not shown).

269 << Table 4 >>

270 In *post-hoc* analyses, we examined relevant interactions between age and features of  
271 severe spinal degeneration by addition of interaction terms to the multivariable models from  
272 Table 3. In order to examine whether relationships between facet joint OA and back pain  
273 would be stronger in older adults, we tested for an interaction between facet joint OA and age  
274  $\geq 75$  years. We found no interaction between age and the presence of any severe facet joint  
275 OA, or the number of joints with severe facet joint OA (data not shown), indicating that facet  
276 joint OA was associated with back pain across the age spectrum of the sample. In order to  
277 examine whether relationships between disc height narrowing and back pain would be  
278 stronger in younger and middle-aged adults, we tested for an interaction between disc height  
279 narrowing and age  $\geq 60$  years. We found a statistically significant interaction between any  
280 severe disc height narrowing and age  $\geq 60$  ( $p=0.02$ ), with a main effect for any severe disc  
281 height narrowing of OR 3.72 (95% CI 0.85-16.3). This interaction is depicted graphically in

282 Figure 2, which shows that disc height narrowing is associated with back pain in participants  
283 < 60 years, but not in participants  $\geq$  60 years. We found a similar interaction between the  
284 number of spinal levels with severe disc height narrowing and age  $\geq$  60 ( $p=0.04$ ), with disc  
285 height narrowing associated with back pain only in the younger group. Severe facet joint OA  
286 remained significantly associated with back pain in all models including an interaction term  
287 (data not shown).

288

<< Figure 2 >>

289

290 **DISCUSSION**

291 Severe facet joint OA was significantly associated with frequent back pain in this  
292 study of community-based US older adults, adjusting for sociodemographics and health  
293 factors, and disc height narrowing. Furthermore, a greater number of joints with severe  
294 facet joint OA conferred greater odds of having frequent back pain. Disc height  
295 narrowing was independently associated with back pain in younger adults < age 60 years,  
296 but not in older adults.

297 To our knowledge, this is the first study demonstrating a clear association  
298 between facet joint OA on advanced spinal imaging and the presence of back pain. Prior  
299 studies examining this relationship have either found no association[8, 10], or  
300 associations that were not statistically significant[9]. Our study had various  
301 distinguishing features from prior work that may explain our positive findings and our  
302 ability to detect an association between facet joint OA and back pain. First and most  
303 importantly is the substantially older age of our study sample, including participants of  
304 mean age 67 years, as compared to prior studies where mean age ranged between 36 to  
305 53 years. Since OA is an age-related degenerative process, it follows logically that  
306 advanced OA might be associated with pain in older adults, but not in younger adults[30,  
307 31]. Indeed, prior studies using comparative diagnostic anesthetic blocks to identify the  
308 source of back pain have demonstrated that the proportion of back pain attributable to the  
309 facet joints is high in older adults, and low in younger adults [13, 14]. Second, our study  
310 applied thresholds for facet joint OA severity that identified severe OA in particular,  
311 inspired by findings from the knee OA literature, where a closer association between  
312 radiographic OA and pain is often seen in the setting of more severe radiographic



313 changes[11, 32, 33]. Earlier studies, including work from our group conducted in another  
314 sample of Framingham participants[10], used thresholds of mild or moderate facet joint  
315 OA[8, 9]. This is likely inappropriate, since mild facet joint OA is essentially ubiquitous  
316 by middle age[34-36], and moderate facet joint OA is nearly so[10, 36]. Third, our study  
317 used a well-characterized and reliable scale for facet joint OA, in contrast to some earlier  
318 studies[8, 9].

319         Various prior studies have reported associations between disc height narrowing on  
320 advanced spinal imaging and back pain, and these have largely included samples of  
321 younger and middle-aged adults [37-39]. A noteworthy finding of this study was the  
322 association between disc height narrowing and back pain in adults < 60 years, but not in  
323 older adults. This observation supports the view held by some clinicians that discogenic  
324 back pain predominates in the young and middle-aged, but may become less symptomatic  
325 (or ‘burn out’) for individuals over the course of time[40]. This hypothesis has been  
326 difficult to test empirically due to the paucity of prior longitudinal imaging studies of  
327 back pain that include both middle-age and elderly persons. Furthermore, the  
328 overwhelming majority of prior cross-sectional studies using advanced spinal imaging  
329 such as CT or MRI examine only the anterior spinal structures of the intervertebral discs  
330 and endplates in young to middle-aged adults- not including older individuals [41]. Our  
331 data suggest the possibility that nonspecific back pain may shift from being discogenic-  
332 predominant in middle age to facetogenic-predominant in older adults, and this  
333 speculation warrants examination in future research.

334         Our study has other features that distinguish it from earlier works. Studies  
335 attempting to link spinal pain to specific posterior spinal structures on imaging (such as

336 facet joint OA) generally come in two categories: 1) examinations of associations  
337 between imaging findings and spinal pain (including subjects with and without pain[8-  
338 10]), or 2) examinations of associations between imaging findings and the results of  
339 diagnostic anesthetic blocks to spinal structures (including only subjects with pain,  
340 usually from clinical convenience samples[7, 42]). Our study falls into the former  
341 category. We view this as a study strength, in light of continuing controversy regarding  
342 the validity of comparative diagnostic blocks[43]. In addition, we included both  
343 assessments of posterior spinal structure degeneration (facet joint OA) and anterior spinal  
344 structure degeneration (disc height narrowing) in the same multivariable models. Such an  
345 approach has been suggested since disc height narrowing might serve as a surrogate for  
346 facet joint OA when only the anterior structures are taken into account[44, 45].

347 Our study detected a modest magnitude association between facet joint OA and  
348 back pain (OR 2.2), which is generally comparable to odds ratio point estimates ranging  
349 from 2.0 – 2.5 for the most commonly studied parameters of intervertebral disk  
350 degeneration on imaging, including disc height narrowing, annular tears, and others[37,  
351 41]. Similar to the case of both disc degeneration and extremity OA, however, the  
352 presence of any severe facet joint OA has limited discriminatory capability: many people  
353 with severe facet joint OA have no back pain, and some with back pain have no severe  
354 facet joint OA. This does not mean, however, that facet joint OA is not a potential cause  
355 of back pain. In fact, modest associations between spinal pathoanatomy and back pain  
356 should be expected due to the myriad confounding factors also contributing to the highly  
357 subjective experience of pain, including genetics, sociocultural factors, pain beliefs,  
358 mood, and other factors[46-49]. Our study, like the majority of prior imaging studies of

359 back pain[50], accounted for only some of these potential confounding factors. On the  
360 contrary, our results showing significant associations between both severity and extent of  
361 facet joint OA and back pain provide some preliminary support for a causal link worthy  
362 of further examination in longitudinal studies.

363         Some limitations of our study are worthy of mention. First, we used a general  
364 back pain question which did not specify locations of lumbar pain corresponding to the  
365 levels that were imaged by CT (L2-S1). Therefore, our definition of frequent back pain  
366 may include not only lumbar pain, but also thoracic pain, which is prevalent in 2-6% of  
367 older adults[51]. Second, our study lacked precise concordance between the timing of  
368 CT scans and assessment of back pain frequency. Given that quantitative changes in  
369 lumbar spinal degeneration on advanced imaging are less than 1-2 % per year[52], we  
370 would expect any delay between CT scan and assessment of back pain to result in low  
371 rates of misclassification, which is supported by the results of our sensitivity analyses.  
372 Importantly, any misclassification in back pain locations or delays between imaging and  
373 pain assessments would be expected to bias towards the null, and would not explain the  
374 positive associations between facet joint OA and back pain detected in this study. Third,  
375 our imaging assessments utilized CT, a modality which is optimal for the cardinal  
376 features of facet joint OA (joint space narrowing, articular process hypertrophy,  
377 osteophytosis, and sclerosis) [13], but may be inferior for visualization of secondary  
378 features of facet joint OA, including joint effusions and articular process bone marrow  
379 lesions[53]. However, CT is currently not recommended as the first choice for advanced  
380 spinal imaging in situations where MRI is available, due in part to the known risks of  
381 ionizing radiation. MRI assessments of facet joint OA show moderate agreement with

382 CT assessments of facet joint OA[20], but it remains to be seen whether severe facet joint  
383 OA on MRI associates with back pain in older adults in the manner seen here when using  
384 CT. Of note, our CT reads did not assess the L1-L2 spinal level, in contrast to most prior  
385 lumbar imaging studies, which include the entire lumbar region. Fourth, sample size in  
386 this study was not determined in advance based on power calculations related to the main  
387 research question pursued here. Nevertheless, the fact that we detected statistically  
388 significant results would suggest against type II error. Fifth, the cross-sectional nature of  
389 our study makes identifying potential confounding factors on conceptual grounds  
390 especially challenging, since temporal order between many of our measures cannot be  
391 determined. Future longitudinal studies of severe facet joint OA and associations with  
392 back pain are needed.

393 In conclusion, the results of this study demonstrate a significant but modest  
394 association between the presence and extent of severe facet joint OA on CT imaging and  
395 back pain in a sample of community-based older adults, independent of  
396 sociodemographics, health factors, and disc height narrowing. Further research is needed  
397 to determine whether imaging of facet joint OA may have a role in refining back pain  
398 case definition or directing back pain treatment for older adults.

399  
400

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406 **CONTRIBUTIONS**

407  
408 PS was involved with study concept and design, acquisition of data, analysis of data,  
409 interpretation of data, and drafting of the manuscript. DJH was involved with study  
410 concept and design and manuscript preparation. JR was involved with study concept,  
411 design, and manuscript preparation. AG was involved with study design, acquisition of  
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