

Osteoarthritis and Cartilage



Association between spinal morning stiffness and lumbar disc degeneration: the Rotterdam Study

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SUMMARY

Objective: To explore the associations between spinal morning stiffness and lumbar disc degeneration (LDD).

Design: Data from a cross-sectional general population-based study (Rotterdam Study-I) were used. Intervertebral disc spaces and osteophytes of people aged ≥ 55 years were scored on lumbar lateral radiographs (L1-2 through L5-S1 was scored). Logistic regression analysis was used to explore associations between spinal morning stiffness and two definitions of LDD (i.e., 'narrowing' and 'osteophytes'). Spinal morning stiffness combined with low back pain and its association with LDD was also analyzed. Similar analyses were performed for knee and hip pain, morning stiffness in the legs, and radiographic knee and hip osteoarthritis (OA) in order to compare these associations with those of LDD. All analyses were adjusted for age, gender, and body mass index (BMI).

Results: Lumbar lateral radiographs were scored for 2,819 participants. Both definitions of LDD were associated with spinal morning stiffness: adjusted odds ratio (aOR) 1.3; 95% confidence interval (CI): 1.1–1.6 for 'osteophytes' and aOR 1.8; 95% CI: 1.4–2.2 for 'narrowing'. Both the odds ratios increased when spinal morning stiffness was combined with low back pain: aOR 1.5; 95% CI: 1.1–2.0 for 'osteophytes' and aOR 2.5; 95% CI: 1.9–3.4 for 'narrowing'. When morning stiffness in the legs was combined with knee or hip pain, the associations with radiographic knee or hip OA were: aOR 3.0; 95% CI: 2.1–4.1 for knee OA and aOR 3.1; 95% CI: 1.9–5.0 for hip OA.

Conclusions: Reported spinal morning stiffness is associated with LDD. The associations increased when we combined spinal morning stiffness with low back pain. The magnitude of the association for the definition 'narrowing' is similar to the association between morning stiffness in the legs and knee or hip OA.

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Introduction

Low back pain is a major health problem, also in the elderly. It is the most reported pain site of all musculoskeletal complaints¹. Low

back pain is often defined as pain possibly with muscle tension or stiffness, localized below the costal margin and above the inferior gluteal folds, with or without radiating leg pain². Since patients with non-specific low back pain are not only a large but also a very heterogeneous group regarding etiology, prognosis and susceptibility to treatment, it is important to identify sub-groups within this population. Low back pain patients with symptoms due to lumbar disc degeneration (LDD) or lumbar osteoarthritis (OA) could be such a subgroup, and clinical symptoms associated with radiographic LDD may help identify those with symptoms due to LDD or lumbar OA in clinical practice.

An association between radiographic LDD and low back pain has been reported in several studies^{3–7}. The study of de Schepper *et al.*

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compared associations between different definitions of LDD and low back pain³. They found an association for the definition based on the presence of disc space narrowing, as well as for the definition based on the presence of osteophytes³.

Although there are no official classification criteria for LDD, it is often characterized by narrowing of the disc space and the presence of osteophytes, seen at the lumbar radiograph⁴. Disk degeneration is associated with and often precedes facet joint OA^{8–10}. Although LDD cannot be defined as real OA because the facet joints are the only synovial joints in the spine, LDD is often used as a proxy for OA of the spine, in particular when imaging (preferably with magnetic resonance imaging) of the synovial joints is not available. OA of the knee and hip already has clinical classification criteria, described by the American College of Rheumatology (ACR). The ACR criteria describe that, besides pain, morning stiffness is an important criteria for hip and knee OA^{11,12}.

Therefore, the present study explores the association between: (1) spinal morning stiffness and LDD, and (2) spinal morning stiffness in combination with low back pain and LDD, cross-sectional in a large general population study. These associations are also compared with the associations between morning stiffness in the legs, and knee or hip OA.

Method

Study population

This study used data from the Rotterdam Study, a general population prospective cohort study of people aged 55 years and older living in Rotterdam (The Netherlands). All inhabitants of Ommoord, a district of the city Rotterdam, aged 55 years and older ($n = 10,215$) were invited to participate in this study. In total, 7,983 adults participated in the baseline measurements (78% of the invited inhabitants)¹³. The detailed study design has been described elsewhere^{13,14}. The present study used the baseline measurements (RS 1-1) which were collected in 1990–1993, and included a home interview and radiographs made in a research center in the participant's district. The Medical Ethics Committee of Erasmus Medical Center approved the protocol of the Rotterdam Study. The present study consisted of a random selection of 2,819 participants with spinal radiographs available at both baseline and at 6.6 years follow-up, as described in a previous study³.

Radiographs

The lumbar spine levels L1-2 through L5-S1 were scored on the lateral lumbar radiograph for the presence and severity of osteophytes (anterior) and disc space narrowing, using the system of Lane *et al.*¹⁵. This system grades both osteophytes and disc space narrowing on a scale from 0 to 3, in which 0 = none, 1 = mild, 2 = moderate, and 3 = severe. The Lane atlas contains lumbar radiograph in which the different grades of osteophytes and narrowing are illustrated. Disc space narrowing was scored if the height between the lumbar vertebrae was different from the normal progression of the spine. The Lane atlas is one of the systems recommended in a recent review on existing grading scales¹⁶.

All spinal radiographs were scored by a single reader [EdS], who was trained to score the radiographs and blinded to the participants' clinical data. A random selection of spinal radiographs (140; 5%) was evaluated by another trained reader to obtain the inter-observer reproducibility. The intraclass correlation coefficient (ICC) was 0.83 for scoring osteophytes and 0.77 for scoring disc space narrowing, which indicates a good reproducibility³.

An earlier report of the Rotterdam Study³ analyzed the association between different radiographic features of LDD and low back pain. They concluded that the association increased after excluding level L5-S1 from the analysis, and when disc space narrowing or osteophytes were present at two or more vertebral levels³. Disc space narrowing of the lumbosacral disc is also more difficult to score due to its narrow height and because the variable height of a normal disc at this level makes it difficult to establish pathology^{17,18}. We used the two different definitions of LDD proposed in the study of de Schepper *et al.*, i.e., 'narrowing' and 'osteophytes'. 'Narrowing' is defined as disc space narrowing (grade ≥ 1) at two or more vertebral levels (L1-2 through L4-L5), and 'osteophytes' as the presence of osteophytes (grade ≥ 2) at two or more vertebral levels (L1-2 through L4-L5)³.

From the 2,819 participants of this study, available weight-bearing anterior–posterior radiographs of right/left knees and the pelvis, were scored for knee and hip OA. Radiological knee and hip OA was assessed using the original description of the Kellgren and Lawrence (K&L) grading system^{19–21}. Radiographic knee OA was present if the right and/or left knee had a K&L score of ≥ 2 . If one of the joints was replaced, the score of the other knee was used in the analyses. The participant was excluded from the analysis if both knees had undergone joint replacement. The same definitions were used for the hip joints. The knee and hip radiographs were scored by several trained readers, who were also blinded to all clinical data of the participants^{20,22}.

Pain and morning stiffness

Questions about pain and morning stiffness were asked during an extensive home interview as part of the baseline measurements. The interviewer asked if joint complaints were present during the last months. If the participants answered yes, the interviewer asked whether the pain was present in the following sites: low back, left knee, right knee, left hip, and/or right hip. The participant had to answer the question for each site separately; it was possible to have complaints at several sites. Knee pain or hip pain was positive if pain was present on the left and/or right side. Back pain was positive if the participant had pain in the lower back during the last month.

The interviewer also asked about the presence, duration and location of morning stiffness. If morning stiffness was present, the interviewer asked what its duration was (possible answers were: less than half an hour, half an hour to 1 h or more than 1 h), and where it was located. The location of the stiffness was divided in: (1) legs, (2) arms, (3) back and/or neck, and (4) legs and arms and back. Spinal morning stiffness was present if the participant answered that the morning stiffness was located at '3' or '4'. Morning stiffness in the legs was defined as stiffness in location '1' or '4'.

Statistical analysis

Multivariable logistic regression analysis was used to explore the associations between morning stiffness and the different radiological features.

First, we explored the association between the duration of spinal morning stiffness, a categorical variable, and the two different definitions of LDD (earlier described). Second, we explored the associations between the two definitions of LDD and (1) the presence of spinal morning stiffness, and (2) spinal morning stiffness in combination with low back pain. Third, we assessed whether the association of morning stiffness and LDD was independent of back pain. Finally, we analyzed the association between the two definitions of LDD and morning stiffness lasting < 1 h.

Table I
Characteristics of the study population

	Men (n = 1,204) n (%)	Women (n = 1,615) n (%)	All (n = 2,819) n (%)
Age: mean ± SD	65.3 ± 6.4	65.9 ± 6.8	65.7 ± 6.6
BMI: mean ± SD*	25.9 ± 2.9	26.6 ± 3.8	26.3 ± 3.5
<i>Pain last month</i>			
Low back pain	173 (14.4)	326 (20.2)	499 (17.7)
Knee pain	154 (12.8)	362 (22.4)	516 (18.3)
Hip pain	84 (7)	244 (15.1)	328 (11.6)
<i>Morning stiffness</i>			
Spinal morning stiffness†	210 (17.4)	426 (26.4)	636 (22.6)
Morning stiffness in legs‡	197 (16.4)	424 (26.3)	621 (22.0)
<i>Radiographic features</i>			
'Osteophytes'	429 (35.6)	410 (25.4)	839 (29.8)
'Narrowing'	162 (13.5)	363 (22.5)	525 (18.6)
Knee K&L ≥2‡	126 (10.5)	324 (20.1)	450 (16)
Hip K&L ≥2**	84 (7)	109 (6.7)	193 (6.8)
Bilateral knee replacement	0 (0)	0 (0)	0 (0)
Bilateral hip replacement	6 (0.5)	18 (1.1)	24 (0.9)

'Osteophytes': the presence of osteophytes (grade ≥2) at two or more vertebral levels on lateral lumbar radiographs.

'Narrowing': disc space narrowing (grade ≥1) at two or more vertebral levels on lateral lumbar radiographs.

* BMI was missing for 12 participants; seven men and five women.

† Location of morning stiffness was missing for eight participants; four men and four women.

‡ Knee Kellgren & Lawrence (K&L) score was missing for 169 participants; 58 men and 111 women.

** Hip K&L score was missing for seven participants; two men and five women.

Participants with spinal morning stiffness lasting >1 h were excluded from this analysis. All analyses were adjusted for age, gender, and body mass index (BMI) because earlier studies already reported an association between LDD and these variables^{3,18,23}. The results of the second and fourth analyses were also presented without adjustment for these variables.

The same four analyses were also used to explore the associations between radiographic knee or hip OA and (1) morning stiffness in the legs, and (2) morning stiffness in the legs in combination with knee or hip pain, respectively.

Results

Population characteristics

Table I presents the characteristics of the study participants. The population comprised 1,204 men and 1,615 women with a mean age of 65.7 years. Low back pain was reported by 499 participants: 173 men and 326 women. Knee pain was reported by 516 participants and hip pain by 328 participants. Spinal morning stiffness was more often present (22.6%) than morning stiffness in the legs

(22.0%). When comparing men and women, men showed a higher prevalence of osteophytes (35.6% vs 25.4%) and a slightly higher percentage of radiographic hip OA (7% vs 6.7%). Lumbar intervertebral disc space narrowing and radiographic knee OA were more often present in women than in men: 22.5% of the women met the definition of narrowing compared with 13.5% of the men, and 20.1% of the women had radiographic knee OA compared to 10.5% of the men.

LDD and spinal morning stiffness

Table II shows the associations between the different durations of spinal morning stiffness and both definitions of LDD. The definition 'narrowing' was more strongly associated than the definition 'osteophytes' for the categories spinal morning stiffness <0.5 h, and spinal morning stiffness ≥0.5 h to ≤1 h. The category spinal morning stiffness >1 h was more strongly associated with 'osteophytes' than with 'narrowing'.

The associations between the dichotomous variable spinal morning stiffness and both definitions of LDD were statistically significant. The association with 'narrowing' was stronger than the association with 'osteophytes': adjusted odds ratio (aOR) 1.8; 95% confidence interval (CI): 1.4–2.2 and aOR 1.3; 95% CI: 1.1–1.6, respectively. When we also adjusted the analyses for back pain, the association became somewhat lower, but stayed statistically significant: aOR 1.3; 95% CI: 1.0–1.5 for the definition 'osteophytes' (P-value <0.05) and aOR 1.5; 95% CI: 1.2–1.9 for the definition 'narrowing' (P-value <0.01). The strength of the associations increased when spinal morning stiffness was combined with low back pain: aOR 2.5 95% CI: 1.9–3.4 for 'narrowing' and aOR 1.5; 95% CI: 1.1–2.0 for 'osteophytes'. The association did not increase when analyzing the associations between spinal morning stiffness <1 h and LDD. All associations are presented in Table III.

The associations decreased when we included only those participants with back pain (n = 499) in the analysis: aOR 1.4; 95% CI: 1.0–2.1 for the association between morning stiffness and 'narrowing' and aOR 1.2; 95% CI: 0.8–1.8 for the association between morning stiffness and 'osteophytes'.

Radiological knee and hip OA and morning stiffness in the legs

Table IV presents data on associations between the different durations of morning stiffness in the legs and radiographic knee and hip OA. The associations between morning stiffness in the legs, and both knee and hip K&L score, were moderate and only statistically significant for knee OA: aOR 1.6; 95% CI: 1.2–2.0 for knee OA, and aOR 1.4; 95% CI: 1.0–1.9 for hip OA. When we also adjusted the analyses for knee/hip pain, the association became somewhat lower and the association between morning stiffness in the legs and knee OA was no longer statistically significant: aOR 1.2; 95% CI: 0.9–1.6 for radiographic knee OA and aOR 1.1; 95% CI: 0.8–1.6 for radiographic hip OA. The strength of the associations increased when

Table II
Associations regarding different durations of spinal morning stiffness and LDD

	'Osteophytes'			'Narrowing'		
	Absent n	Present n	aOR (95% CI)	Absent n	Present n	aOR (95% CI)
No spinal morning stiffness	1,549	626	Ref. category	1,816	359	Ref. category
Spinal morning stiffness lasting <0.5 h	351	156	1.2 (1.0–1.5)	383	124	1.7 (1.3–2.1)**
Spinal morning stiffness lasting ≥0.5 to ≤1 h	55	36	1.7 (1.1–2.7)*	60	31	2.3 (1.4–3.7)**
Spinal morning stiffness lasting >1 h	19	16	2.4 (1.2–4.8)*	26	9	1.9 (0.9–4.3)

'Osteophytes': the presence of osteophytes (grade ≥2) at two or more vertebral levels on lateral lumbar radiographs.

'Narrowing': disc space narrowing (grade ≥1) at two or more vertebral levels on lateral lumbar radiographs. aOR; adjusted for age, gender and BMI.

*P < 0.05; **P < 0.01.

Table III
Associations between spinal morning stiffness, low back pain and LDD

	'Osteophytes'				'Narrowing'			
	Absent <i>n</i>	Present <i>n</i>	OR (95% CI)	aOR (95% CI)	Absent <i>n</i>	Present <i>n</i>	OR (95% CI)	aOR (95% CI)
No spinal morning stiffness	1,549	626	Ref. category	Ref. category	1,816	359	Ref. category	Ref. category
Spinal morning stiffness	426	210	1.2 (1.0–1.5)*	1.3 (1.1–1.6)*	472	164	1.8 (1.4–2.2)**	1.8 (1.4–2.2)**
No spinal morning stiffness	1,549	626	Ref. category	Ref. category	1,816	359	Ref. category	Ref. category
Spinal morning stiffness without low back pain	264	123	1.2 (0.9–1.5)	1.2 (1.0–1.8)	305	82	1.4 (1.0–1.8)*	1.3 (1.0–1.8)*
Spinal morning stiffness in combination with low back pain	162	87	1.3 (1.0–1.8)*	1.5 (1.1–2.0)**	167	82	2.5 (1.9–3.3)**	2.5 (1.9–3.4)**
No spinal morning stiffness	1,549	626	Ref. category	Ref. category	1,816	359	Ref. category	Ref. category
Spinal morning stiffness lasting <1 h†	406	192	1.2 (1.0–1.4)	1.3 (1.0–1.6)*	443	155	1.8 (2.4–2.2)**	1.8 (1.4–2.2)**
No spinal morning stiffness	1,549	626	Ref. category	Ref. category	1,816	359	Ref. category	Ref. category
Spinal morning stiffness lasting <1 h without low back pain	254	117	1.1 (0.9–1.6)	1.2 (1.0–1.5)	292	79	1.4 (1.0–1.8)*	1.4 (1.0–1.8)*
Spinal morning stiffness lasting <1 h in combination with low back pain†	152	75	1.2 (0.9–1.6)	1.4 (1.0–1.9)*	151	76	2.5 (1.9–3.40)**	2.6 (1.9–3.5)**

'Osteophytes': the presence of osteophytes (grade ≥ 2) at two or more vertebral levels on lateral lumbar radiographs.

'Narrowing': disc space narrowing (grade ≥ 1) at two or more vertebral levels on lateral lumbar radiographs. aOR; adjusted for age, gender and BMI.

* $P < 0.05$; ** $P < 0.01$.

† Participants with spinal morning stiffness > 1 h are excluded from this analysis.

morning stiffness in the legs is combined with knee or hip pain. When individuals had both morning stiffness as well as pain in the knee, the association with radiographic knee OA was an odds ratio (OR) 3.0; 95% CI: 2.1–4.1. The association between morning stiffness in the legs in combination with hip pain and radiographic hip OA was aOR 3.1; 95% CI: 1.9–5.0. The strength of the associations did not increase much when replacing morning stiffness in the legs with morning stiffness in the legs with a short duration in the analysis (morning stiffness < 0.5 h for the analysis of knee OA and morning stiffness < 1 h for the analysis of knee OA defined according to the ACR criteria^{11,12}). Table V presents the associations between morning stiffness in the legs, knee/hip pain and knee/hip K&L score.

Discussion

This study investigated the associations between morning stiffness and different radiological features: LDD, hip K&L score and knee K&L score. We found a moderate association between both definitions of LDD and spinal morning stiffness. The association showed to be independent of back pain, but increased when spinal morning stiffness was combined with low back pain. The definition 'narrowing' was more strongly associated with spinal morning stiffness, and the combination of spinal morning stiffness and low back pain, than was the definition 'osteophytes'. These associations for LDD were similar compared to the associations found for radiographic knee and hip OA. To the best of our knowledge, this is the first study investigating the association between spinal morning stiffness and low back pain with LDD.

Earlier, de Schepper *et al.* analyzed the association between LDD and low back pain in this same population, reporting an association of OR 2.1 for the definition 'narrowing' and OR 1.4 for 'osteophytes'³. When comparing these associations for back pain with the results of the present study, both associations were higher when spinal morning stiffness was combined with low back pain, compared with the associations for back pain alone. Another study analyzing the association between low back pain and LDD also compared disc space narrowing with the presence of osteophytes⁶. Both these studies found a stronger association between low back pain and LDD for adults with narrowing of the spine than adults with osteophytes^{3,6}. This is consistent with our results, which show a stronger association for 'narrowing' than for 'osteophytes' when analyzing the relation with spinal morning stiffness.

Our results indicated that there is a moderate association between spinal morning stiffness and LDD. This might indicate that spinal morning stiffness is one of the symptoms that clinicians could use for sub-grouping low back pain patients with symptoms due to LDD. However, the association was lower when we only included participants with back pain in the analysis. This might indicate that the presence of morning stiffness is less discriminative in people with back pain. More studies with back pain patients are needed to confirm our association, and to explore whether treatment response or prognosis differs between patients with pain and morning stiffness, and other patients with non-specific low back pain. In this population, a receiver operating characteristic (ROC) curve could be made to examine accuracy of the selection.

Table IV
Associations between different durations of morning stiffness in the legs and radiographic knee or hip OA

	Knee K&L ≥ 2			Hip K&L ≥ 2		
	Absent <i>n</i>	Present <i>n</i>	aOR (95% CI)	Absent <i>n</i>	Present <i>n</i>	aOR (95% CI)
No morning stiffness in the legs	1,751	304	Ref. category	2,033	139	Ref. category
Morning stiffness in the legs lasting < 0.5 h	366	120	1.6 (1.2–2.1)**	460	44	1.4 (1.0–2.0)
Morning stiffness in the legs lasting ≥ 0.5 to ≤ 1 h	51	22	1.9 (1.1–3.3)*	68	7	1.2 (0.5–2.8)
Morning stiffness in the legs lasting > 1 h	24	1	0.2 (0.0–1.6)	23	2	1.4 (0.3–5.9)

aOR; adjusted for age, gender and BMI.

P-values are not significant.

* $P < 0.05$; ** $P < 0.01$.

Table V
Associations between morning stiffness in the legs, knee pain and radiographic knee OA

	Knee K&L ≥ 2			Hip K&L ≥ 2		
	Absent <i>n</i>	Present <i>n</i>	aOR (95% CI)	Absent <i>n</i>	Present <i>n</i>	aOR (95% CI)
No morning stiffness in the legs	1,751	304	Ref. category	2,033	139	Ref. category
Morning stiffness in the legs	444	144	1.6 (1.2–2.0)**	555	53	1.4 (1.0–1.9)
No morning stiffness in the legs	1,751	304	Ref. category	2,033	139	Ref. category
Morning stiffness in the legs without knee/hip pain	315	64	1.0 (0.7–1.3)	433	28	0.9 (0.6–1.4)
Morning stiffness in the legs in combination with knee/hip pain	129	80	3.0 (2.1–4.1)**	122	25	3.1 (1.9–5.0)**
No morning stiffness in the legs	1,751	304	Ref. category	2,033	139	Ref. category
Short morning stiffness in the legs ^{†,‡}	366	120	1.6 (1.2–2.1)**	528	51	1.4 (1.0–2.0)
No morning stiffness in the legs	1,751	304	Ref. category	2,033	139	Ref. category
Morning stiffness in the legs with a short duration, without knee/hip pain	264	52	1.0 (0.7–1.4)	415	27	0.9 (0.6–1.4)
Morning stiffness in the legs with a short duration, in combination with knee/hip pain ^{†,‡}	102	68	3.1 (2.2–4.4)**	113	24	3.2 (2.0–5.3)**

aOR; adjusted for age, gender and BMI.

* $P < 0.05$; ** $P < 0.01$.

[†] Morning stiffness in the legs with a short duration, was defined as <0.5 h for the analysis of the knee and <1 h for the analysis of the hip.

[‡] Participants with morning stiffness in the legs >0.5 h were excluded from the analysis of the knee and participants with morning stiffness in the legs >1 h were excluded from the analysis of the hip.

Earlier studies of patients with knee pain also reported a similar moderate association between morning stiffness and radiographic knee OA^{24,25}. According to Duncan *et al.*, the relation became stronger when the severity of morning stiffness increased²⁵. Reijman *et al.* also analyzed the associations between different definitions of radiographic hip OA and clinical symptoms, such as pain and morning stiffness, in the Rotterdam Study; they found a moderate association between hip pain and hip K&L score ≥ 2 and a similar association between morning stiffness and hip K&L score ≥ 2 ²⁰.

We expected to find a difference between the associations of (1) morning stiffness, and (2) morning stiffness with a short duration, with the radiographic features LDD, knee or hip OA, because morning stiffness in the knee <0.5 h or hip <1 h is an ACR criterion for knee or hip OA^{11,12} and spinal morning stiffness >1 h is one of the criteria for ankylosing spondylitis^{26,27} however, no such a difference was found. It must be noted, however, that power for this stratified analysis was limited, and so no final conclusion can be drawn from this result.

Our study had a few limitations which might influence the results. First, only lateral radiographs of the lumbar spine were assessed. Therefore, single-sided disc space narrowing and lateral osteophytes may have been missed. Second, because only lateral radiographs of the lumbar spine were available, we could not score the facet joints, which are the only synovial joints in the spine. Therefore we could not examine if the presence of facet joint OA is responsible for the association between spinal morning stiffness and LDD or whether LDD is associated with morning stiffness independently of facet joint OA. A third limitation is that, for another study purpose, only baseline radiographs of participants with baseline and 6.6-years follow-up measurements were scored. On average, participants who were available for 6.6 years follow-up measurements were younger and healthier during baseline than those participants who were not available for follow-up measurements. This caused some selection bias in our study sample. The fourth limitation is that the location of morning stiffness was described as 'spinal morning stiffness' and 'morning stiffness in the legs' without distinction between the precise locations. Therefore we are unable to differentiate between morning stiffness in the hip/knee, or morning stiffness in the cervical, thoracic or lumbar spine. When we analyzed the association between morning stiffness in the legs and radiographic OA in the lower body (hip and/or knee OA), it did not result in a much higher association: aOR 1.6; 95% CI: 1.3–2.0. Another limitation

related to the location of morning stiffness is that participants who indicated that the morning stiffness was located in the arms, spine, and the legs (location 4) had a positive score for both spinal morning stiffness and morning stiffness in the legs. If we had more precise information about the location of the morning stiffness and radiographic information of the facet joint, the associations might have been different.

In conclusion, spinal morning stiffness is frequently reported in this study population. According to our analyses, there appears to be a small association between spinal morning stiffness and LDD. The magnitude of the association was higher when spinal morning stiffness was combined with low back pain.

Contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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Competing interests

The authors declare that they have no conflicts of interest.

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Supplementary material

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.joca.2012.05.011>.

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