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Occupational Physical Activities and Long-Term Functional and Radiographic Outcomes in Patients With Ankylosing Spondylitis

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Abstract

Objective—We sought to identify specific occupational activities associated with functional limitations and radiographic damage in patients with longstanding ankylosing spondylitis (AS).

Methods—We asked patients diagnosed with AS for ≥20 years to report all past occupations, which we mapped to specific physical activities using the Occupational Information Network, which is the US Department of Labor job classification database. For each occupation reported, we obtained ratings for 13 physical abilities of the worker and 13 aspects of the work environment or work tasks (work context) thought to be most relevant to patients with AS. Averages for each measure, weighted by the number of years in each job, were related to the degree of functional limitation as assessed by the Bath AS Functional Index (BASFI) and to the extent of spinal radiographic damage as assessed by the Bath AS Radiology Index for the spine (BASRI-s).

Results—Among 397 patients, those with a history of jobs requiring dynamic flexibility (the ability to repeatedly bend, stretch, twist, or reach) had more functional limitations than those whose past jobs required little or no dynamic flexibility (adjusted mean BASFI score 48.3 in the top quartile versus 38.1 in all others). Those whose past jobs required more dynamic flexibility, extent flexibility, and exposure to whole body vibration also had significantly higher BASRI-s scores.

Conclusion—Bending, twisting, and stretching are the occupational activities associated with greater functional limitations and radiographic damage in patients with longstanding AS. Exposure to whole body vibration was also associated with more radiographic damage.

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AUTHOR CONTRIBUTIONS

Dr. Ward had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study design. Ward, Reveille, Davis, Weisman.

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INTRODUCTION

Work-related physical activity can cause a wide range of musculoskeletal symptoms and have a major impact on functioning. Repetitive tasks, tasks requiring strength or excessive force, and tasks requiring abnormal postures can lead to soft tissue musculoskeletal disorders and neck and back pain (1–4). Specific work activities are established risk factors for osteoarthritis of the knees and hips (4). The work environment may also have important effects, as exemplified by the strong association between exposure to whole body vibration and back pain (1,2). Given the physical demands of many occupations and the susceptibility of inflamed joints to further damage from these stresses, work activities can contribute to worsened inflammation and functional limitations in patients with active rheumatoid arthritis (5,6). We hypothesized that similar processes may occur in patients with ankylosing spondylitis (AS), whereby heavy work activities may stress an inflamed axial skeleton. Cumulating over years, this may result in worse long-term functional and radiographic outcomes.

In support of this hypothesis, we have previously found that patients with AS who had a history of more physically demanding jobs had more severe functional limitations than patients with less demanding jobs (7). Occupational physical activity was rated globally in this study. The categories did not distinguish different types of heavy work (for example, by strength, aerobic, or flexibility requirements) and did not permit identification of any specific activities that might be more closely associated with functional limitations. Knowledge of specific activities would be more useful for vocational counseling, and could help identify processes that influence the severity of AS. In this cross-sectional study, we used a new, detailed, standardized job classification system to identify the specific physical activities associated with functional limitations and the extent of spinal radiographic changes in patients diagnosed with AS for ≥20 years.

PATIENTS AND METHODS

Patients

Patients were participants in the cross-sectional component of the Prospective Study of Outcomes in AS, an observational study the main aim of which is to investigate genetic markers of AS severity. Patients were recruited from the clinics of the investigators and local rheumatologists, from patient support groups, and from the community by advertisement. Enrollment occurred in 2002–2006. Inclusion criteria were a diagnosis of AS by the modified New York criteria (8) and AS for ≥20 years, dated from the onset of persistent musculoskeletal symptoms. All participants underwent a clinical evaluation by one of the study rheumatologists, had pelvic and spinal radiographs taken, and completed questionnaires about their personal and medical history and functional status. The study protocol was approved by the institutional review boards at each site, and all patients provided written informed consent.

Occupational physical activity measures

Patients were asked to report each paid job they had during their work life and the number of years spent in each job. We did not include housework or summer jobs. We used the Occupational Information Network (O*NET; version 11.0), a comprehensive job classification database developed by the US Department of Labor, to identify the specific attributes of each job (9). O*NET rates each job title in 6 domains: worker characteristics (abilities, interests, values, and work styles), worker requirements (knowledge and skills), experience requirements (training and education), labor market information, occupational requirements (work context, conditions, and activities), and occupation-specific information. Information for each domain was collected from job incumbents by self-report, supplemented when necessary by information from industry experts, employers, and trained occupational analysts. We examined only worker abilities and work conditions.

Of 52 measures of worker abilities included in O*NET, we selected by consensus 13 physical abilities relevant to AS because they involved the axial skeleton, in addition to tracer activities not likely affected by AS (e.g., manual dexterity) (Table 1). Abilities were rated in the database on a scale of 0 (low) to 7 (high) based on the level of ability required to perform each job. For example, extent flexibility was rated as a 2 for the ability to reach for an object 2 feet away, and as a 6 for the ability to work under a car dashboard. Of 57 measures of work context, we similarly selected 13 measures (Table 1). Work context was rated in the database on a scale of 1 (never) to 5 (continually or almost continually) depending on the frequency of exposure. O*NET ratings have been extensively tested for reliability and face and construct validity (9).

For each patient, we mapped all reported occupations to O*NET in order to obtain the corresponding values for worker abilities and work context, and computed average exposures for each measure for each patient, weighted by the number of years spent in each job.

Outcome measures

Two outcome measures were used in the primary analyses: the Bath AS Functional Index (BASFI) and the Bath AS Radiology Index for the spine (BASRI-s) (10,11). The BASFI is a 10-item scale that asks respondents to rate the degree of difficulty they experience performing tasks using visual analog scales ranging from 0 (easy) to 100 (impossible). The score is then calculated as the mean of the 10 responses. The BASFI has good reliability and construct validity (10,12–14). The BASRI-s is an ordinal rating of the degree of erosion, sclerosis, or fusion in the sacroiliac joints, lumbar spine, and cervical spine, with a possible range of 0–12. Construct validity of the BASRI-s is supported by correlations of scores with the duration of AS, spinal range of motion, and posture (11,15,16). A single musculoskeletal radiologist (TJL) scored all radiographs. The BASRI-s represents cumulative damage due to AS, and in this cross-sectional study it was used to sort patients into grades of radiographic severity. In this group of patients with longstanding AS, the BASFI was also considered to reflect largely chronic functional impairments.

We also used the disability index of the Health Assessment Questionnaire modified for the spondylarthropathies (HAQ-S) as a second measure of functional limitations (17). The HAQ-S is a 25-item questionnaire that asks respondents to rate the degree of difficulty they have in performing tasks in 10 functional areas (8 areas of the original HAQ and 2 areas related to back and neck functions). Responses for each item can range from 0 (no difficulty) to 3 (unable to do), and the total score is the average of the highest score in the 10 areas.

Statistical analysis

The distribution of most occupational activity measures was positively skewed. Because of this, we examined associations between quartiles of activity measures and the outcome measures. We used analysis of variance to test for differences in BASFI scores across quartiles. For each model, we verified normality assumptions and the assumption of equal variances among groups using Levene's test. For occupational measures that were significantly associated with the BASFI in these analyses, we performed multivariable analyses of variance, including as covariates those factors found in our previous study to be associated with BASFI scores (age, sex, education level, number of comorbid conditions, current smoking, and history of AS in a first-degree relative) (7).

We used ordinal logistic regression analysis to test associations between quartiles of the occupational measures and the BASRI-s. Because the number of patients in some BASRI-s score categories was low, we grouped BASRI-s scores into 6 levels (1.5–4 points, 4.5–6.5 points, 7–8.5 points, 9–10 points, 11–11.5 points, and 12 points), and used these levels as the dependent variable in the logistic regression models. These analyses tested the likelihood that patients in higher quartiles of the occupational measure had BASRI-s scores in a level equal to or higher than patients in lower quartiles of the occupational measure. In this way, summary odds ratios were produced comparing patients in quartile 2, quartile 3, or quartile 4 with those in quartile 1; patients in quartiles 3 and 4 with those in quartiles 1 and 2; and patients in quartile 4 with those in the lower 3 quartiles. In multivariable analyses, we included age, sex, white race, education level, pack-years of smoking, and history of AS in a first-degree relative as covariates.

Ordinal logistic regression models assume that the strength of association is constant across levels of the dependent variable (e.g., the association of an occupational measure and the BASRI-s score between the first and second levels [1.5–4 versus 4.5–6.5] was the same as it was between the second and third levels [4.5– 6.5 versus 7–8.5]). We used the score test to verify that this assumption was met. We used modified Pearson's chi-square test and modified deviance test to assess goodness of fit of the models, and found that none exhibited poor fit (18).

All hypotheses were 2-tailed, and P values less than 0.05 were considered significant. Analyses were performed using SAS software, version 9.1 (Statistical Analysis Systems, Cary, NC).

Sensitivity analyses

We used patient age rather than the duration of AS as the marker of time in the analyses because of the possibility of error in recall of the date of symptom onset. Age and duration of AS were highly correlated (Spearman's r = 0.68), and therefore could not be included together in the models. We repeated all multivariable analyses using duration of AS instead of age with very similar results. We also tested associations using the HAQ-S to determine whether the association of occupational measures with functional limitations differed with the measure used. To test whether associations with the BASRI-s scores were sensitive to the way the scores were grouped, we repeated these analyses using a 5-level grouping (1.5–4 points, 4.5–7.5 points, 8–9.5 points, 10–11 points, and 11.5–12 points).

RESULTS

Patient characteristics

Of 402 patients in the study, we excluded 5 from these analyses (3 homemakers and 1 student, and 1 patient with missing data). The remaining 397 patients had a mean ± SD age of 55 ± 10.7 years, a mean ± SD duration of AS of 31.9 ± 10.0 years, and a mean ± SD education level of 16 ± 3 years. Of the sample, 300 (76%) were men, 351 (88%) were white, and 43 (11%) were current smokers. Eighty-eight percent of the patients were HLA–B27 positive. The mean ± SD BASFI score was 40.7 ± 26.2 points, the mean ± SD HAQ-S score was 0.8 ± 0.6 points, and the median (25th, 75th percentiles) BASRI-s score was 9 (6,12) points. The BASRI-s score was weakly correlated with both the BASFI score (Spearman's r = 0.31; $P < 0.0001$) and the HAQ-S score (r = 0.23; $P < 0.0001$).

The mean time in the workforce was 28 years. Sixty percent of patients reported having had ≥2 occupations, 37% reported ≥3 occupations, and 16% reported ≥4 occupations. Among all patients, 309 unique occupations were reported. At the time of the study, 239 (60%) patients were working and 88 (22%) were retired. Their current or most recent (for retirees) occupations were professional/ technical (67%), managerial (8%), clerical (8%), sales (6%), service workers (4%), farmers/laborers (3%), operatives (2%), and craftsman (2%).

Associations with functional limitations

In unadjusted analyses, BASFI scores were associated with all of the worker abilities and many of the work contexts, with higher scores among those with more cumulative exposure (apart from the expected inverse association with sitting) (Table 2). In the multivariable analyses, strong associations remained between BASFI scores and static strength, dynamic strength, dynamic flexibility, gross body equilibrium, standing, and sitting. There were weaker associations with arm-hand steadiness, trunk strength, and extent flexibility. Among all measures, dynamic flexibility had the strongest association with BASFI score. The most important confounders of the association between BASFI score and the occupational measures were education level, number of comorbid conditions, and current smoking.

Only dynamic flexibility was independently associated with BASFI score (all $P \leq 0.005$) in multivariable models that included both dynamic flexibility and either static strength, dynamic strength, gross body equilibrium, standing, or sitting ($P \geq 0.18$ for the other occupational measures). There was no evidence of collinearity between occupational measures in these models. There was also no evidence of interactions between dynamic flexibility and the other occupational measures in their associations with the BASFI score. Results were similar in analyses in which the top quartile was compared with the remaining quartiles, instead of examining trends across quartiles.

Associations between occupational measures and the HAQ-S were generally weaker than with the BASFI, but both demonstrated a similar pattern. In multivariable analyses, the HAQ-S was associated with dynamic flexibility ($P = 0.006$), dynamic strength ($P = 0.008$), arm-hand steadiness ($P = 0.009$), gross body equilibrium ($P = 0.02$), and static strength ($P = 0.03$). Of these, only dynamic flexibility was independently associated with the HAQ-S. Adjusted mean ± SE scores across groups of dynamic flexibility were 0.58 ± 0.03 (lowest 2 quartiles), 0.58 ± 0.04 (third quartile), and 0.79 ± 0.04 (highest quartile).

Associations with radiographic damage

In unadjusted analyses, only dynamic flexibility and exposure to whole body vibration demonstrated a graded increase in BASRI-s scores with increasing exposure (Table 3). For both measures, the median BASRI-s score among patients in the lowest quartile was 8, and the median BASRI-s score among patients in the highest quartile was 10. For both measures, those in the highest quartile had significantly higher BASRI-s scores than those in the lowest quartiles, even after adjustment for potential confounding factors (adjusted odds ratio [OR] for dynamic flexibility 1.56, 95% confidence interval [95% CI] 1.00–2.43; $P = 0.05$; adjusted OR for whole body vibration 1.81, 95% CI 1.05–3.11; $P = 0.04$). In addition, those in the highest quartile of extent flexibility had significantly higher BASRI-s scores than those in the lowest quartile in multivariable analysis (adjusted OR 1.75, 95% CI 1.03–2.97; $P = 0.04$). None of the other occupational measures demonstrated graded associations with BASRI-s scores. The most important covariates in the multivariable analyses were age, sex, family history of AS, and smoking history.

BASRI-s scores were likely to be higher among patients who were in the highest quartiles of both dynamic flexibility and extent flexibility than among those in the highest quartile of only 1 of these measures (Figure 1). Similarly, BASRI-s scores were likely to be higher among those in the highest quartiles of both dynamic flexibility and exposure to whole body vibration than among those in the highest quartile of only 1 of these measures. There was no evidence of an interaction between extent flexibility and exposure to whole body vibration.

Results were similar in a sensitivity analysis using alternative cut points and categorizing BASRI-s scores into 5 levels instead of 6. In these models, only dynamic flexibility, extent flexibility, and exposure to whole body vibration demonstrated graded associations with BASRI-s scores, with ORs that were similar to those of the original analysis. The adjusted OR for highest quartile versus lowest quartile was 1.61 in dynamic flexibility (95% CI 1.02– 2.52, $P = 0.04$), 1.86 in extent flexibility (95% CI 1.06– 3.09, $P = 0.03$), and 1.87 in whole body vibration (95% CI 1.08–3.22, $P = 0.03$).

DISCUSSION

Physical activity has long been considered beneficial for patients with AS, helping reduce pain and stiffness, maintain good posture, and improve functioning (19–22). Our findings highlight the distinction between work-related physical activity and therapeutic or recreational physical activity, and the very different association that work-related physical activity may have with health outcomes. Among our patients with longstanding AS, those who had past jobs that typically required repeated bending, stretching, or twisting (i.e., dynamic flexibility) had BASFI scores that averaged 11 points higher than those with past jobs that did not involve these activities. A similar association was present when functional limitations were measured using the HAQ-S, indicating that this association was not specific for tasks represented in the BASFI. Patients with past jobs requiring dynamic flexibility were also more likely to have higher BASRI-s scores. Work-related dynamic flexibility likely requires bending, stretching, and twisting for long periods, without adequate rest, in abnormal positions, and despite symptoms. These activities would be expected to affect an inflamed axial skeleton differently than therapeutic back exercises. Our results suggest that these work activities lead to more spinal damage and functional limitations over time.

The level of dynamic flexibility associated with poorer outcomes was relatively low. Those in the highest quartile on a scale of difficulty ranging from 0 to 7 had a mean score of 0.4 and a maximum score of 1.6. A representative task with a score of 2 on this measure is picking apples from a tree by hand. It should be recognized that these values represent average exposures over the patients' work life. Individual jobs performed for shorter periods may have had more intensive demands. However, our results suggest that exposure to jobs with even modest requirements for dynamic flexibility may be associated with poorer outcomes. Higher exposure to jobs requiring extent flexibility, a closely related occupational measure, was also associated with higher BASRI-s scores. In contrast, tracer activities that do not stress the back, such as manual dexterity and arm-hand steadiness, were not independently associated with functional or radiographic severity. The consistency of the relationship between dynamic flexibility and both functional and radiographic outcomes, and between dynamic flexibility and extent flexibility, reinforces the validity of this association. Having jobs that required both dynamic and extent flexibility was associated with higher BASRI-s scores than having jobs that required either activity alone.

Exposure to whole body vibration, such as from driving trucks or tractors or operating heavy equipment, was the single measure of work context associated with more severe radiographic damage. Mean exposure to vibration among patients in the highest quartile occurred at least once yearly, and maximum exposure occurred at least weekly, averaged over their working life. Again, exposures over shorter periods may have been more intense. Whole body vibration is an established risk factor for low back pain (1,2). In the lumbar spine, vertebral end plates, inter-vertebral discs, and facet joints can be damaged by prolonged exposure to whole body vibration (23,24). Compensatory muscle contractions can lead to paraspinal muscle fatigue and susceptibility to further injury (23,25). The mechanisms by which whole body vibration may be associated with radiographic damage in AS are unclear. Vibration may increase spinal inflammation in patients with AS, which may then lead to more extensive radiographic changes. Some research suggests that low magnitude whole body vibration is osteogenic (26–28). This may represent an inflammation-independent mechanism by which vibration leads to higher BASRI-s scores, but the response of vertebral bone to low magnitude vibration may be different from its response to work-related vibration.

Previous studies of work in patients with AS have largely focused on the impact of functional impairment on work disability (29). Rarely has it been considered that this association might be bidirectional, and that work activities may impact functional or radiographic outcomes. In a cross-sectional study of 182 patients with AS, prolonged standing or carrying of loads were not associated with functional limitations, but only activities of the patients' current job were tested (30). AS activity was found to be lower among professionals/managers than among manual workers in another cross-sectional study, but physical functioning was similar between these occupational groups (31). Lower levels of formal education have been associated with more functional limitations in patients with AS, but this does not necessarily imply a link with heavy occupational physical activity (32–34). Our analyses were adjusted for education level. This, along with the finding that only selected occupational exposures were associated with the outcomes, also suggests that the occupation measures were not acting as surrogates for social class, in which case associations might have been expected for a broader range of activities denoting heavy physical work. In addition, these associations were found despite the fact that patients with more severe AS may have selected or migrated to less physically demanding occupations.

The strengths of this study include the large, well-characterized sample, the collection of lifetime history of occupations rather than only the most recent jobs, the use of a new detailed compendium to identify specific occupational activities and work contexts as risk factors, and testing the sensitivity of the results to different outcomes. We restricted the analysis to patients with longstanding AS to permit better identification of factors associated with stable irreversible changes and structural damage. Inclusion of patients with early AS might have obscured these associations, given that radiographic changes may not have had sufficient time to evolve and functional limitations may be impacted more by AS activity in these patients. However, the study was cross-sectional, and cannot establish causal associations. Despite this, the occupational exposures we examined predated the outcomes, and preserved the temporal relationship between exposure and outcome. The strength, consistency, and biologic plausibility of the associations also suggest possible causality. The occupational measures were based on job titles, rather than direct measurement, and may not have accurately captured the particular work experiences of all patients. However, this method is more accurate than self-report, and is the only practical way to assess occupational exposures over decades (35–36). Similarly, we could not assess AS activity retrospectively, and therefore could not test whether these occupational activities were associated with poorer outcomes because they perpetuated spinal inflammation. We also did not examine therapeutic exercise or psychosocial stressors at work among these subjects, which might also be associated with outcomes we studied, or which might confound the associations with work activities and work contexts (37,38).

Our results suggest that specific occupational activities and exposures can influence long-term outcomes in patients with AS. In particular, occupations that require repeated bending, stretching, and twisting, or exposure to whole body vibration, are associated with more functional limitations and/or more extensive radiographic spinal damage. These findings are analogous to the consequences of overuse of inflamed or susceptible peripheral joints. Further studies are needed to replicate these findings and to understand the mechanisms underlying these associations. However, given that it is possible to use O*NET to stratify occupations based on the requirement for these activities, these findings may have direct application in vocational counseling for patients with AS.

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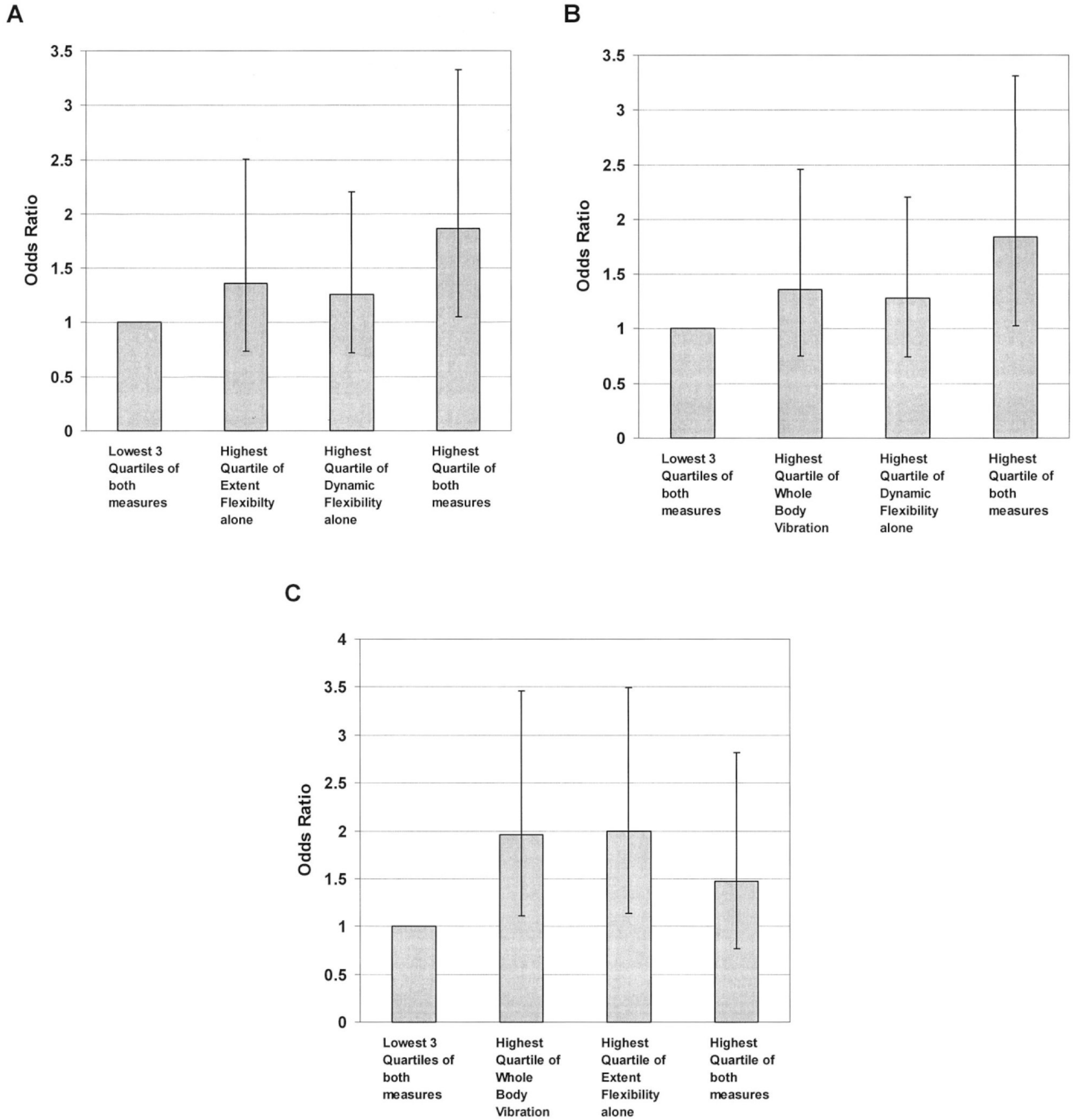

Figure 1.
Adjusted odds ratios (ORs) of the association between Bath Ankylosing Spondylitis Radiology Index for the spine score levels and **A**, being in the highest quartile of both dynamic flexibility and extent flexibility, **B**, being in the highest quartile of both dynamic flexibility and exposure to whole body vibration, or **C**, being in the highest quartile of both extent flexibility and exposure to whole body vibration. ORs are based on multivariable ordinal logistic regression models adjusted for age, sex, ethnicity, education level, pack-years of smoking, and family history of ankylosing spondylitis. Error bars represent 95% confidence intervals.

Table 1

Worker abilities and work contexts based on the Occupational Information Network*

Measure	Examples	Cut points
Worker abilities (definition)		
Arm-hand steadiness (ability to keep hand steady while moving arm, or holding arm and hand in one position)	Light a candle = 2; Thread a needle = 4	0.7, 1.6, 2.3
Manual dexterity (ability to quickly move hands or arms to grasp, manipulate, or assemble objects)	Screw in a light bulb = 2; Pack fruit in a crate quickly = 4	0.6, 1.4, 2.4
Multi-limb coordination (ability to coordinate 2 or more limbs while sitting, standing, or lying down)	Row a boat = 2; Operate a forklift = 4	0.4, 1.4, 2.0
Speed of limb movement (ability to quickly move arms and legs)	Saw wood = 2; Swat a fly with a swatter = 4	0.1, 0.5, 1.3
Static strength (ability to exert maximum force to lift, push, pull, or carry objects)	Push an empty cart = 1; Pull a 40-pound sack = 4	0.2, 0.8, 2.0
Dynamic strength (ability to exert muscle force repeatedly or continuously over time)	Trim bushes with shears = 2; Climb a 48-foot ladder = 5	0, 0.3, 1.1
Explosive strength (ability to use short bursts of force to propel oneself [jumping or sprinting] or throw an object)	Hammer a nail = 2; Jump onto a 3-foot high Platform = 4	0, 0, 0.3†
Trunk strength (ability to use abdominal and lower back muscles to support the body repeatedly or continuously without fatiguing)	Sit up in an office chair = 2; Shovel snow for 30 minutes = 4	1.1, 1.8, 2.4
Stamina (ability to exert oneself physically over long periods without getting winded)	Walk one-quarter mile = 1; Climb 6 flights of stairs = 4	0.1, 0.6, 1.4
Extent flexibility (ability to bend, stretch, twist, or reach)	Reach for automobile controls on a dashboard = 2; Reach a box on a high shelf = 4	0.3, 1.0, 1.9
Dynamic flexibility (ability to quickly and repeatedly bend, stretch, twist, or reach out)	Pick a bushel of apples from a tree = 2; Perform a dance routine = 5	0, 0, 0.1†
Gross body coordination (ability to coordinate movement of arms, legs, and torso when whole body is in motion)	Get in and out of a truck = 2; Swim the length of a pool = 4	0.3, 0.7, 1.5
Gross body equilibrium (ability to keep or regain balance when in an unstable position)	Stand on a ladder = 2; Walk on ice across a pond = 4	0, 0.4, 1.0
Work context		
Time spent sitting		4.0, 3.5, 2.8
Time spent standing		2.3, 2.7, 3.3
Time spent walking or running		1.8, 2.2, 2.7
Time spent climbing		1.0, 1.2, 1.4
Time spent kneeling, stooping, or crawling		1.3, 1.5, 1.9
Time spent bending or twisting		1.5, 1.8, 2.1
Time spent keeping or regaining balance		1.1, 1.3, 1.5
Time spent using hands to feel or control objects, controls, or tools		2.1, 3.0, 4.4
Time spent making repetitive motions		2.2, 2.7, 3.5
Exposure to cramped work spaces that require awkward positions		1.3, 1.6, 2.0
Exposure to whole body vibration		1.0, 1.1, 1.2
Exposure to work outdoors in all weather conditions		1.4, 1.8, 2.5
Exposure to extreme heat or cold		1.4, 1.8, 2.4

*Cut points represent the values of each occupational measure that define the quartiles used in the analyses. Values for worker abilities ranged from 0 (low) to 7 (high) based on the level of ability required for each job. Values for work context ranged from 1 (never) to 5 (continually or daily) based on the frequency of exposure.

†Slightly more than 50% of patients had no jobs with a requirement for these abilities. The lower 2 quartiles were therefore collapsed, and only 3 categories of exposure were considered for analyses.

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Table 2

Mean ± SE scores of the Bath Ankylosing Spondylitis Functional Index by quartile of occupational measures*

	Quartile				
Measure	**1 (low)**	**2**	**3**	**4 (high)**	***P***
Worker abilities					
Arm-hand steadiness					
Unadjusted	34.2 ± 2.6	37.3 ± 2.6	44.7 ± 2.5	46.5 ± 2.6	0.0002
Adjusted	36.9 ± 2.4	37.5 ± 2.3	44.5 ± 2.3	44.2 ± 2.5	0.01
Manual dexterity					
Unadjusted	34.7 ± 2.6	38.0 ± 2.6	43.0 ± 2.6	47.4 ± 2.6	0.002
Adjusted	37.3 ± 2.4	39.7 ± 2.4	43.1 ± 2.4	43.2 ± 2.5	0.07
Multi-limb coordination					
Unadjusted	34.8 ± 2.6	38.6 ± 2.5	41.0 ± 2.6	49.4 ± 2.7	0.0001
Adjusted	37.6 ± 2.4	39.4 ± 2.3	42.3 ± 2.3	44.3 ± 2.6	0.05
Speed of limb movement					
Unadjusted	36.9 ± 2.6	39.0 ± 2.7	38.3 ± 2.5	48.4 ± 2.6	0.004
Adjusted	40.1 ± 2.4	38.0 ± 2.6	40.4 ± 2.3	44.3 ± 2.4	0.18
Static strength					
Unadjusted	34.8 ± 2.5	35.6 ± 2.6	43.8 ± 2.7	49.5 ± 2.6	< 0.0001
Adjusted	37.1 ± 2.3	37.4 ± 2.4	44.3 ± 2.4	45.0 ± 2.5	0.006
Dynamic strength					
Unadjusted	34.5 ± 2.3	38.6 ± 2.7	40.0 ± 2.8	51.2 ± 2.6	< 0.0001
Adjusted	37.0 ± 2.1	38.8 ± 2.6	41.1 ± 2.5	47.2 ± 2.5	0.002
Explosive strength†					
Unadjusted	36.4 ± 1.8		43.5 ± 2.7	46.9 ± 2.6	0.001
Adjusted	38.9 ± 1.7		41.7 ± 2.5	43.9 ± 2.4	0.10
Trunk strength					
Unadjusted	34.5 ± 2.6	39.0 ± 2.6	43.2 ± 2.7	46.1 ± 2.5	0.0007
Adjusted	36.0 ± 2.3	40.2 ± 2.3	44.9 ± 2.5	42.5 ± 2.4	0.03
Stamina					
Unadjusted	33.4 ± 2.5	42.3 ± 2.6	40.2 ± 2.5	47.7 ± 2.7	0.0006
Adjusted	36.3 ± 2.3	42.9 ± 2.4	40.7 ± 2.3	43.7 ± 2.5	0.08
Extent flexibility					

Measure	Quartile 1 (low)	2	3	4 (high)	*P*
Unadjusted	33.7 ± 2.4	39.9 ± 2.7	40.0 ± 2.6	50.3 ± 2.6	< 0.0001
Adjusted	36.2 ± 2.2	41.1 ± 2.5	41.3 ± 2.4	45.4 ± 2.5	0.01
Dynamic flexibility[†]					
Unadjusted	34.8 ± 1.7		41.3 ± 2.7	51.9 ± 2.5	< 0.0001
Adjusted	37.1 ± 1.6		40.4 ± 2.5	48.3 ± 2.3	0.0001
Gross body coordination					
Unadjusted	38.2 ± 2.5	34.7 ± 2.7	41.4 ± 2.8	47.4 ± 2.5	0.003
Adjusted	40.0 ± 2.3	36.6 ± 2.5	42.2 ± 2.5	43.9 ± 2.3	0.10
Gross body equilibrium					
Unadjusted	35.1 ± 2.5	36.5 ± 2.7	41.4 ± 2.5	49.6 ± 2.6	< 0.0001
Adjusted	36.5 ± 2.3	37.9 ± 2.5	41.9 ± 2.3	46.7 ± 2.4	0.002
Work context					
Sitting					
Unadjusted	50.7 ± 2.6	39.9 ± 2.6	36.5 ± 2.5	35.6 ± 2.6	< 0.0001
Adjusted	45.7 ± 2.5	42.0 ± 2.3	38.4 ± 2.3	37.0 ± 2.4	0.007
Standing					
Unadjusted	34.6 ± 2.6	38.0 ± 2.6	39.3 ± 2.5	51.2 ± 2.6	< 0.0001
Adjusted	36.7 ± 2.4	39.0 ± 2.4	41.2 ± 2.3	46.3 ± 2.5	0.005
Walking or running					
Unadjusted	32.3 ± 2.6	39.9 ± 2.6	42.9 ± 2.5	47.2 ± 2.6	< 0.0001
Adjusted	36.5 ± 2.5	40.8 ± 2.3	42.9 ± 2.3	42.7 ± 2.5	0.07
Climbing					
Unadjusted	38.3 ± 2.6	42.6 ± 2.7	38.4 ± 2.6	43.6 ± 2.7	0.33
Adjusted	39.7 ± 2.4	45.6 ± 2.4	38.3 ± 2.3	39.8 ± 2.5	0.56
Kneeling, stooping, or crawling					
Unadjusted	36.5 ± 2.6	38.4 ± 2.4	41.1 ± 2.7	47.7 ± 2.7	0.003
Adjusted	40.9 ± 2.5	40.6 ± 2.3	40.1 ± 2.4	41.6 ± 2.6	0.89
Bending or twisting					
Unadjusted	34.6 ± 2.5	42.7 ± 2.6	36.8 ± 2.6	48.7 ± 2.6	0.002
Adjusted	38.2 ± 2.4	43.2 ± 2.4	38.7 ± 2.4	43.2 ± 2.4	0.36
Balancing					

Measure	Quartile 1 (low)	2	3	4 (high)	*P*
Unadjusted	35.1 ± 2.6	38.9 ± 2.4	41.1 ± 2.6	48.6 ± 2.8	0.0004
Adjusted	36.9 ± 2.4	42.3 ± 2.3	41.2 ± 2.3	42.6 ± 2.7	0.18
Using hands to feel or control objects					
Unadjusted	34.7 ± 2.6	39.2 ± 2.6	41.6 ± 2.6	47.2 ± 2.6	0.0007
Adjusted	37.7 ± 2.4	42.6 ± 2.4	40.9 ± 2.3	42.1 ± 2.5	0.32
Repetitive movements					
Unadjusted	34.7 ± 2.6	39.2 ± 2.6	41.6 ± 2.6	47.2 ± 2.6	0.0007
Adjusted	37.7 ± 2.4	42.6 ± 2.4	40.9 ± 2.3	42.1 ± 2.5	0.32
Cramped spaces					
Unadjusted	36.8 ± 2.6	40.6 ± 2.6	38.3 ± 2.6	47.0 ± 2.6	0.02
Adjusted	39.3 ± 2.4	42.1 ± 2.4	39.8 ± 2.4	42.0 ± 2.5	0.61
Whole body vibration					
Unadjusted	36.6 ± 2.6	41.8 ± 2.7	39.6 ± 2.5	44.9 ± 2.6	0.06
Adjusted	39.9 ± 2.4	43.2 ± 2.5	38.3 ± 2.3	42.1 ± 2.5	0.89
Outdoor weather					
Unadjusted	40.2 ± 2.6	40.2 ± 2.5	40.0 ± 2.7	42.5 ± 2.7	0.58
Adjusted	41.7 ± 2.4	42.8 ± 2.3	37.6 ± 2.5	40.8 ± 2.5	0.49
Extreme hot or cold					
Unadjusted	38.4 ± 2.6	38.0 ± 2.4	41.0 ± 2.8	45.8 ± 2.6	0.04
Adjusted	41.0 ± 2.5	39.7 ± 2.2	42.5 ± 2.6	40.5 ± 2.6	0.92

*Adjusted means are based on multivariable models that included the covariates of age, sex, ethnicity, education level, number of comorbid conditions, current smoking, and family history of ankylosing spondylitis. *P* values are for linear trend across quartiles.

†Slightly more than 50% of patients had no jobs with a requirement for these abilities. The lower 2 quartiles were therefore collapsed, and only 3 categories of exposure were considered for analyses.

Table 3

Median score values and adjusted odds ratios (ORs) of the Bath Ankylosing Spondylitis Radiology Index for the spine (BASRI-s), by quartile of occupational measures*

	Quartile			
Measure	**1 (low)**	**2**	**3**	**4 (high)**
Worker abilities				
Arm-hand steadiness				
Unadjusted median	9 (6, 11)	9 (7, 11.5)	9 (6.5, 12)	8.75 (5, 12)
Adjusted OR	1.00†	1.21 (0.72–2.02)	1.02 (0.61–1.70)	1.14 (0.66–1.95)
Manual dexterity				
Unadjusted median	9 (5, 11)	9 (6, 11)	10 (8, 12)	8 (6, 12)
Adjusted OR	1.00†	1.01 (0.60–1.68)	1.54 (0.92–2.60)	1.07 (0.62–1.84)
Multi-limb coordination				
Unadjusted median	9 (6, 11.25)	9 (4, 11)	8.5 (6, 12)	9.25 (7, 12)
Adjusted OR	1.00†	0.73 (0.44–1.21)	0.87 (0.52–1.45)	1.02 (0.58–1.79)
Speed of limb movement				
Unadjusted median	9 (6, 11)	8.5 (4.5, 12)	9 (6, 11)	9 (7, 12)
Adjusted OR	1.00†	0.97 (0.57–1.67)	1.05 (0.63–1.73)	1.30 (0.76–2.22)
Static strength				
Unadjusted median	8.75 (6, 11)	9 (4.5, 12)	9.25 (7, 12)	9 (6.5, 12)
Adjusted OR	1.00†	1.22 (0.73–2.01)	1.44 (0.86–2.41)	1.50 (0.88–2.55)
Dynamic strength				
Unadjusted median	9 (6, 11.25)	9 (7, 11)	9 (6, 11.5)	9 (6.5, 12)
Adjusted OR	1.00†	1.12 (0.67–1.85)	1.11 (0.67–1.84)	1.38 (0.83–2.30)
Explosive strength‡				
Unadjusted median	8.5 (6, 11)		10 (7, 12)	9 (6.25, 12)
Adjusted OR	1.00†		1.69 (1.06–2.70)	1.08 (0.68–1.71)
Trunk strength				
Unadjusted median	9 (6, 11)	9 (6.75, 12)	9 (5, 11)	9 (6, 12)
Adjusted OR	1.00†	1.79 (1.07–2.99)	1.01 (0.60–1.70)	1.20 (0.71–2.01)
Stamina				
Unadjusted median	9 (5, 11)	9 (5, 12)	9.5 (7, 11)	9 (6, 12)
Adjusted OR	1.00†	1.23 (0.73–2.06)	1.70 (1.02–2.82)	1.49 (0.87–2.56)
Extent flexibility				
Unadjusted median	9 (5.5, 11)	9 (7, 11)	9 (5, 12)	9 (6.5, 12)
Adjusted OR	1.00†	1.28 (0.77–2.14)	1.16 (0.70–1.90)	1.75 (1.03–2.97)
Dynamic flexibility‡				
Unadjusted median	8 (6, 11)		9 (6, 12)	10 (7, 12)
Adjusted OR	1.00†		1.27 (0.80–2.02)	1.56 (1.00–2.43)
Gross body coordination				
Unadjusted median	9 (5, 11)	8.5 (4.5, 12)	10 (7, 12)	9 (6.5, 12)
Adjusted OR	1.00†	0.98 (0.58–1.64)	1.65 (0.98–2.78)	1.32 (0.80–2.19)

	Quartile			
Measure	**1 (low)**	**2**	**3**	**4 (high)**
Gross body equilibrium				
Unadjusted median	9 (6, 11)	9 (6, 11)	9 (6, 12)	9 (6, 12)
Adjusted OR	1.00†	1.39 (0.82–2.34)	1.40 (0.84–2.31)	1.47 (0.87–2.48)
Work context				
Sitting				
Unadjusted median	9 (6.5, 12)	9 (6, 11.5)	9 (5, 12)	9 (6, 11.5)
Adjusted OR	1.00†	1.01 (0.59–1.70)	0.98 (0.57–1.66)	0.94 (0.55–1.67)
Standing				
Unadjusted median	9 (5.25, 11)	9 (6, 12)	9 (6, 12)	9 (6.5, 12)
Adjusted OR	1.00†	1.18 (0.70–1.97)	1.29 (0.78–2.15)	1.24 (0.72–2.13)
Walking or running				
Unadjusted median	9 (6, 11.5)	9 (4, 12)	8.75 (6, 11)	9 (6.5, 12)
Adjusted OR	1.00†	0.90 (0.53–1.52)	1.15 (0.68–1.93)	1.07 (0.61–1.86)
Climbing				
Unadjusted median	8.5 (5, 11)	9 (7, 11)	9.75 (7, 12)	9 (6, 12)
Adjusted OR	1.00†	1.13 (0.68–1.90)	1.10 (0.65–1.84)	0.80 (0.46–1.39)
Kneeling, stooping, or crawling				
Unadjusted median	9 (6, 11)	9 (5, 12)	9 (6, 12)	8.5 (6, 12)
Adjusted OR	1.00†	0.99 (0.60–1.62)	1.37 (0.79–2.35)	0.82 (0.46–1.45)
Bending or twisting				
Unadjusted median	9 (6, 11)	10 (6.5, 12)	8 (6, 12)	9 (6.5, 12)
Adjusted OR	1.00†	1.12 (0.67–1.87)	0.97 (0.57–1.62)	1.17 (0.68–2.01)
Balancing				
Unadjusted median	9 (6, 12)	8 (4, 11)	9 (6, 12)	9 (7, 12)
Adjusted OR	1.00†	0.74 (0.44–1.23)	1.13 (0.67–1.91)	1.13 (0.63–2.00)
Using hands to feel or control objects				
Unadjusted median	9.5 (6, 12)	8.5 (5, 11)	9 (7, 12)	9 (6, 12)
Adjusted OR	1.00†	1.13 (0.67–1.90)	1.16 (0.69–1.96)	0.97 (0.56–1.66)
Repetitive movements				
Unadjusted median	9.5 (6, 12)	8.5 (5, 11)	9 (7, 12)	9 (6, 12)
Adjusted OR	1.00†	1.13 (0.67–1.90)	1.16 (0.69–1.96)	0.97 (0.56–1.66)
Cramped spaces				
Unadjusted median	9 (6, 11.5)	8 (5, 11)	9 (6, 12)	9 (6.5, 12)
Adjusted OR	1.00†	0.93 (0.55–1.56)	0.97 (0.58–1.63)	0.89 (0.51–1.52)
Whole body vibration				
Unadjusted median	8 (5, 11)	9 (6, 12)	9 (6, 11)	10 (8, 12)
Adjusted OR	1.00†	1.69 (0.99, 2.88)	1.07 (0.64, 1.78)	1.81 (1.05, 3.11)
Outdoor weather				
Unadjusted median	8.5 (4.5, 11)	9.5 (7, 12)	9 (6, 12)	9 (7, 12)
Adjusted OR	1.00†	1.21 (0.73–2.01)	0.88 (0.51–1.50)	0.85 (0.49–1.47)
Extreme hot or cold				

	Quartile			
Measure	**1 (low)**	**2**	**3**	**4 (high)**
Unadjusted median	8.75 (4.5, 11.5)	9 (6, 11)	9 (6, 12)	9 (7, 12)
Adjusted OR	1.00†	0.87 (0.52–1.43)	0.96 (0.55–1.66)	0.90 (0.50–1.58)

*Unadjusted medians listed as median (25th, 75th percentile); adjusted ORs listed as OR (95% confidence interval). Adjusted ORs are based on multivariable ordinal logistic regression models that included the covariates of age, sex, ethnicity, education level, pack-years of smoking, and family history of ankylosing spondylitis, and represent the likelihood that patients in a given quartile of an occupational measure will have a BASRI-s score at a level equal to or higher than patients in a lower quartile.

†Reference group.

‡Slightly more than 50% of patients had no jobs with a requirement for these abilities. The lower 2 quartiles were therefore collapsed, and only 3 categories of exposure were considered for analyses.