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Spine Radiographs in Patients with Low-Back Pain

An Epidemiological Study in Men*

BY JOHN W. FRYMOYER, M.D.†, ARTHUR NEWBERG, M.D.‡, MALCOLM H. POPE, PH.D.†, DAVID G. WILDER, M.S.M.E.†, JANICE CLEMENTS, B.S.†, AND BRIAN MACPHERSON, M.S.†, BURLINGTON, VERMONT

From the Department of Orthopaedics and Rehabilitation and the Biometry Facility, University of Vermont, College of Medicine, Burlington

ABSTRACT: A cohort of 321 men between the ages of eighteen and fifty-five was randomly selected from a group of 1221 men who had been surveyed by a questionnaire. They then had radiographs made of the lumbar spine. Of the 292 subjects fulfilling the criteria for inclusion in the study, ninety-six (32.9 per cent) had never had low-back pain, 134 (45.9 per cent) had had or were having moderate low-back pain, and sixty-two (21.2 per cent) had had or were having severe low-back pain. In the three groups there was a similar frequency of transitional vertebrae, Schmorl's nodes, the disc vacuum sign, narrowing of the disc space between the third and fourth lumbar and the fifth lumbar and first sacral vertebrae, and claw spurs. When there were traction spurs or disc-space narrowing, or both, between the fourth and fifth lumbar vertebrae, an increased incidence of severe low-back pain was evident. There also was a significant association of these two radiographic findings with symptoms (pain, weakness, and numbness) in the lower limbs. The measured lumbar lordosis, the length of the transverse process of the fourth lumbar vertebra, and the relationship between the fourth and fifth lumbar vertebral bodies with reference to the intercristal line had no association with the low-back pain.

Increased lumbar lordosis had a significant association with decreased disc-space height and wedging deformity of the disc between the fourth and fifth lumbar vertebrae. Narrowing at the lumbosacral disc space was associated with wedging of that disc and also with a decreased lordotic angle between the first and third lumbar levels. Spurs, but not disc-space narrowing, increased in incidence with increased age. Spurs and disc-space narrowing had no correlation with occupation, occupational requirements for lifting, or exposure to vehicular and other forms of vibration.

Radiographic abnormalities such as intervertebral disc-space narrowing, spinal osteophytes, Schmorl's nodes, transitional vertebrae, and accentuated lumbar lordosis have been commonly cited as significant findings in patients with low-back pain[1,4,13,15,27]. In some industrial centers, employment is refused to applicants who have one or more of these radiographic abnormalities because the affected individuals are presumed to be at increased risk for low-back pain. However, Nachemson has stated that in no more than one in 2000 patients do the radiographs of the spine constitute essential evidence for the diagnosis, prognosis, or treatment of low-back pain.

These inconsistent assessments stem in part from conflicting data obtained from radiographic surveys. In their studies of Scandinavian workers, both Hult and Horal found no relationship between narrowing of the disc spaces or spinal osteophytes and low-back pain. However, they did observe that the incidence of spinal osteophytes increased as a function of age. Surveys of workers in selected industries have shown an equal prevalence of disc-space narrowing, spinal osteophytes, facet tropism, Schmorl's nodes, and transitional vertebrae unrelated to the incidence of low-back pain[9]. Torgerson and Dotter reported a significant association between the height of the intervertebral disc space and low-back pain, and a marginal degree of correlation of low-

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† Department of Orthopaedics and Rehabilitation and Biometry Facility, University of Vermont, College of Medicine, Burlington, Vermont 05405.

‡ Department of Radiology, New England Baptist Hospital, Boston, Massachusetts 02120.

back pain with accentuated lumbar lordosis in patients who underwent intravenous pyelograms. Fahrni and Trueman, Lawrence, and Kellgren and Lawrence identified accentuated lumbar lordosis, as well as degenerative joint disease of the spine, as being more prevalent in residents of industrial societies than in so-called primitive populations. Because the primitive populations had fewer people who complained of low-back pain, it was suggested that the degenerative changes and the pain were causally related.

In this study we attempted to relate the findings on radiographs of the lumbar spine in men with three categories of previous or current low-back pain — none, moderate, or severe — and with previous or current symptoms in the lower extremities. We also explored the relationship between the radiographic appearance of the lumbar spine and the environmental factor of repeated mechanical stresses by assessing occupational, vehicular, and recreational activities. Our objective was to determine what role, if any, exists for radiographic studies as part of prospective epidemiological investigations of low-back pain.

Methods and Materials

The survey population of 1221 men from which the subjects for this radiographic study were recruited has been described in detail[8]. The 1221 subjects were divided, according to their history of current and previous low-back pain, into three groups: those with no pain, those with moderate pain, and those with severe pain. The classification was based on a Likert-type scale derived from the McGill pain questionnaire, in which subjects rate their pain as mild, discomforting, distressing, horrible, or excruciating. We combined the mild, discomforting, and distressing groups into our moderate low-back-pain category, and the horrible and excruciating pain descriptions into our severe low-back-pain category. These pain categories were associated with other, more objective measures of low-back dysfunction, as has been previously reported[8]. For example, the utilization of health-care professionals, treatment required, and work loss were identified as being significantly greater for the severe-pain group than for the moderate-pain group.

Each subject was assigned a number at random, and we attempted to contact individuals from each pain group sequentially according to their randomly assigned number in such a way that the proportions of patients with no pain, moderate pain, and severe pain remained similar to analogous proportions in the survey population. The 321 men who had spine radiographs were compared, in terms of all questionnaire variables, with the 1221 questionnaire respondents, and subsequent statistical analyses revealed that they were a representative sample of the 1221 questionnaire respondents in terms of all of the demographic, occupational, recreational, health-care-utilization, work-loss, and other variables studied.

The 321 subjects completed a questionnaire about their health and spine symptoms, underwent an abbreviated MMPI test[24] and a biomechanical test, and had an examination of the spine and neurological examination. For 303 subjects we performed occupational analyses which included a more detailed determination of exposure to vehicular vibration and other imposed vibrational stresses, recreational activities, and requirements for lifting[2]. Eighteen subjects who had both radiographic and occupational analyses were excluded because they did not fulfill all of the criteria to be included in this part of the study.

Radiographic Studies

We made the decision to include radiographic analyses in our epidemiological studies with recognition of the medical and ethical issues involved. We included only men, and gonadal shielding always was provided. The completed studies, including radiographs of the spine, were made part of each subject's complete medical record.

Each subject had standing anteroposterior and lateral radiographs made with the x-ray beam centered at the fourth lumbar interspace[22]. On the lateral radiographs (Fig. 1) measurements were made, at the three lower lumbar levels, of the intervertebral disc-space heights, normalized as the ratio of the transverse diameter of the space to the vertical height of the space, and of the asymmetrical narrowing (wedging) of each disc space, expressed as the ratio of the anterior height of the space to its posterior height. Lumbar lordosis was expressed as the angle between the first and fifth lumbar vertebrae, subdivided into the angle between the first and third and that between the third and fifth lumbar vertebrae[5]. On the anteroposterior radiographs (Fig. 2), the intercristal line was drawn and the relationship of that line with the fifth lumbar vertebral body, the disc between the fourth and fifth lumbar vertebrae, or the fourth lumbar vertebral body was marked. The length of each transverse process was determined by the relationship of the length of the third lumbar transverse process with that of the fourth and fifth lumbar transverse processes. These measurements were made because MacGibbon and Farfan have shown that the lengths of the third and fifth lumbar transverse processes may be related to patterns of disc disease between the fourth and fifth lumbar vertebrae or the fifth lumbar and first sacral vertebrae.

All radiographs were evaluated by a radiologist, with the radiographs randomized so that he had no knowledge of the patients' symptoms. He noted the presence or absence of anterior, posterior, and lateral osteophytes at each lumbar intervertebral level and, when they were present, classified them as either traction or claw spurs[17] (Fig. 3). He also noted whether there were Schmorl's nodes, scoliosis, other structural abnormalities (such as spina bifida occulta), or narrowing of the disc space between the third and fourth lumbar, fourth and fifth lumbar, or fifth lumbar and first sacral vertebrae. The determination of disc-space height was based on two general rules. First, an over-all impression of the thickness of each disc space was defined as either narrow or normal. Because there is a normal progression of increasing disc-space height from the third and fourth to the fourth and fifth lumbar vertebrae, and then a relative narrowing of the height of the lumbosacral disc space, the disc space between the fourth and fifth lumbar vertebrae was defined as narrowed when its height was less than that of either the disc between the third and fourth lumbar vertebrae or the lumbosacral disc space[10]. In some subjects multiple disc spaces were narrowed, and for them the radiologist had to rely on his judgment and experience with the normal progression of disc-space heights[10]. A random sample of seventy-three radiographs was reinterpreted for intra-observer reliability, and the mean coefficient of reliability (phi) for the twenty-four radiographic variables that had been analyzed was 0.80. The worst reliability was for Schmorl's nodes between the second and third lumbar vertebrae (phi = 0.49), while absolute reliability was recorded for Schmorl's nodes between the fourth and fifth lumbar vertebrae and at the lumbosacral level, vacuum signs, claw spurs, and traction spurs (phi = 1.000).

Statistical Analyses

The relationship between categorical variables was examined using the chi-square test for independence. Spear-

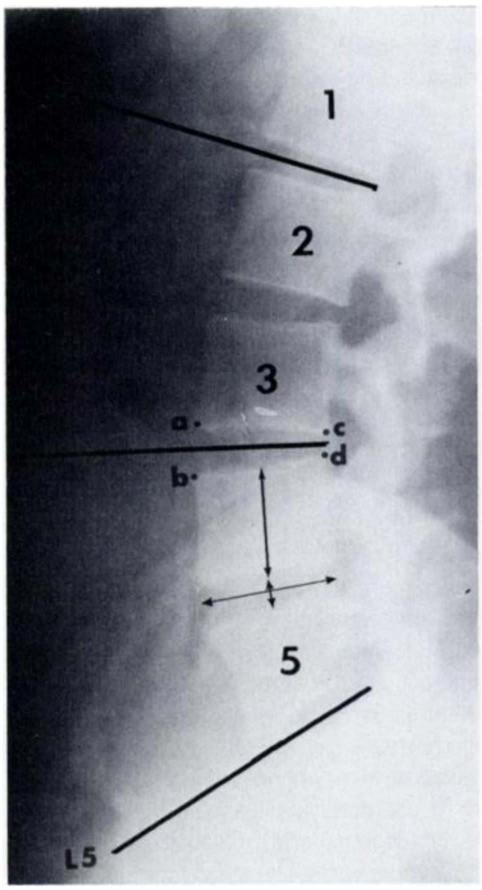

FIG. 1

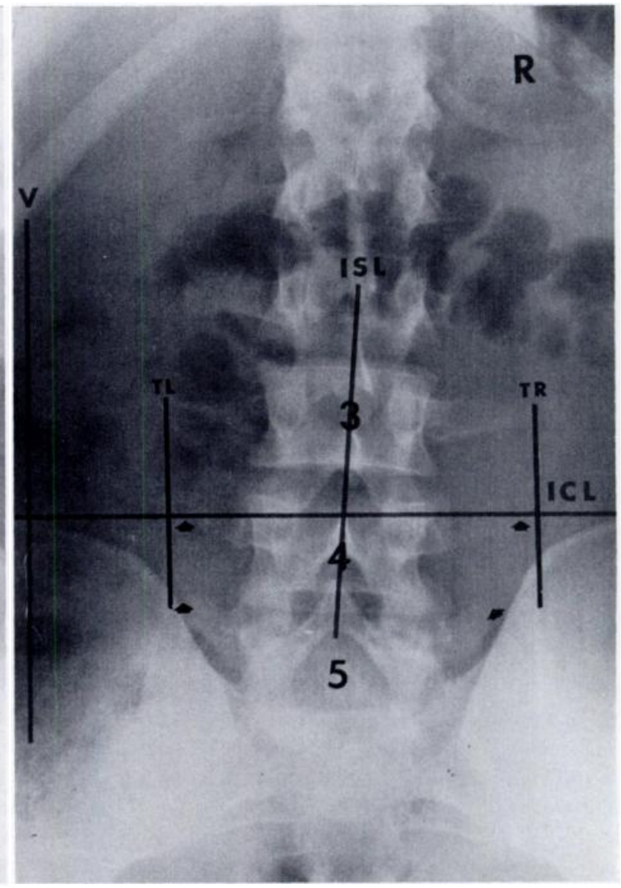

FIG. 2

Fig. 1: Lateral radiograph showing the measurements made in this study. Lines bisect the discs between the first and second lumbar, third and fourth lumbar, and fifth lumbar and first sacral vertebrae. The angles formed by the intersection of these lines are the basis for the measurements of lordosis. The angle between the first and third lumbar levels represents the upper lumbar lordosis; that between the third and fifth lumbar levels, the lower lumbar lordosis; and that between the first and fifth lumbar levels, the total lumbar lordosis.

Measurements of disc-space height are demonstrated at the interspace of the fourth and fifth lumbar vertebrae. Three lines are constructed. A vertical line is drawn at the mid-point of the vertebral body, extending from the projected ovoid of the end-plate above to that below. This disc-space height is normalized to one of two lines. The R1 method divides the disc-space height by the width of the intervertebral disc to the back of the disc, while the R2 method normalizes it to the height of the vertebral body above it[21]. The error of this measurement, dependent on rotation for scoliosis, is ± 1.6 millimeters.

Disc-space wedging is shown on this figure between the fourth and fifth lumbar vertebrae. The anterior height of the disc is measured from point a to point b and the posterior height, from point c to point d, which represent the two corners of the adjacent vertebral bodies. When spurs are present, this line is estimated by drawing a construction parallel to the posterior and anterior aspects of the vertebral bodies above and below the disc. Wedging is expressed as the ratio of height ab to height cd. In the example shown, there is posterior intervertebral disc-space wedging.

Fig. 2: Measurements made on the anteroposterior radiographs. The intercristal line (ICL) connects the two posterior superior iliac crests, and in this patient it interacts with the superior portion of the fourth lumbar vertebral body. We classified five individual subgroups of interaction of the intercristal line: with the upper part of the fourth lumbar vertebral body, with the lower part of the fourth lumbar vertebral body, with the disc between the fourth and fifth lumbar vertebrae, with the upper part of the fifth lumbar vertebral body, and with the lower part of the fifth lumbar vertebral body. In the first configuration, the interaction of the intercristal line with the upper part of the fourth lumbar vertebral body, the disc between the fourth and fifth lumbar vertebrae and the fifth lumbar vertebra as one disc is fully protected from torsional mechanical forces by its relationship with the pelvis, whereas when the intercristal line intersects the lower part of the fifth lumbar vertebral body, neither the disc between the fourth and fifth lumbar vertebrae nor that between the fifth lumbar and first sacral vertebrae is well protected.

Lines TL and TR are constructed from the tips of the left and right third lumbar transverse processes. The interactions of these lines with the fourth and fifth lumbar transverse processes are calculated (arrows). In this subject both the fourth and fifth lumbar transverse processes lie within lines TL and TR. Line V is a representation of a vertical plumb line that is perpendicular to the floor. The interspinous line connects the fifth, fourth, third, and second lumbar spinous processes. Deviation of line ISL from line V of more than 5 degrees is considered a lateral deviation.

man's rank or the correlation coefficient was used to measure the relationships between the ordered variables (severity of low-back pain and related symptoms in the lower limbs) and the radiographic findings. We compared the specific subgroups of low-back pain using analysis-of-variance techniques, with additional tests for multiple comparisons.

FIG. 3

Traction spurs are shown most prominently at the anteroinferior portion of the fourth lumbar vertebral body as well as at the superior portion of the fifth lumbar vertebral body. As defined by Macnab, a traction spur points either directly anteriorly or away from the disc space and is separated from the adjacent osseous end-plate by three to five millimeters. In this particular subject a traction spur is shown at the superior portion of the fourth lumbar vertebral body, a posterior osteophyte is shown on the inferior portion of the fourth lumbar vertebral body, and there are small interior spurs anteriorly at the lumbosacral level.

The association of levels of low-back pain and symptoms in the lower limbs with the radiographic variables was examined using one-way analysis-of-variance techniques. The relationship of several other measurements with radiographic variables was examined using multiple regression. This statistical technique made it possible to estimate the effect of each potential radiographic finding on the severity of pain while controlling for other relevant variables (such as age). Analyses were conducted on a DEC 2060 computer using Statistical Packages for the Social Sciences (SPSS)[20] and Biomedical Computer Programs (BMDP)[3].

Results

Three hundred and twenty-one subjects had a complete radiographic study, but only 292 (90 per cent) were suitable for inclusion in this study. Twenty-nine subjects (9 per cent) with radiographs were not included: for eleven the radiographs were insufficient to permit accurate measurements; eleven had undergone prior lumbar surgery, which is known to be associated with predictable changes in disc-space height and often with the formation of osteophytes[7]; and for seven subjects important values were missing from either the radiographic analyses or the questionnaires. Of the 292 subjects with suitable radiographs, ninety-six (32.9 per cent) had had no low-back pain, 134 (45.9 per cent) had had or were having mild pain, and sixty-two (21.2 per cent) had had or were having severe pain. This distribution conformed to that of the original 1221 questionnaire respondents[8], as had been planned in the randomization procedure. The mean age was thirty-two years for the subjects with no pain, 32.6 years for those with moderate pain, and 33.2 years for those with severe pain. The age range for all groups was eighteen to fifty-five years. Three associated symptoms (pain, numbness, and weakness) in the lower limbs were studied. Two hundred and five (70.2 per cent) of the subjects were not having and never had had any of the symptoms, thirty-five (11.9 per cent) had had or were having one of the symptoms, twenty-one (7.5 per cent) had had or were having two of the symptoms, and thirty-one (9.2 per cent) had had or were having all of the symptoms.

Analyses of the Lateral Radiographs

Schmorl's nodes: Schmorl's nodes were present between the first and second lumbar vertebrae in ten subjects (3.4 per cent), between the second and third lumbar vertebrae in eight (2.7 per cent), between the third and fourth lumbar vertebrae in four (1.4 per cent), between the fourth and fifth lumbar vertebrae in one (0.3 per cent), and at the lumbosacral level in none. These figures confirm the observation of Farfan et al.[6] that Schmorl's nodes are more prevalent in the upper segments. The presence of Schmorl's nodes was not related to low-back pain or to complaints concerning the lower extremities.

Lumbar lordosis: The measured lordotic angle[5] between the first and fifth lumbar levels was similar for all three groups, being 53.96 degrees ($\pm$ 11.92 degrees) for the subjects with no pain, 52.80 degrees ($\pm$ 8.75 degrees) for those with moderate pain, and 52.40 degrees ($\pm$ 10.11 degrees) for those with severe pain.

Spinal osteophytes: Table I shows the percentage of subjects who had claw or traction spurs at each of three lower-lumbar levels, in each pain subcategory (none, moderate, and severe), and according to whether they had zero, one, two, or three symptoms in the lower limbs. There was a relationship between the presence of claw spurs between the third and fourth lumbar vertebrae and severe low-back pain as well as between claw spurs at that level and the presence of three symptoms in the lower limbs. This cor-

TABLE I

ASSOCIATION OF SEVERITY OF LOW-BACK PAIN AND NUMBER OF SYMPTOMS IN THE LOWER LIMBS WITH THE PRESENCE OF SPINAL OSTEOPHYTES

	Severity of Low-Back Pain (Per cent of Patients)			No. of Symptoms in the Lower Limbs (Per cent of Patients)			
	None (N = 96)	Moderate (N = 134)	Severe (N = 62)	0 (N = 205)	1 (N = 35)	2 (N = 23)	3 (N = 27)
Claw spurs							
L3-L4	5.2	2.2	8.1	3.9	2.9	4.5	11.1
L4-L5	1.0	5.2	3.2	1.9	2.9	13.6	7.4
L5-S1	10.0	0.3	0.0	0.0	0.0	0.0	0.3
Traction spurs							
L3-L4	1.0	3.0	3.2	1.9	8.6	0.0	0.0
L4-L5	2.1	2.2	11.3	1.9	5.7	4.5	18.5
L5-S1	2.1	0.0	1.6	1.0	1.0	0.0	3.7
Claw or traction spurs							
L3-L4	6.3	5.2	11.3	5.8	11.4	4.5	11.1
L4-L5	3.1	7.5	14.5	3.9	8.6	18.2	25.9
L5-S1	0.7	0.3	0.3	0.7	0.0	0.0	0.7
All levels	11.5	11.9	24.2	10.6	20.0	18.2	33.3

relation was not statistically significant, however. Traction spurs were significantly associated with both back and lower-limb symptoms, but only if the spurs were between the fourth and fifth lumbar vertebrae (chi-square test, $p = 0.005$ and $p = 0.0007$). When the data for claw and traction spurs were combined, there was a significant association between spurs at the disc between the fourth and fifth lumbar vertebrae and symptoms in both the back and the lower limbs (chi-square test, $p = 0.02$ and $p = 0.0001$). Similarly, the presence of spurs at all levels was associated with symptoms in the back and lower limbs (chi-square test, $p = 0.05$ and $p = 0.009$).

Disc-space narrowing: We found the radiologist's impression of disc-space narrowing to be more discriminating than the actual measurement of disc-space height, although the two were highly associated (Pearson correlation, $p = 0.005$). Disc-space narrowing was present at any of the three lower lumbar levels in 103 (35.2 per cent) of the subjects. Twelve (4.1 per cent) had narrowing between the third and fourth lumbar vertebrae; sixty-four (22 per cent), between the fourth and fifth lumbar vertebrae; and twenty-seven (9.2 per cent), at the lumbosacral level. Disc-space narrowing between the fourth and fifth lumbar vertebrae only was significantly correlated with the presence of low-back pain and symptoms in the lower limbs. Nineteen (19.8 per cent) of the ninety-six subjects with no pain, twenty-two (16.4 per cent) of the 134 with moderate pain, and twenty-three (37.1 per cent) of the sixty-two subjects with severe pain had narrowing between the fourth and fifth lumbar vertebrae (chi-square test, $p = 0.004$). Forty (19.3 per cent) of the 208 subjects with no symptoms in the lower limbs, five (17.1 per cent) of the thirty-five with one symptom, five (22.7 per cent) of the twenty-two with two symptoms, and thirteen (48.1 per cent) of the twenty-seven subjects with three symptoms in the lower limbs were observed to have disc-space narrowing between the fourth and fifth lumbar vertebrae (chi-square test, $p = 0.005$).

Vacuum sign: The vacuum sign, which is generally regarded as unequivocal evidence of disc degeneration, was seen on the radiographs of seventeen subjects (5.8 per cent): in one each between the third and fourth and the fourth and fifth lumbar vertebrae and in fifteen at the lumbosacral level. This finding was not related to pain in the back or symptoms in the lower limbs.

Disc-space wedging: The presence or absence of disc-space wedging as observed on the lateral radiographs did not discriminate between the three categories of low-back pain, nor was it related to symptoms in the lower limbs.

Analyses of the Anteroposterior Radiographs

Transitional vertebrae: Five subjects (1.6 per cent) had four lumbar vertebrae, twelve subjects (4.1 per cent) had six, and the remaining 275 subjects (94.6 per cent) had five. The number of lumbar segments did not correlate with the presence, absence, or severity of low-back pain or of symptoms in the lower limbs.

Intercristal line: The position of the intercristal line was unrelated to back pain or to symptoms in the lower limbs. Six possible positions of the intercristal line were identified, according to the measurements used by MacGibbon and Farfan, and the distribution of the six positions in our series was similar to that reported by those investigators.

Lengths of the transverse processes: The lengths of the fifth lumbar transverse processes compared with those of the third lumbar transverse processes were not related to complaints in either the back or the lower limbs. In our population, in 33.8 per cent of the subjects both of the fifth lumbar transverse processes were longer than those at the third lumbar level, in 21.2 per cent both of the fifth lumbar processes were shorter than the third lumbar processes, in 34.0 per cent the fifth lumbar transverse processes were equal in length to the third lumbar processes, and in 21.5 per cent the fifth lumbar transverse processes were asymmetrical, with one side being either longer or shorter than the third lumbar transverse processes. These distributions conformed to those observed by MacGibbon and Farfan.

Scoliosis: Scoliosis (lateral deviation of more than 5 degrees) was observed in 114 (39.0 per cent) of the 292 subjects. True structural scoliosis accompanied by vertebral-body wedging and rotational abnormalities was not observed. The scoliosis was not related to low-back pain or to symptoms in the lower limbs.

Miscellaneous findings: Diffuse idiopathic skeletal hyperostosis and sacro-iliitis were not identified on the radiographs of this male population. Spina bifida was observed in forty-five subjects (14.1 per cent), and was unrelated to symptoms in the back or lower limbs.

Further Statistical Analyses

We considered several variables jointly in our statistical analyses: (1) age; (2) disc-space height between the fourth and fifth lumbar vertebrae and at the lumbosacral level; (3) lordotic angles from the first to the third, from the third to the fifth, and from the first to the fifth lumbar vertebra, as illustrated in Figure 1; (4) wedging of the disc between the fourth and fifth lumbar and the fifth lumbar and first sacral vertebrae (Fig. 1); (5) spurs (traction and claw); (6) occupational requirements for lifting[2]; and (7) exposure to vehicular and industrial vibrations[2,8]. Each covariate was analyzed for its interaction with the other covariates.

Occupational Analyses

Two hundred and eighty-five subjects met all of the criteria for inclusion in the occupational and radiographic studies. There was no relationship of any of the radiographic findings to either lifting requirements or vibrational exposure. The presence of any type of spinal osteophytes tended to be correlated to vibrational exposure, but this comparison did not achieve statistical significance (two-sample t test, $p = 0.10$).

Covariate Interaction

The major interactions occurred between the various measurements of disc-space height and wedging. There was a significant interaction (Pearson correlation, $p = 0.001$ to $p = 0.005$) between the R1 and R2 measurements of disc-space height (Fig. 1) and the radiologist's interpretation at each of the three lower disc-space levels (Pearson correlation, $p = 0.005$). There were significant positive interactions between the heights of the disc spaces between the fourth and fifth lumbar and the fifth lumbar and first sacral vertebrae; that is, if there was narrowing at one level there was an increased probability of narrowing at the other (Pearson correlation, $p = 0.005$). Measured narrowing of the disc space was also significantly related (Pearson correlation, $p = 0.005$) to wedging of the disc space; that is, diminished disc-space height at either level was related to increased wedging at the same level.

There was also interaction of the covariates of disc-space height, wedging, and lumbar lordotic angles. An increased lower-lumbar lordotic angle (that is, between the third and fifth lumbar vertebrae) correlated with greater wedging (Pearson correlation, $p = 0.005$), and with a greater probability of diminished disc-space height (Pearson correlation, $p = 0.005$) between the fourth and fifth lumbar vertebrae. This relationship was not present at the lumbosacral level, however, although at this level disc-space height and wedging correlated with the upper lordotic angle: as the upper lordotic angle increased, wedging decreased (Pearson correlation, $p = 0.005$) and disc-space height increased (Pearson correlation, $p = 0.005$).

Interactions of the Radiographic Variables with Age

Increasing age was associated with two radiographic variables. The first was an increasing probability of either traction or claw spurs between both the fourth and fifth lumbar vertebrae and the fifth lumbar and first sacral vertebrae: 2.4 per cent of the subjects between eighteen and thirty-four years old, 9.5 per cent between twenty-five and thirty-four, 33.7 per cent between thirty-five and forty-four, and 54.8 per cent between forty-five and fifty-five had either traction or claw spurs at one of the three lower-lumbar levels. The second variable associated with increasing age was a decreasing lower-lumbar lordotic angle and increasing upper-lumbar lordotic angle (Pearson correlation, $p = 0.05$). Increasing age was not correlated with disc-space height, measured or merely observed by the radiologist, or with any of the remaining measurements or observations.

Discussion

Our studies have demonstrated that findings from standing anteroposterior and lateral radiographs are not associated with the presence, absence, or severity of current or previous low-back pain or with the presence, absence, or number of associated symptoms in the lower limbs. The findings in question — transitional vertebrae, the positions of the fourth and fifth lumbar and lumbosacral vertebral bodies relative to the iliac crest, Schmorl's nodes, disc-space wedging, lumbar lordosis, and non-structural scoliosis — were equally distributed, independent of back or lower-limb symptoms. These observations in men between the ages of eighteen and fifty-five years are compatible with the prior observations of others[9], as is the prevalence of the so-called abnormal radiographic findings[1] observed in our population. Disc-space narrowing between the fourth and fifth lumbar vertebrae and traction spurs were the most common findings associated with symptoms in both the back and the lower limbs in our population. However, our attempt to quantitate disc-space narrowing precisely proved to be a less valuable procedure than a trained radiologist's visual assessment. This observation is compatible with that of Schultz and Andersson. Torgerson and Dotter identified a marginally significant association between low-back pain and disc-space narrowing between the fourth and fifth lumbar vertebrae as assessed by pyelography, but we may have found a more significant association between disc-space height at that level and low-back pain because we made radiographs in the standing position so they were specifically designed for measurement of disc-space height[22].

Traction spurs, particularly between the fourth and fifth lumbar vertebrae, were associated with both low-back and lower-limb symptoms at a level of statistical significance, whereas there was no association with claw spurs at this level in the spine. Spurs at multiple levels were also associated with both back and lower-limb symptoms. Macnab identified the traction spur as one radiographic sign of segmental instability, whereas the claw spur has been viewed as a benign physiological response to external stress[19]. Because our studies did not include flexion-extension radiographs, there was no way to determine if the traction spurs were associated with instability. It should be emphasized that only 10.8 per cent of our population had traction spurs, and many of these subjects had not experienced low-back pain. Thus, the observation of this anomaly on pre-employment radiographs, or in other prospective epidemiological studies, is of marginal significance.

We also studied the interaction of various radiographic findings with each other, as well as the relationship of these radiographic findings to external occupational and vehicular stresses. In our group of men between the ages of eighteen and fifty-five, occupations requiring heavy labor were not related to any specific radiographic finding, although there was a marginal association of heavier labor with claw spurs. Hult, Horal, Lawrence, and Kellgren and Lawrence have shown that spinal osteophytes become more numerous as a function of age and heavy labor, but they did not differentiate claw spurs from traction spurs. Also, their populations included much larger numbers of workers engaged in heavy labor than did our study group. Similarly, stenosis in the spinal canal, as measured by ultrasonic scanning, has been identified more commonly in people working at heavy labor than in those working at light labor[23]. We did, however, confirm previous observations that spinal osteophytes increase as a function of age[10-12,14].

One question that should be asked is to what degree our population of men between the ages of eighteen and fifty-five is representative of other populations. In a previous publication[8] we characterized this population as a mixture of suburban "white-collar" commuters and workers engaged in heavier labor, many of whom were farmers. Clearly, no single population can be representative of all segments of society. For example, the heavier labor engaged in by the population identified by Kellgren and Lawrence may account for some of their observations relating to spinal osteophytes. Similarly, our exclusion of men older than fifty-five could have biased our findings. However, the proportion of our population that had had surgery was not significantly different from that reported by others.

We were unable to identify any specific changes on the spine radiographs that were associated with "excessive" exposure to vehicular and occupational vibrations. Because of the association of both low-back pain and herniated nucleus pulposus with vehicular and vibrational stresses[8,14], we first postulated that increased disc-space narrowing and possibly osteophytes might be observed as a function of these exposures, but we were unable to support that postulate with either radiographs or clinical evidence.

One other important observation that we made is that some abnormal radiographic findings, although generally independent of symptoms in the back and lower limbs, do tend to cluster in certain patterns and may be presumed to represent degenerative joint disease in the spine. For example, increased lordosis between the third and fifth lumbar levels was associated with greater disc-space narrowing and greater wedging between the fourth and fifth lumbar vertebrae. This relationship is compatible with the mechanical concept that increased shear forces are related to accelerated degeneration in these joints. The absence of a similar finding at the lumbosacral level and the fact that narrowing at the lumbosacral level was associated with a decrease in lordosis between the third and fifth lumbar levels and an increase in the lordotic angle between the first and third lumbar levels are difficult to explain unless one presumes a protective role for the transverse processes and sacral transverse ligament. This latter concept was presented by MacGibbon and Farfan, who noted that these structures constitute a protective mechanism against axial torsion.

Perhaps the most important aspect of our data is that they emphasize how little use there is in plain radiography of the spine for determining causes of low-back pain in men between the ages of eighteen and fifty-five. Since that age group constitutes the major segment of the United States work force, this observation is of considerable relevance. Nachemson's studies of lumbar degeneration, previous surveys of selected industrial populations[9], and recent clinical studies[25] have also emphasized this point. Part of the problem of showing the precise value of radiographs relates to the intra-observer and inter-observer variations in the interpretation of radiographic findings, even when the observer is a radiologist who has specialized in the field. Inter-observer error has been demonstrated to be quite high when more than one observer interprets the radiographs[13,15], and our attempts to use objective and quantitative methods for assessing radiographs of the spine did not prove to be of value either for clinical interpretation or for our epidemiological survey. Therefore, we anticipate little value in plain radiography of the spine in prospective studies of low-back pain. Similarly, the usefulness of spine radiographs in predicting who is at risk for low-back pain in the industrial setting appears to be minimum. Whether other radiographic techniques (particularly motion radiography) might be of greater value cannot be determined from these studies.

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