RHEUMATISM IN COAL MINERS

PART III : OCCUPATIONAL FACTORS

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(RECEIVED FOR PUBLICATION MAY 12, 1954)

In previous reports rheumatic complaints in miners and non-mining members of the same population have been compared. Miners lost more working time from rheumatic complaints and had more frequent and severe changes both of degeneration of the intervertebral discs and of osteo-arthritis of the knees and other joints (Lawrence and Aitken-Swan, 1952 ; Kellgren and Lawrence, 1952).

SCOPE OF THE PRESENT STUDY

In the present study an attempt has been made to discover the factors in mining which are responsible for the observed increase of disc degeneration and osteo-arthritis by investigating the relative effect of work at the coal-face and in the roadways, the effect of damp, of posture, and of heavy lifting.

Other factors which have been investigated include injury, distance walked, height of the miner, stem height, body weight, and evidence of healed rickets.

Method of Selection of Main Groups

Roadway Workers.—In Part II a random sample of underground workers between the ages of 41 and 50 employed at the Bedford Colliery in Leigh was compared with a similar sample of non-miners. As most underground workers are at the coal-face this meant that only a few of our random sample were employed on the roadways or at the pit bottom. To give a useful comparison between face and roadway workers, therefore, all remaining roadway workers within the 41 to 50 age-group at the Bedford Colliery were examined. This gave similar numbers of face and roadway workers and thus enabled a broad comparison to be made between these two main groups.

Work in Wet Conditions.—As the Bedford Colliery has for the most part been a dry mine and few of the workers had ever worked in damp either there or at the collieries round about, the survey was extended to a mine containing wet workings.

It was necessary to go to the Yorkshire coalfield where, at Firbeck Colliery, water had been present in one of the workings for many years. As this seam was of similar height to those at the Bedford Colliery (3 to 4 ft.), employed the same method of working, and appeared in every other way similar, it seemed unlikely that other factors than climate would enter into any comparisons which might be made. All the workers between the ages of 41 and 50 on this face and on a comparable dry face at the same colliery were examined.

Posture.—Miners have often to adopt awkward postures while working. A stopping posture is particularly common and might well, by throwing an additional strain on the lumbar spine, be responsible for an increased incidence of disc disorders.

During the early stages of this survey pilot studies were made in pits having varying conditions of work situated in the Lancashire area. From these it was possible to study the incidence of rheumatic complaints in men who had worked at different seam heights. It was found that rheumatic complaints reached a maximum in two peaks, one at a seam height of 3 ft. to 3 ft. 5 in. and the other at a height of 4 ft. 6 in. to 4 ft. 11 in. These peaks were not present in the younger workers but became apparent about the fourth and fifth decades and were still present in the whole group after correction for age. Loss of work from rheumatism showed a similar increase at the same two heights.

The radiological studies at the Bedford Colliery gave little information on this point, as nearly all the face workers had been accustomed to roof heights of between 3 and 4 ft., and though in the roadways the roof is higher, comparison of face and roadway workers introduces other variables and cannot be used to determine the effect of posture. A study has therefore been made of men working in seams of 4 ft. 6 in. to 5 ft. 6 in. These were available in

Walkden at both the Sandhole and Mosley Common collieries. All those at the Sandhole Colliery working at this seam height and between the ages of 41 and 50 were therefore examined, and as the numbers proved inadequate a random sample was taken of those working in the same condition at the Mosley Common Colliery. This gave a total group of similar size to that examined at the Bedford and Firbeck collieries. It was equally divided between the Mosley Common and Sandhole collieries.

Heavy Lifting.—To determine the importance of this factor a group of dock workers has been studied. This enabled comparisons to be made between heavy workers in and outside the mines, and, with the groups examined from the Walkden Engineering Yard and the National Coal Board Offices in the first part of the survey, gave a comparison of three grades of "heaviness" of work independent of mining. A random sample of 66 dockers was taken from those between the ages of 41 and 50 who had worked for 11 or more years at the docks. For the most part these were general workers of the type known as stevedores, though a few had limited themselves in earlier years to carrying timber.

Mode of Examination

The routine followed in the examination of each man has already been described in a previous paper (Kellgren and Lawrence, 1952). The radiographs of the cervical spine and hand were, however, omitted from this part of the survey and routine radiographs taken only of the lumbar spine and knees, other parts being radiographed when indicated by the clinical findings. In addition to the changes observed and noted in the first part of the survey the location of the affected intervertebral discs and the most-affected disc were also determined in each case. The radiographs were read by two observers without a knowledge of the individual's occupation or of his symptoms or physical findings. The criteria used for grading radiological changes are those already laid down in the above paper. (The problem of observer error in reading radiographs is discussed in the appendix.)

RESULTS

Although the lumbar spine and knees have been studied in equal detail the spine will have a greater place in the results which follow as the investigation into factors causing knee symptoms proved less informative.

Spine

The cervical spine has been dealt with in a previous report (Kellgren and Lawrence, 1952) and, as no further information is available from the present study, it will not be considered here.

The dorsal discs may be dismissed briefly as radiographs were not taken with the specific purpose of showing them and information is therefore only available on those discs which were visible in the lumbar radiographs, usually the eighth to the eleventh (the twelfth dorsal disc was included with the lumbar discs). Only three (7%) of the office workers showed radiological changes in these lower dorsal discs, and eight (18%) of the light manual workers. By contrast, changes were found in 26% of the Bedford face workers, 40% of the Bedford roadway workers, 46% of the Mosley Common and Sandhole workers, and 50% of the Firbeck men and dockers. The changes were generally classified as slight; only in some 10% were they considered severe. Nor did the number of discs affected vary markedly from group to group, but 8% of the Mosley Common and Sandhole workers and 6% of the roadway workers showed changes in three or more discs.

It may be concluded that the lower dorsal discs are more affected in those engaged in mining and other heavy work. In this respect they behave in the same way as the lumbar discs as will be shown subsequently.

Possible causative factors of lumbar disc degeneration may be divided into two main groups: (1) occupational, *e.g.*, type of work, climate, and position at work, and (2) personal, *i.e.*, body build and previous injury or disease. The occupational factors may be considered either from the qualitative or quantitative aspect, *e.g.*, the heaviness of the work and the number of years during which heavy work has been practised, the degree of stooping, and the number of years worked in a stooping position. The qualitative side is best exemplified by a comparison of the main occupational groups and these will first be considered.

Symptoms, Incapacity, and Radiological Changes According to Occupation.

—There are four main occupational groups in this survey: miners, dockers, light manual, and office workers (Table 1 and Fig. 1). The miners are subdivided into roadway and face workers and the latter into three subgroups, the Bedford face workers (low roof and dry workings), the Firbeck face workers (low roof and wet conditions), and the Sandhole and Mosley Common face workers (high roof and dry conditions). There are thus seven groups in all.

The Bedford face workers have more radiological changes assessed as severe, 16% against 10%, than the Bedford roadway workers; but the difference is small and not significant ($P > 0.2$), and the total with radiological change is almost identical (95% and 96%); nor are there significant differences

between face and roadway workers in any other respect.

This is in marked contrast to the light manual or office workers, particularly the latter in whom severe disc changes were not seen. Some roadway workers had perhaps served at the face in the past and been transferred to the roadways because of disability caused by a spinal disorder. It is, in fact, known from our records that of the 50 roadway workers at least 33 had served at the face at some time, and 15 had more experience of face than of roadway work. It is thus difficult to exclude coal-face conditions as a factor even in the disc disorders of roadway workers. It is clear, however, that severe spinal changes are common to all miners.

The dockers, although they complain as frequently of low back sciatic pain, lose work to roughly the same extent and have radiological changes as often, do not show the same grade of severity in the radiological change as the miners and fewer discs are involved, both these differences being significant. Thus, whereas 12% of miners show the highest grade of radiological change only 2% of dockers fall into this category; 36% of miners show involvement of four or more discs, but only 18% of dockers are affected to this extent. The dockers on the other hand are considerably worse off than the light manual workers,

FIG. 1.—Spinal pain and radiological changes in main occupational groups. In the diagrams the doubtful and minimal radiological changes are grouped together as slight and the moderate and severe as severe.

TABLE 1
SPINAL PAIN, INCAPACITY, AND RADIOLOGICAL * CHANGES IN PRIMARY GROUPS OF WORKERS

	Miners				Non-miners		
	Face Workers			Roadways	Heavy Manual	Light Manual	Sedentary
	Firbeck	Mosley Common and Sandhole	Bedford	Bedford	Dockers	Walkden Yard	N.C.B. Offices
Total men	46	61	64	50	54	45	42
Back-hip-sciatic pain	30 (65%)	31 (50%)	29 (45%)	19 (38%)	22 (41%)	13 (29%)	18 (43%)
Off work 1 week or more ..	13 (28%)	13 (21%)	9 (14%)	8 (16%)	8 (15%)	4 (9%)	6 (14%)
Off work 3 months or more ..	7 (15%)	5 (8%)	2 (3%)	3 (6%)	2 (4%)	0 (0%)	1 (2%)
Radiological changes :							
None	1 (2%)	4 (7%)	3 (5%)	2 (4%)	3 (6%)	18 (40%)	28 (67%)
Doubtful	0	7	7	6	11	4	4
Minimal	19 (41%)	26 (43%)	24 (38%)	24 (48%)	23 (43%)	10 (22%)	8 (19%)
Moderate	20 (43%)	19 (31%)	20 (31%)	13 (26%)	16 (30%)	12 (27%)	2 (5%)
Severe	6 (13%)	5 (8%)	10 (16%)	5 (10%)	1 (2%)	1 (2%)	0
No. of lumbar discs affected † :							
1-3	28 (61%)	34 (56%)	39 (61%)	34 (68%)	41 (76%)	25 (56%)	12 (29%)
Over 3	17 (37%)	23 (38%)	22 (34%)	14 (28%)	10 (18%)	2 (4%)	2 (5%)

* The radiological findings in all Tables included in this report are the mean readings of two observers and are not, therefore, identical with those given in the earlier report where the radiological readings of the senior observer were used.

† In this Table, and those which follow, the disc between D.12 and L.1 vertebrae has been included as one of the lumbar discs.

having greater disability and more frequent radiological changes. However, when radiological changes are present in the light manual workers they are just as severe as in the dockers, the difference being rather in the numbers with doubtful or minimal changes.

There are definite differences between the face workers at Bedford and Firbeck. Fewer men at Firbeck are symptom-free and loss of work is twice as frequent. Moreover, prolonged disability is five times as common in the Firbeck men. Radiological changes are absent or doubtful in only one (2%) of the Firbeck workers but in 10 (16%) of the Bedford men, a significant difference ($P < 0.05$). The radiological changes are for the most part of moderate severity but it was found that they affected on an average three discs as against two in the Bedford workers. It may be concluded that the Firbeck men have more frequent involvement of discs and that these are more often of moderate severity and less often minimal. Men from the wet and dry seams at Firbeck have not been analysed separately in Table 1 as it was found that the differences in pain and disability were not striking and that in fact there had been much interchange of workers between the seams so that almost all had worked in wet conditions at some time.

The group of men from the Mosley Common and Sandhole collieries were working in dry conditions at a roof height of 4 ft. 6 in. to 5 ft. 6 in. They were thus in a similar climate to the Bedford workers but

had to adopt a stooping position and did not kneel. They complained rather more than the Bedford workers of back-hip-sciatic pain, had 50% more incapacity, and nearly three times as much prolonged disability. The radiological changes, however, were no greater and the number of discs affected was also very similar.

To elucidate this further, all face workers who had not worked in wet conditions were divided up according to the predominant roof height at which they had worked (Fig. 2), *i.e.*, the height of roof at which the miner had worked for the greatest time and not necessarily the height at which he was working at the time of the survey. This confirmed previous findings as to symptoms and loss of work. Radiological changes were also most frequent in those working at a roof height up to 3 ft. 5 in. and least common in those working at 4 ft. to 4 ft. 5 in. The most severe changes, however, were found in both these groups. There were no consistent differences in the number of discs affected at different seam heights. The radiological differences were below accepted levels of significance and gave no clear evidence that there is a pathological basis for the increased disability at these roof heights though they certainly do not exclude such a basis.

The distribution of affected discs in the main occupational groups has been considered from two points of view: (1) the worst affected disc and (2) the number of instances in which each disc is affected.

TABLE 2
AFFECTED LUMBAR DISCS IN MINERS, DOCKERS, LIGHT MANUAL, AND OFFICE WORKERS *

	Bedford Miners		Firbeck	Mosley Common and Sandhole	Dockers	Light Manual	Office
	Face	Roadway					
Total men	64	50	46	61	54	45	42
Total men with abnormal discs ..	61	48	45	57	51	27	14
Worst affected disc:							
D.12	4	3	1	6	7	3	—
L.1	5	5	3	5	4	3	—
L.2	8	13	11	6	13	6	1
L.3	21	18	16	25	21	7	6
L.4	13	5	12	8	3	5	5
L.5	10	4	2	7	3	3	1
Not known	0	0	1	0	0	0	1
All affected discs:							
D.12	19	15	14	16	15	6	0
L.1	23	18	23	24	17	9	3
L.2	34	33	36	32	35	13	7
L.3	54	43	43	46	39	17	10
L.4	43	28	31	39	27	10	7
L.5	19	10	7	14	7	4	2
L.6	0	0	0	0	0	0	0
Not known	1	0	1	0	0	0	1
Total discs	192	147	154	171	140	59	29

* The results in this Table are taken from the readings of a single observer.

FIG. 2.—The relation of spinal pain and radiological changes to heavy lifting, work in wet, injury, and roof height.

In each of the main occupational groups (Table 2) the third lumbar disc is not only the one most frequently affected but it is most often the worst affected, and there is a fairly even distribution about this level. The distribution does, however, show less scatter in the Mosley Common and Sandhole workers in whom there is a sharper peak for the worst affected disc at L.3 as though in the position in which these men worked the brunt of the strain fell more heavily on this disc. The differences in distribution, however, are no greater than might be due to chance and with the numbers studied are only suggestive. A similar peak distribution is found also in the office workers, whose posture at work may well be comparable. The majority of them show either the third or fourth lumbar disc most affected, and none shows the greatest changes in D.12 or L.1, whereas in 22% of the light manual workers these discs are the worst affected, a significant difference ($P=0.01$). When, instead of the

worst, all affected discs are considered the conclusions are similar, for example, D.12 being quite unaffected in the office workers. Face workers tend to have the lower discs (L.4 and L.5) more affected than the roadway workers, dockers, or light manual workers, and in this respect they resemble the office workers, but this is not a significant difference and it cannot be said that the distribution of affected discs gives any indication as to causative factors in these groups.

Time Study of Occupational Factors.—The occupational factors which have been studied from this point of view are heavy lifting, work in wet, at the coal-face, and in a stooping position. Although in such studies age is commonly a factor, in this instance it can be ruled out. All the men were in the fifth decade and within this decade no age differences in relation to radiological changes were found to exist.

TABLE 3

RELATIONSHIP OF HEAVY LIFTING* TO SPINAL PAIN, INCAPACITY, AND RADIOLOGICAL CHANGES IN MINERS AND DOCKERS

Duration of Lifting in Years	- 25	- 30	30+
Total Men	45	64	56
Back-hip-sciatic pain ..	19 (42%)	25 (39%)	32 (57%)
Back-hip-sciatic pain, off work 1 week or more ..	3 (7%)	12 (19%)	16 (29%)
Back-hip-sciatic pain, off work 3 mths or more ..	1 (2%)	2 (3%)	9 (20%)
Radiological changes :			
None	2 (4%)	3 (5%)	1 (2%)
Doubtful	8 (18%)	8 (12%)	4 (7%)
Minimal	22 (67%)	27 (55%)	21 (44%)
Moderate	11 (24%)	21 (41%)	24 (44%)
Severe	2 (5%)	5 (11%)	6 (11%)
No. of lumbar discs affected :			
1	4 (9%)	4 (6%)	4 (7%)
2	16 (36%)	15 (23%)	12 (21%)
3	11 (24%)	21 (33%)	16 (29%)
4	8 (18%)	18 (28%)	14 (25%)
5	3 (7%)	3 (5%)	7 (13%)
6+	1 (2%)	0	2 (4%)

* Information on heavy lifting was not obtained until the second half of the survey.

Heavy Lifting.—The relationship of heavy lifting to spinal pain, incapacity, and radiological changes is shown in Fig. 2 and Table 3. Only the duration of heavy lifting is considered. The actual weight lifted, the degree of strain on the structures of the back, and the continuity of such strain have not been investigated except in so far as they vary in the main occupational groups studied.

An increase of symptoms is found only in those who have carried out heavy lifting for more than 30 years, but is not significant ($P > 0.1$). Incapacity for work, however, becomes progressively greater as the duration of heavy lifting increases, and in those who have lifted for more than 30 years it is four times as great as in those who have lifted for less than 25 years. Prolonged disability (three months or more) from spinal pain also increases, being recorded in only 2% of those who have lifted for less than 25 years but in 20% of those who have been engaged in such work for more than 30 years.

The proportion showing no radiological change is small in all groups, but there are progressively fewer minimal and more numerous severe changes with increasing experience of heavy lifting, the difference between the first and last groups being significant for the most severe changes ($P < 0.02$). The number of affected discs also shows a progressive increase as the duration of heavy lifting rises. These findings are not due to an admixture of dissimilar groups. A separation of miners from dockers showed that the relationship of heavy lifting to radiological changes occurred in both groups though more marked in miners.

TABLE 4

RELATIONSHIP OF DURATION OF WORK IN WET CONDITIONS TO SPINAL PAIN, INCAPACITY, PHYSICAL SIGNS, AND RADIOLOGICAL CHANGES IN FACE WORKERS

	No Work in Wet	Work in Wet - 5 Years	Work in Wet 5 Years +
Total Men	45	82	31
Back-hip-sciatic pain ..	14 (31%)	46 (56%)	19 (61%)
Back-hip-sciatic pain, off work 1 week or more ..	5 (11%)	18 (22%)	11 (36%)
Back-hip-sciatic pain, off work 3 mths or more ..	4 (9%)	6 (7%)	4 (13%)
Physical signs : Lumbar spine, limitation ..	14 (31%)	39 (48%)	19 (61%)
Radiological changes :			
None	5 (11%)	3 (4%)	0 (0%)
Doubtful	8 (18%)	3 (4%)	2 (6%)
Minimal	15 (33%)	33 (40%)	12 (39%)
Moderate	11 (24%)	33 (40%)	13 (42%)
Severe	16 (36%)	10 (12%)	4 (13%)
No. of lumbar discs affected :			
1	6 (13%)	6 (7%)	1 (3%)
2	14 (31%)	14 (17%)	11 (36%)
3	4 (9%)	29 (35%)	8 (26%)
4	9 (20%)	17 (21%)	7 (23%)
5	5 (11%)	10 (12%)	4 (13%)
6+	2 (4%)	3 (4%)	0

Work in Wet.—In Table 4 and Fig. 2 the relationship of work in wet to symptoms, signs, and radiological changes is analysed. Only face workers have been used for this analysis as it is desired to eliminate other variables as far as possible. These workers have been divided, regardless of the colliery in which they worked, into those who have not been in wet and those working for varying periods in wet conditions. The information is derived from the man's statement and is thus dependent on memory. An element of bias cannot, therefore, be entirely excluded, but in view of the negative correlation with knee pain, which will be referred to later, it would seem improbable that such a bias has played an important part.

The relationship of work in wet to symptoms is quite striking. There is an increasing incidence of back-hip-sciatic pain so that those working for more than five years in wet have twice as high an incidence as those who have always worked in dry conditions. This difference is significant ($P < 0.05$). Similarly, loss of working time from back-hip-sciatic pain shows a step-by-step relationship with work in wet, and is three times as frequent in those who have worked for more than five years in wet conditions. Prolonged disability, however, shows no clear relationship but physical signs in the spine are related in the same way as symptoms.

The incidence of radiological changes in the spine shows a similar progressive relationship to work in wet, and, indeed, none of those who have worked for more than five years in wet has a normal spine compared with 11% of those who have not worked

in wet. Doubtful changes similarly are more frequent in the dry workers whereas the wet workers have more minimal and moderate changes. This is offset, however, by the most severe changes which are most frequent in the dry workers ($0.1 > P > 0.05$). A study of the number of affected discs shows no significant relationship to work in wet conditions.

It may be concluded that work in wet is associated with a disproportionate increase of pain and disability, and that radiological changes in such workers, though they may be more frequent, are unlikely to be severe.

Duration of Work at Face in Miners.—In view of the similar incidence of both spinal pain and radiological changes already noted between face and roadway workers, it is not surprising that no constant relationship to the duration of work at the face was found. Back-hip-sciatic pain appeared to be entirely independent of the time worked at the face, and the proportion losing working time also showed no constant relationship. Prolonged disability was four times as common in those who had worked over 30 years at the coal face, and this difference was highly significant ($P < 0.01$). The radiological changes on the other hand showed no definite trend. It was, however, noticeable that those who had had a variety of jobs fared better in this respect than those who had remained all the time either in the roadways or at the face. It should be pointed out that those who remained all the time in the roadways were generally concerned with development work, a task which involves much heavy lifting.

Duration of Stooping.—Pain was most frequently present in men who had worked from 15 to 25 years in a stooping position. Those who had stooped less or more than this, less often complained. Loss of work and prolonged disability were also greater in this group. The physical signs, on the other hand, particularly limitation of straight leg raising, became less with prolonged stooping, but radiological changes became increasingly severe and involvement of multiple discs increasingly more probable. The increase of severity, however, was not marked and was within the limits of chance, but there were significantly more men with five or six discs involved amongst the prolonged stoopers (over 30 years $P = 0.02$).

Prolonged stooping thus appears to have an adverse effect on the intervertebral discs but there is some measure of adaptation with persistence at this type of work. The alternative that those most susceptible to pain go over to work of a different nature and so do not develop such severe changes must, of course, be considered. In either event it

would appear that prolonged stooping is one of the factors in mining which tends to increase the severity and frequency of disc changes.

Personal Factors.—The following personal factors possibly causing lumbar disc degeneration have been studied.

Injury to Back.—In those with a history of injury to the back (Table 5 and Fig. 2), pain in the back-

TABLE 5
RELATIONSHIP OF SPINAL PAIN, INCAPACITY, AND RADIOLOGICAL CHANGES TO A HISTORY OF BACK INJURY IN MINERS AND OTHER MANUAL WORKERS

	Back Injuries	Other Injuries	No Injuries
Total Men 289	75 (26%)	86 (30%)	128 (44%)
Back-hip-sciatic pain ..	48 (64%)	30 (35%)	50 (39%)
Back-hip-sciatic pain, off work 1 week or more ..	24 (32%)	14 (16%)	15 (12%)
Back-hip-sciatic pain, off work 3 mths or more ..	8 (11%)	5 (6%)	5 (4%)
Radiological changes :			
None	1 (1%)	7 (8%)	19 (15%)
Doubtful	7 (9%)	12 (14%)	13 (10%)
Minimal	34 (45%)	36 (42%)	44 (34%)
Moderate	24 (32%)	26 (30%)	42 (33%)
Severe	9 (12%)	5 (6%)	10 (8%)
No. of lumbar discs affected :			
1	8 (11%)	8 (9%)	12 (9%)
2	17 (23%)	27 (31%)	29 (23%)
3	23 (31%)	20 (23%)	38 (30%)
4	16 (21%)	15 (17%)	18 (14%)
5	8 (11%)	9 (10%)	9 (7%)
6+	2 (3%)	0 (0%)	3 (2%)

hip-sciatic distribution is almost twice as common as in those without such a history, and incapacity and prolonged disability are also twice as great. Those who have had an injury to some other part do not show this high incidence of pain and incapacity. Radiological changes are absent in only one man (1%) with a history of back injury but in 8% of those with other injuries and 15% of those without a history of injury. All these differences are significant ($P = 0.05$). The radiological changes are not, however, more severe in those who have suffered a back injury, though multiple disc involvement is more likely. The pattern of disc involvement was similar in those with and without injury, the third lumbar disc being most affected in each group and there was no indication that injury was associated with a different type of disc degeneration.

These figures, of course, cannot be accepted without reserve. It must be considered first whether an injury to the back is more likely to be remembered by a man with pain in the back, particularly if associated with loss of work, and whether such men are more likely to have radiological changes.

To determine these points a sample of 100 men was taken and details of the injuries received were collected from the colliery records, comparison being made with the accidents remembered at the time of interview. It was found that although in some instances injuries were forgotten and in others men stated that they had had injuries which were not found in the records (presumably sustained while working at other collieries), there was very substantial agreement between the remembered and recorded injuries. Nor did those with pain prove to have better memories than those without; quite the reverse was, in fact, found.

Whatever the part played by injury in causing disc degeneration it is clear that injury, at least as defined by the colliery records, is not the only factor. Only 28% of those with definite radiological changes gave a history of back injury.

Other Personal Factors.—The remaining personal characteristics of the miner—height, stem height, and old healed rickets as evidenced by genu varum—have not appeared to play an important part in determining the onset and progress of disc degeneration. The taller men more often complained of back-hip-sciatic pain and had more severe radiological changes and where the increased height was due to a long back they suffered greater incapacity.

FIG. 3.—Knee pain, physical signs, and radiological changes in main occupational groups.

Those with genu varum also had more frequent pain and lost more work but did not show greater radiological change.

Knees

The incidence of knee pain (Table 6 and Fig. 3) differed considerably in the groups studied. It was

TABLE 6

KNEE PAIN, INCAPACITY, PHYSICAL SIGNS, AND RADIOLOGICAL CHANGES IN MINERS, DOCKERS, LIGHT MANUAL, AND OFFICE WORKERS

	Bedford Face	Bedford Roadways	Mosley Common and Sandhole	Firbeck	Dockers	Light Manual	Office
Total men	64	50	61	46	54	45	42
Knee pain	9 (14%)	12 (24%)	2 (3%)	10 (22%)	4 (7%)	6 (13%)	4 (10%)
" " off work one week or more	3 (5%)	3 (6%)	1 (2%)	6 (13%)	1 (2%)	2 (4%)	0 (0%)
" " off work three months or more	0 (0%)	1 (2%)	0 (0%)	3 (7%)	0 (0%)	1 (2%)	0 (0%)
Physical signs	18 (28%)	15 (30%)	14 (23%)	11 (24%)	10 (18%)	8 (18%)	10 (24%)
Radiological changes :							
None	37 (58%)	21 (42%)	40 (66%)	20 (43%)	37 (68%)	34 (76%)	35 (83%)
Doubtful	16 (25%)	11 (22%)	9 (15%)	12 (26%)	11 (20%)	6 (13%)	4 (10%)
Minimal	9 (14%)	13 (26%)	9 (15%)	13 (28%)	5 (9%)	3 (7%)	3 (7%)
Moderate	2 (3%)	5 (10%)	2 (3%)	1 (2%)	1 (2%)	2 (4%)	0 (0%)
Severe	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total with radiological changes	27 (42%)	29 (58%)	21 (34%)	26 (57%)	27 (32%)	11 (24%)	7 (17%)
Total with definite radiological changes	11 (17%)	18 (36%)	12 (20%)	14 (30%)	6 (11%)	5 (11%)	3 (7%)

greatest in the underground roadway workers, the face workers having less but showing great variation in different mines. For example, amongst face workers in the wet Firbeck mine, knee pain was almost as frequent as in the roadway workers at Bedford, but in the high seams at the Mosley Common and Sandhole collieries the incidence was low. The light manual and office workers and the dockers occupied an intermediate position, the dockers complaining least. The proportion losing work was similarly distributed except that the Firbeck miners suffered relatively more incapacity.

The radiological changes showed quite marked variation between the groups, following closely the incidence of symptoms. Thus the roadway workers showed the highest incidence, 36% having definite evidence of osteo-arthritis. Next in frequency came the Firbeck miners and then the other face workers. The difference between the face and roadway workers is just significant ($P=0.05$). The dockers and light manual workers showed less radiological evidence, and of the office staff only 7% had definite changes. Both the face and roadway workers had significantly more radiological change than the office workers, but the dockers and light manual workers did not differ significantly from the office staff.

It may be concluded that there is some factor in mining which is not present in dock or light manual work and which results in an increased incidence of osteo-arthritis of the knees. This has been investigated from several angles—kneeling, walking, injury, exposure to wet, and heavy lifting, also personal factors such as body weight or faulty mechanics due to pre-existing deformity.

Kneeling was not found to be a factor and indeed knee pain and incapacity so arising were more frequent in those who had worked predominantly in the higher seams of over 4 ft. Radiological changes in the knees were unaffected either by the duration of kneeling or the seam height.

Only a few of the men gave a history of injury to the knee, but it was evident that when this did occur it was a potent source of osteo-arthritis. Despite the small number involved the increase of symptoms, loss of work, physical signs, and radiological changes were all significant. This accounted for only a very small proportion of the osteo-arthritis found in the knees. Whether minor injuries which had been forgotten or had not been thought worth reporting could have been responsible for all the osteo-arthritis is uncertain. The injuries to the knee recorded were roughly equally divided between strains and blows.

There was no evidence of any relationship of distance walked at work to knee complaints or

radiological changes, nor did it appear that heavy lifting or the duration of work in wet was an important factor in osteo-arthritis of the knees.

There were virtually no really obese men in this survey, but within the range encountered there was no evidence of any relationship between body weight and pain, loss of work, or physical signs. Radiological changes in the knees, however, showed a close relationship, being progressively more common with increase of body weight. It was, however, chiefly the doubtful and minimal radiological changes which were so influenced.

Those with a definite degree of genu varum (over 2 cm.) complained rather more often of pain in the knee and more often lost time from work, which was usually prolonged. There was also a rather higher incidence of radiological changes in this group but the increase was not significant. Thus, though it cannot be denied that genu varum may increase to some extent a tendency to osteo-arthritis of the knees, it cannot be said that it bears an important causal relationship.

Other Joints

Of the remaining joints the elbow was most frequently affected, the highest incidence being in the workers at Firbeck. The roadway workers at Bedford, however, showed almost as much, but there was a lower incidence at Mosley Common, at Sandhole, and at Bedford coal-face. The dock workers had roughly the same proportion as the Bedford face workers. No osteo-arthritis of the elbow was encountered amongst the light manual and office workers.

The possibility was considered that in miners the use of a pneumatic drill might be responsible, and altogether 177 men were asked about drilling. Of those who had not drilled, 22 (16%) were found to have osteo-arthritis of the elbow, whereas of 39 who had drilled for more than a year 12 (31%) were affected. The numbers, however, are small and the difference is not statistically significant. It is apparent that osteo-arthritis often occurs in those who have done no drilling, and is, moreover, a feature of all heavy work studied.

Osteo-arthritis of the remaining joints was relatively less common.

Other Rheumatic Pains

Disc prolapse was diagnosed in seven men; in six it was situated in the lumbar spine, in one it was cervical. No conclusions as to occupational influence could be drawn.

Only four examples of rheumatoid arthritis were encountered in the survey; two of these were

light manual workers and two miners. This incidence of 1% thus corresponds with our finding of a 1.4% incidence in males of this age group in the Leigh survey of the general population.

Spondylitis and gout were not encountered, as might be expected, in view of their low incidence of approximately one per thousand.

The remaining examples of skeletal pain were of a less defined character and have been labelled "undetermined". The most frequent sites of this pain were in the dorso-pectoral or cervico-brachial distribution, but a large number were lumbar. The commonest single site was the region of the deltoid muscle. Both the dorso-pectoral and deltoid pain were encountered most often in dock workers. The cervico-brachial pain, on the other hand, was more common in the Firbeck miners and the lumbar pain in the Bedford face workers who also complained more of scapular and interscapular pain. Ankle and foot pain was a feature rather of work in the underground roadways, where also there was more complaint of multiple pains. These occupational differences are not large and none differs significantly from the mean value.

DISCUSSION

The main feature of this survey has been the high incidence in coal-miners of degenerative changes in the lower dorsal and lumbar intervertebral discs and the high proportion losing work because of corresponding lumbar and sciatic pain. It is important, therefore, to decide how this is caused and what measures, if any, can be taken to prevent the onset of these changes or of the disabling symptoms with which they are commonly associated. Factors influencing these changes may be divided into those acting on the discs themselves and those which affect symptomatology and, still more important, incapacity. A factor which affects disc change will in general also increase symptoms and incapacity but the reverse need not follow.

Trauma

The importance of trauma in disc degeneration has long been recognized. A compression fracture of the spine is nearly always associated with gross changes in the discs, and disc degeneration often follows injury which is insufficient to damage the bony structures or results only in a small chip fracture of the anterior border of one of the vertebral bodies or slight damage to the vertebral plate (Schmorl and Junghanns, 1951). Injury is unfortunately an outstanding feature of work in the mines, and though in recent years the incidence of

serious or fatal accidents has been reduced, the accident rate is still very much greater in the mines than in factories (Ministry of Fuel and Power, 1953; Ministry of Labour and National Service, 1953). A feature of mining, as of other heavy occupations such as dock work, is, as our figures show, the high proportion of back injuries and the association of those with degenerative changes in the discs. It may be considered whether certain "strains" to the back are symptomatic rather than causative as obviously a man with disc degeneration will be more susceptible to strain than a man with a healthy spine. It was found, however, in this survey that radiological changes were increased almost to the same extent in those giving a history of a blow on the back and in those in whom the injury was described as a strain. It would thus appear improbable that the injury was merely a "symptom" of pre-existing disease, though in many instances pathological changes undoubtedly preceded the injury.

But though radiological changes are more frequent and more severe in those with a history of injury, they are nevertheless quite considerable in those without such a history, and miners in this category still have more radiological change than, for example, manual and office workers. An injury might of course have been forgotten by these men, but when data are obtained quite independently from the colliery records a high incidence of radiological change is still found in the uninjured. Moreover, these records include not only severe injuries qualifying for compensation, but also relatively minor injuries not associated with loss of working time. Admittedly these records cannot be complete, as many minor accidents must remain unreported and others may have been sustained during employment at another colliery. Nevertheless, it would seem unlikely that a definite injury is responsible for all cases of disc degeneration. It may be, of course, that very minor injuries, if repeated on frequent occasions, will operate in a similar manner. This was suggested as long ago as 1928 by Schmorl, and Lindblom (1952) has since shown that even continuous slight pressure may cause disc degeneration with rupture of the annulus fibrosus. Such injuries are implied in the expression "heavy lifting" and in the heaviness of the occupation in general.

Heavy Lifting

This may be measured in a number of ways as, for example, the weight lifted, the height to which it is raised, and the duration and frequency of such incidents of lifting. It may be expressed as the number of years during which a man has engaged in heavy lifting. Only the last can be assessed with

any degree of precision in miners or dockers. Some measure of the former might be obtained either by job analysis or by quantitative electromyographic studies made while carrying out the work, but before this could be done it would be necessary to know what effect each individual task might have on the incidence of disc changes. It has not been possible to make a detailed study of this in miners as the occupations encountered in mining are so many and varied, and the numbers in each relatively small. It has, however, been possible to assess men engaged in the two main occupations, those of collier and ripper, and it was found that the men in each of these groups had more disc degeneration than other miners, the colliers showing more instances of the most severe forms of disc degeneration than the rippers. The work of a collier would thus be suitable for comparison with dockers and other manual workers on the lines indicated above, and inquiries are at present under way with a view to obtaining some measure of the stresses involved. It would seem reasonable to suppose that the order of severity—in miners, dockers, light manual, and office workers—indicated by this radiological study corresponds with the heaviness of the task involved.

This is confirmed to some extent by the incidence of chip fractures of the vertebral bodies and of herniation of disc substance through the intervertebral plates (Schmorl's nodes). One or other of these was encountered in 6% of miners, 4% of dockers, 1% of light manual workers, and in none of the office workers. These changes indicate only a single severe strain. There can be little doubt that repetition, perhaps of relatively minor strains, plays just as important a part. This is indicated in miners and dockers by the relationship of spinal symptoms and signs to the duration of heavy lifting; this is closer than to any of the other possible causative factors.

Position at Work

Much importance has been attached in the past to the position of the back when lifting heavy weights, and data from the earlier survey appeared to indicate that this was a factor in mining as pain and disability were greatest in those working at seam heights which involved most stooping. The radiological changes found in this part of the survey, although they suggest a greater severity at these critical seam heights, are not sufficiently marked to be significant with the small number of men involved, and we are thus unable to provide definite evidence on the point. It is apparent, however, that this is not so important a factor as injury and heavy lifting.

Damp

The effect of wet conditions, though quite definite, is more difficult to explain. From the findings in the previous survey it was clear that miners working in wet more often had symptoms attributable to lumbar disc degeneration, but it was felt that this might be due to a lowering of the pain threshold rather than to increased tissue change. This may well be a factor in view of the disproportionate incidence of symptoms and incapacity in those working in wet. Thus twice as many Firbeck miners lose work from back-hip-sciatic pain and there are also more with milder symptoms not giving rise to incapacity. Such a finding would be expected in view of the known effect of cooling on deep pain (Kellgren, McGowan, and Hughes, 1948), and this would also explain the relatively mild character of the radiological changes in those who have worked in wet, for the heightened pain sensibility would tend to have a protective effect. It does not, however, explain the more frequent radiological changes in miners.

In view of the influence of heavy lifting and injury to the back on disc changes, it must be considered whether these are operative to a greater degree in men working in wet conditions. A higher accident rate in wet workings might account for the increased radiological changes but, in fact, a history of injury to the back was less frequently elicited from the workers at Firbeck than at any other colliery. The possibility must also be considered that men in the wet seam may have had more heavy lifting to do. If this were so it might be expected that the "output per man/shift" would be greater in wet than in dry workings and in fact this was found to be the case at Firbeck. It is not, however, a universal finding in wet mines and may well at Firbeck have been due to other factors. It is known, for example, that roof conditions were more difficult in the dry workings and this would tend to reduce output. However caused, the increased output might of itself be sufficient to explain the more frequent radiological changes in those working at the wet face in this mine.

In the previous survey it was shown that the psychologically stable miners were more likely to show radiological change in the spine, due no doubt to their willingness to accept heavier tasks (Heron and Braithwaite, 1953), and it might be thought that such miners would be more likely also to accept work in a wet seam. This, however, is not supported by our findings. Both our psychometric and clinical assessments indicate that miners working in wet are less stable. This may, of course, be a result rather than a cause of accepting such work.

Air Velocity

It has not been found possible from our material to investigate the effect of air velocity either on incapacity or radiological changes as exposure to high air velocity is encountered only in the more restricted parts of the intake air-way where only a few haulage men, usually young lads not of an age to have disc changes, are employed. As, however, there is no increase of symptoms or radiological changes in the roadway workers as a whole, it would seem unlikely that work in high-velocity air currents is an important cause of disc change. It would be expected, of course, that a face worker might suffer no pain while in the relatively warm atmosphere of the face even though subjected to a degree of strain sufficient to cause appreciable damage to the intervertebral discs or ligaments, but on passing into the cold air the pain threshold would be lowered and the symptoms become apparent. The symptoms would thus be attributed by the victim to the cooling which immediately preceded their onset rather than to the earlier physical stress. Work in a cold current of air would, therefore, be intolerable to a man suffering from disc degeneration and result in loss of work unless a more suitable site could be found for him.

Knees

Apart from injury to the knee we have found no factor in mining which appears causally related to osteo-arthritis of the knee. A history of injury to the knee was obtained in 4% of miners, being greatest amongst roadway workers who also have most radiological change. Overt trauma accounts for only a few examples. As in the spine, the question of repeated minor injuries arises and is supported by the relatively low incidence of arthritis of the knee in the light manual and office workers who gave no history of overt trauma and probably suffered far less minor injury to the knee. The possibility that wet conditions may play a part in the symptomatology is suggested by the high incidence of incapacitating knee symptoms without increased radiological change at Firbeck. The fact that roadway workers in the mines have more osteo-arthritis of the knees than face workers should be interpreted with caution as it is likely that knee pain would be a frequent cause of transfer from the face to roadways.

SUMMARY

Factors responsible for the high incidence of intervertebral disc degeneration in miners have been investigated.

Comparison with dock workers has shown that disc degeneration is also severe in this heavy occupation but less so than in miners.

In both mining and other manual work there was a close relationship between the duration of heavy lifting and disc degeneration. Injuries to the back, whether blows or strains, were similarly related.

Of the miners, those working in wet conditions had more back-hip-sciatic pain and lost more work as a result. They also had more radiological changes of disc degeneration but these were less severe.

In miners there was a relationship between the position at work and spinal symptoms and incapacity. Those who stooped most were more severely affected. There was, however, no definite relationship between radiological changes and position at work, nor was there any very clear relationship between the duration of work in a stooping position and spinal symptoms or radiological changes. Personal factors, such as body height, length of back, and evidence of old rickets, were associated with a greater degree of incapacity but did not influence the severity of the radiological change.

Osteo-arthritis of the knees was found to be most frequent in underground roadway workers, less so in face workers, and still less in dockers and other manual workers. It was related to injury but not to kneeling, height of seam, distance walked, or heavy lifting. Though those working in wet showed more incapacity from knee symptoms, this was not increased by prolonged work in wet and the radiological changes were not affected. Radiological changes in the knees were related to body weight but symptoms and incapacity were unrelated. Deformity of the knees, on the other hand, affected symptoms and incapacity but not radiological changes.

Osteo-arthritis of the elbow, wrist, and hand were more frequent in miners than in other occupational groups.

I wish to thank Professors J. H. Kellgren and R. E. Lane and Dr. R. S. F. Schilling of the Departments of Rheumatism Research and Occupational Health of the University of Manchester for their generous help and guidance in carrying out this survey, also Mr. Nightingale and Dr. Waddell of the National Dock Labour Board and many members, and the staff of the N.C.B. and officials of the trades unions concerned. I am indebted to Miss N. Goodman for assistance in the statistical analysis.

Owing to lack of space it has been possible to include in this paper only a few of the Tables on which the conclusions have been based. The author will, however, be glad to supply further data to any who are interested and would care to write to him.

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APPENDIX

Unless the observer error in reading radiographs can be shown to be less than differences produced by occupational and environmental factors, doubt must inevitably be felt as to the validity of the results.

The radiographs were each read three times, once by each of two observers separately and once together. In the first half of the survey the individual readings preceded the combined reading (by some two years); in the second half they followed by one to two months. For the purpose of this study the radiological changes were divided into three grades: none, slight, and severe. The individual readings made by Observers 1 and 2 were of the same grade as the combined reading in 81% and 75% of instances respectively. Of the remainder some 12% were graded higher and 10% lower. In only 1% were the readings two grades out. As would be expected, agreement was closer in the second half of the survey.

In group results (Table A) the indications are that the maximum error is unlikely to be more than $\pm 11\%$. For the purpose of compiling the Tables in this paper a mean value calculated from the individual and combined readings has been used so avoiding the more marked observer differences. It follows that the radiological findings in this paper do not exactly correspond with those in our previous report based on the readings of one observer. In particular the use of the mean readings

TABLE A
OBSERVER ERROR IN TOTAL READINGS OF SPINAL RADIOGRAPHS

386 Men			Severity			
			None	Slight	Severe	Not Known
Observer 1	..	..	76	176	134	—
Observer 2	..	..	83	152	151	—
Combined	..	..	70	186	129	1

tends to reduce the proportion with no radiological changes as even two negative readings may be offset by a third high reading. The differences caused by this alternative method of expressing results are not however such as to alter the conclusions previously expressed, and the advantages of using the mean value undoubtedly outweigh the disadvantage of such slight discrepancies as may arise.

The radiographs of the knees were similarly read to the same grade as the combined reading in 78 and 79% of cases respectively. In some 9% they were read as more severe and in 13% as less severe. The difference on individual readings is thus very similar in radiographs of spines and knees, but the error involved in reading groups was rather greater, being of the order of $\pm 20\%$ on the decision to classify the change as severe.