BRITISH MEDICAL JOURNAL

LONDON SATURDAY APRIL 28 1951

MASS RADIOGRAPHY FINDINGS IN THE NORTHAMPTONSHIRE BOOT AND SHOE INDUSTRY, 1945-6*

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Recent studies of miniature mass radiography and National Service records (Smith, 1947; Stewart and Hughes, 1949) have revealed the following facts about the boot and shoe industry: (*a*) there is a high incidence of active pulmonary tuberculosis among factory operatives; (*b*) there is more disease in large than in small factories; and (c) the industry tends to recruit men of poor physique. These findings suggest that the high death rate from pulmonary tuberculosis in the industry as a whole (Registrar-General, 1891–1931) is due to selective recruitment, and that the higher rate for factory operatives than for home workers (Registrar-General, 1921–1931) is due to carriers infecting fellow workers.

This hypothesis was put forward in the preliminary report of the present investigation (Stewart and Hughes, 1949). Since then we have re-examined the original mass radiography records and have also collected other data relating to working conditions and to the incidence of pulmonary tuberculosis. A complete report on all this material is not yet available, but two papers, one giving a historical survey of tuberculosis mortality in the printing and shoemaking trades (Cairns and Stewart, 1951) and the other the result of bacteriological sampling of the air in boot and shoe factories (Hirch, 1951), have been accepted for publication since the preliminary report appeared. The purpose of this third paper is to complete the account of the mass radiography survey.

PART I.—COMPARISON OF BOOT AND SHOE WORKERS WITH WORKERS IN OTHER OCCUPATIONS

During its first tour of the county (March 1, 1945, to January 1, 1947) the Northamptonshire mass radiography unit examined 18,660 workers in boot and shoe factories and 23,738 other persons over the age of 14 years (see Table I).

There are minor differences in the data analysed in this and the earlier reports. The first paper (Smith, 1947) refers to all persons examined before June 1, 1946, and the second only to "skilled operatives in boot and shoe factories." In the present paper and in the original report (but not in the interim report) "boot and shoe workers" or "shoemakers" include office and maintenance staff, skilled and unskilled operatives, and all workers in the heel-building and closing factories.

TABLE I.—*Age and Sex Distribution of Workers Examined by Mass Radiography, 1945–6*

Sex	Age Group (in Yrs.)	Occupational Group					
		Boot and Shoe		Other		Total	
		No. Examined	Coverage*	No. Examined	Coverage*	No. Examined	Coverage*
			%		%		%
M	14–34	1,863 (19%)	71	4,954 (35%)	69	24,511	70
M	35+	8,284 (81%)		9,410 (65%)			
F	14–34	4,823 (57%)	69	6,866 (73%)	67	17,887	68
F	35+	3,690 (43%)		2,508 (27%)			
Total	All ages	18,660	70	23,738	69	42,398	69

* The number of persons examined expressed as a percentage of the total number on the pay-roll of each factory.

All three reports are based on the records kept by the medical officer in charge of the survey (Dr. M. C. Brough), who was responsible for reading all the films. In the case of serious lung disease, the records incorporate a second professional opinion and, where available, the results of one contemporary sputum test.

The first report includes an occupational analysis of the control group—that is, workers in "other" occupations. Suffice it to say here that half the workers came from engineering, clothing, or leather-dressing factories, and approximately 16% were in professional or clerical occupations.

The coverage (see Tables I, VII, and X) is based on a comparison between the number of persons on the pay-roll of the factories and institutions visited, and the number who attended for examination.

Rather more men than women attended for examination, and shoemakers were better represented than controls, but the only important difference between the two occupational groups was in respect of age: 81% of men and 43% of women in the boot and shoe groups were over the age of 34 years, compared with 65% and 27% respectively in the control group.

In Table II the subjects who were recalled for a large film and those who were not are shown separately. The former includes persons who were found to have tuberculous lesions, other chest diseases, or no disease, and the latter a small number of persons who were suspected of having lung disease but refused to be re-examined. Over 94% of the subjects showed no radiological evidence of disease and less than 0.1% refused to be re-examined.

*Further report of an investigation initiated by representatives of the boot and shoe industry and public health authorities in Northamptonshire, and financed by the Medical Research Council.

†With a grant from the Medical Research Council.

TABLE II.—*Incidence of Tuberculous and Non-tuberculous Lung Diseases*

Disease Category		Occupational Group							
		Boot and Shoe				Other Occupations			
		Males		Females		Males		Females	
Main Group	Subgroup	No.	%	No.	%	No.	%	No.	%
Pulmonary tuberculosis*	Active	71 (*32*)	0·70	54 (*6*)	0·63	41 (*17*)	0·29	60 (*7*)	0·64
	Quiescent	369	3·64	199	2·34	397	2·76	139	1·48
Other diseases	Pneumoconiosis	2†	0·02	—	—	14	0·10	—	—
	Other lung	71	0·70	22	0·26	129	0·90	30	0·32
	Cardiovascular	35	0·35	6	0·07	37	0·26	25	0·27
	Undiagnosed‡	5	0·04	7	0·08	4	0·03	6	0·06
Nil	Large film	27	0·27	33	0·39	40	0·28	39	0·42
	Small film	9,567	94·28	8,192	96·23	13,702	95·38	9,075	96·81
Total		10,147	100	8,513	100	14,364	100	9,374	100

* Including previously notified persons who were recalled for large films.
† Both men were ex-miners.
‡ Recalled for large film, but failed to attend.
Figures in italics indicate cases with tubercle bacilli in sputum (single examination at time of survey).

Non-tuberculous Disease

Hitherto, no mass radiography statistics relating to non-tuberculous disease among shoemakers have been published. It is necessary, however, to consider these, since a high rate of tuberculosis in an industry could be due to dust disease.

In spite of being older, the shoemakers had no more non-tuberculous disease than the controls. Cardiovascular lesions were relatively uncommon among female boot and shoe workers, but in other respects there was little difference between the two occupational groups. Two of the male shoemakers showed radiological evidence of pneumoconiosis, but since they were both ex-miners it is clearly unrealistic to attribute this to leather dust.

The figures are in line with the fact that shoemakers, in spite of having a high tuberculosis mortality, have a low mortality from other lung diseases. In this respect they offer a striking contrast to potters, tin-miners, and other workers exposed to a silica-dust hazard (Registrar-General, 1891–1931 ; Collis, 1925 ; Cairns and Stewart, 1951).

Tuberculous Disease

In the earlier reports, only "newly discovered active tuberculosis of the lungs in persons who require to stay off work for treatment" was considered. To discover why this type of case was exceptionally common among shoemakers, who do not suffer from pneumoconiosis, several lines of inquiry must be followed. It has, for instance, been suggested that working conditions in boot and shoe factories favour spread of the disease. However, tuberculosis might have been unduly common solely because the trade had recruited an exceptionally large number of tuberculous subjects. Workers who had already been notified were automatically excluded from the newly discovered active group, but conceivably the latter was wholly composed of persons who, though not notified, had in fact developed the disease before entering the industry. Possibly, also, shoemakers are more susceptible to infection than other workers and therefore more liable to develop overt disease. These hypotheses are not mutually exclusive, and to give each its due weight it is necessary to consider five overlapping categories of tuberculous disease: active and quiescent, previously notified and newly discovered, and cases with tubercle bacilli in the sputum.

All Forms of Disease

Radiological evidence of pulmonary tuberculosis was detected in 1,330 cases. In 1,104 of these the disease was quiescent, and in 226 it was active. The former group included 89 previously notified persons, and the latter 15 previously notified and 62 with tubercle bacilli in their sputum. All forms of the disease were more common among shoemakers than controls, but the disparity varied with age, sex, and clinical condition (see Table III).

Quiescent Disease (Newly Discovered and Previously Notified)

Unless tuberculin tests have been made, it is impossible to estimate the infection rate in any one population ; but the *relative* rate of infection in two populations can be judged by comparing the percentage of persons among them who

TABLE III.—*Incidence of Active and Quiescent Tuberculosis*

Age Group (Yrs.)	Sex	Occupation	Workers Examined	Pulmonary Tuberculosis									
				Active				Quiescent				All Cases	
				Newly Discovered		Previously Notified		Newly Discovered		Previously Notified			
				No.	%	No.	%	No.	%	No.	%	No.	%
14–34	M	Boot and shoe	1,863	12 (*2*)	0·64	3 (*2*)	0·16	43	2·31	4	0·21	62 (*4*)	3·33
		Other	4,954	8 (*1*)	0·16	1	0·02	77	1·55	12	0·24	98 (*1*)	1·98
	F	Boot and shoe	4,823	48 (*6*)	1·00	—	—	84	1·74	10	0·21	142 (*6*)	2·95
		Other	6,866	54 (*6*)	0·79	—	—	78	1·14	3	0·04	135 (*6*)	1·97
35+	M	Boot and shoe	8,284	50 (*25*)	0·60	6 (*3*)	0·07	288	3·48	34	0·41	378 (*28*)	4·56
		Other	9,410	28 (*14*)	0·30	4 (*2*)	0·04	292	3·10	16	0·17	340 (*16*)	3·61
	F	Boot and shoe	3,690	5	0·14	1	0·03	97	2·63	8	0·22	111	3·01
		Other	2,508	6 (*1*)	0·24	—	—	56	2·23	2	0·08	64 (*1*)	2·55
All ages	M	Boot and shoe	10,147	62 (*27*)	0·62	9 (*5*)	0·09	331	3·26	38	0·37	440 (*32*)	4·34
		Other	14,364	36 (*15*)	0·25	5 (*2*)	0·03	369	2·57	28	0·19	438 (*17*)	3·05
	F	Boot and shoe	8,513	53 (*6*)	0·62	1	0·01	181	2·13	18	0·21	253 (*6*)	2·97
		Other	9,374	60 (*7*)	0·64	—	—	134	1·43	5	0·05	199 (*7*)	2·12

Figures in italics indicate cases with tubercle bacilli in sputum.

have not knowingly suffered from the disease but who show healed and active lesions. In the present instance, since only one person was responsible for the complete set of records, the "newly discovered quiescent cases" can be assumed to be proportional to the number of healthy tuberculin reactors in the two occupational groups.

There was a higher proportion of cases of quiescent newly discovered tuberculosis among the men than among the women, and more among the shoemakers than among the controls (see Table III). These differences are partly due to differences in the age structure of the four groups, but they cannot be wholly explained in this way. For example, when the subjects were divided into two age groups it was found that 2.31% of male and 1.74% of female boot and shoe workers under the age of 35 years were included in the relevant category, compared with 1.55% of male and 1.14% of female controls. These differences are statistically significant, and similar ones exist in the older age group (see Table III). From this it can be inferred that the shoemakers had been more exposed to infection than the controls rather than more liable to succumb when infected.

Previously Notified Disease (Active and Quiescent)

Men and women who take up work after being treated for tuberculosis do so knowing that they are physically handicapped. Hence the number of previously notified cases in a given occupational group is a measure of conscious selective recruitment. The proportion of these cases found to be suffering from active disease at any given time is also an indication of the breakdown rate after apparent recovery.

In the shoemaking group 0.46% of the men and 0.22% of the women had already been notified as cases of pulmonary tuberculosis, compared with 0.22 and 0.05% of male and female controls. The proportion of active cases in the previously notified group was distinctly higher for men (17.5%) than for women (4.2%), but approximately the same for male and female shoemakers (15.2%) and men and women in other occupations (13.2%).

cases (0.09 and 0.03%) and partly to an excess of newly discovered cases in the older age group (0.60 and 0.30%), but chiefly to the fact that the incidence of newly discovered cases in the younger age group was four times as high for shoemakers as for controls (0.64 and 0.16%).

In theory, an exceptionally large number of newly discovered cases of active pulmonary tuberculosis in the boot and shoe industry could be due solely to choice of this trade by persons who were conscious of ill-health but unaware that the cause was tuberculosis. There are, however, several reasons why this is unlikely. For instance, although young men move relatively easily from one industry to another, they usually suffer from an acute form of tuberculosis which is soon incompatible with work. Older men tend to have a more chronic type of disease, but they are relatively immobile, because change of work at that stage involves loss of status and reduction in earnings. On the other hand, since the boot and shoe industry undoubtedly attracts men of poor physique, some of the men with newly discovered active lesions may have entered the industry after developing the disease. Since persons with chronic lesions are likely to be carriers, the attack rate may also be unduly high among shoemakers.

To obtain further evidence on this last point, the following procedure was adopted. First the original radiographs (large films) of the active cases were reassembled. Then an independent witness* who was not told the age, sex, or occupation of the subjects, or whether they had already been notified, was asked to classify these films as follows:

Group I.—Cases showing radiological evidence of recent infiltration of otherwise healthy lungs.†

Group II.—Intermediate between I and III.

Group III.—Cases showing radiological evidence of old-standing disease, with or without signs of recent exacerbation.

When the classification was completed it was found that within the group of active cases there were no occupational differences in the radiological grading. There were, however, marked sex differences, nearly 90% of the women having recently acquired lesions, compared with only a quarter of the men (see Table IV). Finally, the average age of the subjects, and the number of persons with tubercle bacilli in the sputum, were lowest in Group I and highest in Group III.

TABLE IV.—*Radiological Classification of Cases of Active Tuberculosis*

Sex	Occupational Group	Total Cases		*X*-ray Group									
				Group I				Group II				Group III	
				Cases		Age in Yrs.		Cases		Age in Yrs.		Cases	Age in Yrs.
		No.	%	No.	%	Mean	S.D.	No.	%	Mean	S.D.	No. %	Mean* S.D.
M	Boot and shoe	71 (*32*)	100	18 (*4*)	25	33·6	5·9	21 (*10*)	30	44·4	3·6	32 (*18*) 45	50·3 5·3
	Other	41 (*17*)	100	11 (*1*)	27	30·7	5·8	12 (*5*)	29	44·8	5·0	18 (*11*) 44	52·4 5·4
F	Boot and shoe	54 (*6*)	100	48 (*3*)	89	23·8	3·3	6 (*3*)	11	31·7	4·4	— —	— —
	Other	60 (*7*)	100	52 (*5*)	87	21·2	2·3	8 (*2*)	13	36·0	3·8	— —	— —

Figures in italics indicate cases with tubercle bacilli in sputum.

The distinctions between men and women are probably due to economic factors, and between shoemakers and other workers to the nature of the work performed. As shoemaking does not demand strenuous physical exertion, skilled men who develop tuberculosis find it relatively easy to return to their own occupation. For the same reason men from heavy industries may take up shoemaking after contracting the disease. It was unfortunately not possible to discover how many of the previously notified men attending the mass radiography survey were shoemakers before notification and how many had subsequently migrated into the industry.

Active Disease (Newly Discovered and Previously Notified)

In addition to the newly discovered cases of active pulmonary tuberculosis described in the earlier reports, there were a few previously notified cases with active disease. Taking these two types of case together there was no difference between the women in the two occupational groups, but the rate for male shoemakers was over twice as high as the rate for other men (see Tables II and III). This difference was due partly to an excess of previously notified

This attempt to group the active cases according to the age of the disease process, on *x*-ray evidence alone, has obvious weaknesses, and it is unlikely that two observers would have agreed in all cases (Birkelo *et al.*, 1947; Fletcher and Oldham, 1949). There are, however, several cogent reasons why the classification can be accepted as generally true of the group, in spite of possible errors in the placing of a few individuals. In the first place, the different results for the two sexes are such as would have been expected. Secondly, the results for the two occupations, where no

*We are indebted to Dr. W. T. Bermingham, who succeeded Dr. Brough as medical officer in charge of the mass radiography unit after the first survey was completed, for this part of the investigation.

†For the purpose of this investigation, a calcified Ghon or Assmann focus was not regarded as evidence of previous disease.

differences were to be expected, are, in fact, identical. Thirdly, there is a definite and steady age gradient. Fourthly, there is an equally marked increase from group to group in the number of cases with tubercle bacilli in the sputum. Finally, none of the previously notified cases was mistaken for recently acquired disease. Hence, the admitted weaknesses of this method of grading, from the point of view of individual diagnosis, do not invalidate its use for showing what very different types of disease are included in the category "newly discovered active cases revealed by mass radiography," and indicating their approximate proportions.

Since the overall incidence of newly discovered active cases, and also the incidence of recently acquired and old-standing lesions, were greater among the shoemakers than among the controls, there must have been a high attack rate as well as a high carrier rate in the boot and shoe factories.

PART II.—COMPARISON BETWEEN DIFFERENT GROUPS OF SHOEMAKERS

In the interim report of the present investigation it was suggested that the relationship between factory size—that is, total working population—and incidence of newly discovered active cases of pulmonary tuberculosis might be due to the fact that, given similar working conditions, including spacing of operatives, the risk of contracting the disease was proportional to the number of persons per room. This hypothesis assumes (*a*) that it is possible for carriers to infect fellow workers, (*b*) that carriers are randomly distributed in boot and shoe factories, and (*c*) that there are usually more persons per room in large factories than in small ones.

In order to obtain further evidence on these points the statistics for boot and shoe operatives were analysed in terms of factory size, occupation, and region. The following definitions were also adopted:

Attack Rate.—The number of newly discovered active cases of pulmonary tuberculosis in *X*-ray Group I per stated number of workers.

Carrier Rate.—The number of cases of active pulmonary tuberculosis (newly discovered and previously notified) in *X*-ray Groups II and III per stated number of workers.*

1. Factory-size Analysis

Carrier and Attack Rates in Factories of Different Sizes

In Tables V and VI, male and female shoemakers are shown in five factory-size groups. Table V includes all cases with tuberculous lesions (active and quiescent) and also distinguishes the previously notified from the newly discovered cases.

In the interim report males and females were not discussed separately. However, Table V shows that the correlation between factory size and incidence of newly discovered active pulmonary tuberculosis holds true for both sexes. It also shows that the distribution of previously notified and quiescent cases is not influenced by factory size.

In Table VI the active cases, with and without tubercle bacilli in the sputum, have been placed in the three *x*-ray groups. Estimated attack rates and carrier rates for the five factory-size groups, calculated from these basic data, are also included.

TABLE V.—*Shoemakers Only. Factory-size Analysis. Incidence of Active and Quiescent Tuberculosis*

Factory-size Groups (Working Population)	Workers Examined		Cases of Pulmonary Tuberculosis				
			No.		Rates		
	No.	Over 35 Yrs. %	Active	Quiescent	A/ND	Q/ND	P/N
Males:					%	%	%
1-100 ..	1,936	82	9 (3)	67 (4)	0·31	3·25	0·36
101-200 ..	2,443	80	15 (2)	93 (7)	0·53	3·52	0·37
201-350 ..	2,341	81	17 (3)	75 (8)	0·60	2·86	0·47
351-600 ..	1,712	79	11	73 (12)	0·64	3·56	0·70
Over 600 ..	1,715	77	19 (1)	61 (7)	1·05	3·15	0·47
Total ..	10,147	80	71 (9)	369 (38)	0·61	3·26	0·46
Females:							
1-100 ..	1,505	45	7 (1)	32 (6)	0·40	1·73	0·47
101-200 ..	2,037	44	8	45 (3)	0·39	2·06	0·15
201-350 ..	1,773	44	11	47 (6)	0·62	2·31	0·34
351-600 ..	1,319	42	10	40 (2)	0·76	2·88	0·15
Over 600 ..	1,879	40	18	35 (1)	0·96	1·81	0·05
Total ..	8,513	43	54 (1)	199 (18)	0·62	2·13	0·22

A/ND = Active newly discovered. Q/ND = Quiescent newly discovered. P/N = Previously notified. Figures in italics indicate previously notified cases.

TABLE VI.—*Shoemakers Only. Factory-size Analysis. Estimated Attack Rates and Carrier Rates for Pulmonary Tuberculosis*

Factory-size Groups (Working Population)	Workers Examined		*X*-ray Groups			Estimated Attack Rate*	Estimated Carrier Rate*
	No.	Over 35 Yrs.	Group I	Group II	Group III		
Males:		%				%	%
1-100 ..	1,936	82	1 (1)	4 (3)	4 (1)	0·05	0·41
101-200 ..	2,443	80	3	3	9 (4)	0·12	0·49
201-350 ..	2,341	81	4	5 (2)	8 (6)	0·17	0·56
351-600 ..	1,712	79	4	5 (3)	2 (1)	0·23	0·41
Over 600 ..	1,715	77	6 (3)	4 (2)	9 (6)	0·35	0·76
Total ..	10,147	80	18 (4)	21 (10)	32 (18)	0·18	0·52
Females:							
1-100 ..	1,505	45	5	2	—	0·33	0·13
101-200 ..	2,037	44	8 (1)	—	—	0·39	—
201-350 ..	1,773	44	9 (1)	2 (2)	—	0·51	0·11
351-600 ..	1,319	42	9	1	—	0·68	0·08
Over 600 ..	1,879	40	16 (1)	2 (1)	—	0·85	0·11
Total ..	8,513	43	47 (3)	7 (3)	—	0·55	0·08

* Estimated attack rates based on cases in *X*-ray Group I; estimated carrier rates based on cases in *X*-ray Groups II and III.
Figures in italics indicate cases with tubercle bacilli in sputum.

These figures show that both the attack rate and the carrier rate for males were lowest in factories with fewer than 100 workers and highest in factories with over 600 workers. The numbers are too small to assess the significance of the differences between each factory-size group, but, if factories with over and under 600 workers are compared, the difference in the two attack rates is found to approach statistical significance

$$\left(\text{i.e., } \frac{\text{the observed difference}}{\text{standard error of the difference}} = 1.9\right)$$

The difference between the two corresponding rates is not statistically significant. In the case of females the attack rate also increased with size of factory. The gradient was less steep than in the case of men, but for factories with over 600 workers the attack rate was two and a half times as high as the rate for factories with fewer than 100 workers.†

Only tentative conclusions may be drawn from these results. The steady rise in the attack rate suggests that factory size has an important influence on the risk of contracting tuberculosis. On the other hand, it is uncertain whether the rise in the male carrier rate was due

*According to this definition, a carrier is "a person known to have active pulmonary tuberculosis and suspected of having had it for some time." Originally a more rigid definition was used which included only persons in *X*-ray Group III known to have tubercle bacilli in their sputum. Whichever definition is used, the results are essentially the same, but it is more convenient numerically to express the relationship between carriers and "victims" in terms of the index which incorporates the larger number of cases.

†It should be noted here that there is even less segregation of male and female operatives in boot and shoe factories than the occupational grouping suggests (see Tables VIII and IX). There is, for instance, a traditional association between clickers and closers and between finishers and shoe-room workers, and in several factories all the workers are housed in the same room. It is therefore reasonable to assume that many of the young women with active tuberculosis had been in contact with male carriers.

to the fact that carriers were not randomly distributed or to the impossibility of making a clear-cut distinction between carriers and victims. So far as they go, the female rates support the latter explanation.

Numerical and Spatial Arrangement of Workers

No record of the internal working arrangements in boot and shoe factories was made at the time of the mass radiography survey. When, however, it was found that factory size was influencing the distribution of newly discovered active cases the factories were revisited and the following information obtained: (*a*) the number of separate workrooms in each factory; (*b*) the number of workers (in the main occupational groups) in each room; and (*c*) the floor area of each workshop.

In a representative sample of 25 factories the actual distance between typical groups of workers was also measured. From these data mean values for workers per room, floor space per worker, and distance between adjacent workers were obtained for the five factory-size groups and the six clearly defined occupations (see Tables VII and X). This analysis revealed a positive correlation between factory size and number of workers per room. Thus the third assumption made in the interim report (that there are usually more persons per room in large than in small factories) was clearly justified. It was also found that the workshops in large factories tend to be more congested than the workshops in small factories. Hence the risk of contracting diseases due to droplet infection is likely to be greater in the former.

TABLE VII.—*Shoemakers Only. Factory-size Analysis. Numerical and Spatial Arrangement of Workers*

Factory-size Groups (Working Population)	No. of Factories	Workers Examined		Numerical and Spatial Arrangement of Workers (Mean Values)		
		No.	Coverage*	Persons per Room	Floor Area per Worker	Distance Between Workers
			%		sq. ft. (m.²)	ft. (m.)
1–100 ..	100	3,441	70	14·7	111 (10·31)	6·5 (1·98)
101–200 ..	43	4,480	68	34·9	93 (8·64)	6·2 (1·89)
201–350 ..	23	4,114	73	61·0	104 (9·66)	6·4 (1·95)
351–600 ..	9	3,031	66	70·8	90 (8·36)	5·9 (1·80)
Over 600 ..	6	3,594	72	97·3	77 (7·15)	5·5 (1·68)
Total ..	181	18,660	70	37·1	95 (8·83)	6·1 (1·86)

* The number of workers examined expressed as a percentage of the total number on the pay-roll of each factory.

2. Occupational Analysis

Attack Rates and Carrier Rates in Boot and Shoe Factories

There are six clearly defined occupational groups in boot and shoe factories. In four of these (clicking, lasting, finishing, and rough stuff) male workers are in a majority, and in two (closing and shoe rooms) the majority are women (see Table VIII).

The first report of the mass radiography survey showed that the incidence of newly discovered active pulmonary tuberculosis was exceptionally high in the clicking, lasting, and finishing, but not in the rough-stuff, closing, or shoe-room departments. Since workers in closing and shoe rooms are usually women, it is not surprising that the rates for newly discovered active cases in these departments were not significantly different from those for women in the control group (see Table III). In the rough-stuff departments, however, it was the male workers who were found to have significantly lower rates than the other men (see Smith, 1947, also Table VIII). To discover why male rough-stuff workers (most of whom are sole-cutters) are an exception to the general rule, the occupational groups were reanalysed in terms of previously notified and newly discovered cases, *x*-ray groups and numerical and spatial arrangement of workers. Table VIII shows that the incidence of newly discovered quiescent cases was actually lower among male rough-stuff workers than among male clickers, lasters, or finishers, though this difference is slight and not statistically significant. It is unlikely, therefore, that the low rate for newly discovered active cases among rough-stuff workers was due to a high level of acquired resistance to tuberculosis. The proportion of previously notified male cases was less in the rough-stuff rooms than elsewhere. Possibly tuberculous subjects prefer working in other departments, since the rough-stuff rooms are notoriously dusty, are often situated in a basement or semi-basement, and include one of the few shoemaking occupations which can be described as moderately heavy work—namely, sole-cutting.

TABLE VIII.—*Shoemakers Only. Occupational Analysis. Incidence of Active and Quiescent Tuberculosis*

Sex	Occupation	Workers Examined		Tuberculosis Lesions				
		Total No.	Over 35 Yrs.	No.		Rates		
				Active	Quiescent	A/ND	Q/ND	P/N
			%			%	%	%
Males	Clickers	1,975	76	16 (*1*)	89 (*15*)	0·76	3·75	0·81
	Closers	46	68	2 (*1*)	1	2·17*	2·17*	2·17*
	Rough stuff	1,091	86	3	35 (*3*)	0·27	2·93	0·27
	Lasters	3,505	80	26 (*4*)	123 (*7*)	0·63	3·31	0·31
	Finishers	1,988	86	16 (*1*)	73 (*7*)	0·75	3·32	0·40
	Shoe room	228	93	1	11 (*2*)	0·44*	3·95*	0·88*
	Other	1,314	83	7 (*2*)	37 (*4*)	0·38	2·51	0·46
	Total	10,147	80	71 (*9*)	369 (*38*)	0·61	3·26	0·46
Females	Clickers	172	41	1	6 (*1*)	0·58*	2·91*	0·58*
	Closers	4,999	45	28 (*1*)	127 (*12*)	0·54	2·30	0·26
	Rough stuff	493	55	1	10 (*1*)	0·20*	1·83*	0·20*
	Lasters	407	49	6	9 (*2*)	1·47*	1·72*	0·49*
	Finishers	101	44	—	4	—	3·96*	—
	Shoe room	923	47	7	30 (*2*)	0·76	3·03	0·22
	Other	1,418	32	11	13	0·78	0·92	—
	Total	8,513	43	54 (*1*)	199 (*18*)	0·62	2·13	0·22

A/ND = Active newly discovered. Q/ND = Quiescent newly discovered. P/N = Previously notified. * Figures based on fewer than 500 workers. Figures in italics indicate previously notified cases.

Table IX shows that, in the male occupational groups, the number of active cases with "old" lesions—that is, *X*-ray Groups II and III—and the number with "new"

TABLE IX.—*Shoemakers Only. Occupational Analysis. Estimated Attack Rates and Carrier Rates for Pulmonary Tuberculosis*

Sex	Occupation	Workers Examined		Cases of Active Tuberculosis				
		Total No.	Over 35 Yrs.	*X*-ray Groups			Estimated Attack Rate†	Estimated Carrier Rate†
				I	II	III		
			%				%	%
Males	Clickers	1,975	76	4	6 (*2*)	6 (*3*)	0·20	0·61
	Closers	46	68	—	1 (*1*)	1 (*1*)	—	4·35*
	Rough stuff	1,091	88	—	1	2 (*1*)	—	0·27
	Lasters	3,505	80	8 (*2*)	7 (*3*)	11 (*7*)	0·23	0·51
	Finishers	1,988	86	4 (*1*)	4 (*2*)	8 (*4*)	0·20	0·60
	Shoe room	228	93	—	1 (*1*)	—	—	0·44*
	Other	1,314	83	2 (*1*)	1 (*1*)	4 (*2*)	0·15	0·38
	Total	10,147	80	18 (*4*)	21 (*10*)	32 (*18*)	0·18	0·52
Females	Clickers	172	41	1	—	—	0·58*	—
	Closers	4,999	45	24 (*1*)	4 (*2*)	—	0·48	0·08
	Rough stuff	493	55	1	—	—	0·20*	—
	Lasters	407	49	5 (*1*)	1 (*1*)	—	1·23*	0·25*
	Finishers	101	44	—	—	—	—	—
	Shoe room	923	47	7	—	—	0·76	—
	Other	1,418	32	10 (*1*)	1	—	0·71	0·07
	Total	8,513	43	48 (*3*)	6 (*3*)	—	0·56	0·07

* Figures based on fewer than 500 workers.
† Estimated attack rates based on cases in *X*-ray Group I; estimated carrier rates based on cases in *X*-ray Groups II and III.
Figures in italics indicate cases with tubercle bacilli in sputum.

lesions, that is, *X*-ray Group I—bear a fairly constant relationship to one another. As the male rough-stuff workers included relatively few cases in *X*-ray Groups II and III and none in Group I, it is likely that both the carrier rate and the attack rate were unusually low in this department. Table X also shows that there are

TABLE X.—*Shoemakers Only. Occupational Analysis. Numerical and Spatial Arrangement of Workers*

Factory Department	Workers Examined		Numerical and Spatial Arrangement of Workers (Mean Values)		
	No.	Coverage*	Workers per Room†	Floor Area per Worker	Distance Between Workers
		%		sq. ft. (m.²)	ft. (m.)
Clicking ..	2,147	73	53	86 (7·99)	5·3 (1·62)
Closing ..	5,045	72	64	40 (3·72)	3·0 (0·91)
Rough stuff ..	1,584	70	46	140 (13·01)	7·6 (2·32)
Lasting ..	3,912	73	63	84 (7·80)	4·8 (1·46)
Finishing ..	2,089	72	66	94 (8·73)	4·7 (1·43)
Shoe room ..	1,151	72	42	133 (12·35)	5·9 (1·80)
Total ..	15,928	72	57	95 (8·83)	6·1 (1·86)

* The number of workers examined expressed as a percentage of the total number on the pay-roll of each factory. (N.B.—The total number on the pay-roll is an *estimate*, based on records collected after the mass radiography survey was completed. Hence the figure for all workers is slightly different from that shown in Table VII.)

† N.B.—A room may contain more than one department.

fewer workers per room and more space per worker in the rough-stuff departments than in any other occupational group. Hence the risk of droplet infection is relatively slight.

The occupational analysis as a whole indicates that the low incidence of active pulmonary tuberculosis among male rough-stuff workers was due to the fact that they were less exposed to infection than other men. It also suggests that the difference between these men and other boot and shoe operatives may be due, in the first instance, to selective recruitment.

Regional Analysis

In the first report it was shown that there was a statistically significant excess of newly discovered active cases of pulmonary tuberculosis in male boot and shoe workers in the Northampton, Kettering, and Rushden areas, but not in the Wellingborough area. As soon as the relationship between factory size and incidence of overt pulmonary tuberculosis was established, the apparently exceptional state of affairs in the Wellingborough area became understandable. Although this region includes the third largest town in the county, it has only one factory with more than 200 workers and none with more than 350. There were no other findings of special interest in the regional analysis.

Discussion

Hitherto, reports on the tuberculosis findings of mass radiography surveys have tended to concentrate attention upon newly discovered active cases and to ignore other types of disease (Ministry of Health Annual Reports, 1943–9; Clive, 1943; Brooks, 1944; Dick, 1945; Bradbury, 1947; etc.). Persons in need of treatment are undoubtedly of greater interest to clinicians than those in whom the disease is quiescent, but it is surely an overstatement to say that the incidence of healed lesions "is of no practical importance." In fact, an epidemiologist has as much—or more—to learn from the distribution of inactive and previously notified cases as from the distribution of active newly discovered cases.

At present there is no agreement between medical officers in charge of mass radiography units on what cases should be included in the inactive disease categories.* It is therefore inadvisable to compare one survey with another. On the other hand, the records of one observer can be used to discover what relationship, if any, the distribution of quiescent lesions bears to the distribution of active cases in different subgroups of the population examined.

Furthermore, while some mass radiography units invite all and sundry to avail themselves of the services provided (Medical Research Council, 1945; Dick, 1945; Maclean, 1947), others advertise the service as one which is not intended for those who are already under medical supervision (Bradbury, 1947). In any case, without special propaganda, known tuberculous subjects are less likely to attend than other persons. Provided, however, they were not deliberately excluded it might be possible to study the relative incidence of previously notified cases in different sections of a single community surveyed at one time, and to discover what proportion of these persons continue working in spite of having active disease.

The staff of mass radiography units are instructed to keep a careful record of the age, sex, and occupation of all persons examined. They are, however, rarely asked to obtain the same information about those who are not examined, even in clearly defined groups such as schools and factories. Unless, however, steps are taken at the time of the survey to establish the age, sex, and occupational constitution of the whole "population at risk," to discover which of the subjects have shared a common background and how many of their immediate colleagues have not been examined, it is impossible for the medical officer in charge to extract more than a limited amount of information from his records.

The present body of data is unique in more respects than one. In the first place, the original survey included approximately two-thirds of all workers in the staple industry of one county. This enabled Dr. C. M. Smith to identify more active undiagnosed cases in boot and shoe factories than elsewhere and to show that the excess was largely confined to three of the four departments in which there were a majority of male workers. A detailed study of the records of individual boot and shoe factories then showed that the incidence of active tuberculosis was a function of factory size. At this point it became evident that, even supposing all the patients had contracted their disease elsewhere, there must still be something in factory life, as such, which was determining the disease pattern. In order to discover what this obviously important factor was, a detailed study of working conditions was made.

Here again we were fortunate. Although there is a wide range in the size of factories in the boot and shoe industry in Northamptonshire, the internal working arrangements are very similar. In some factories all the operatives are housed in one or two large workshops, and in others there is a separate room for each of the six main operations. Every factory is, however, equipped with the same type of machinery. Even the position of the machines conforms to a standard pattern, and in

* In Ministry of Health returns from 23 mass radiography units (July–December, 1947), the incidence of all types of "quiescent pulmonary tuberculosis" ranged from 0.24 to 13.32% for males and 0.23 to 11.03% for females. The corresponding figures for "inactive post-primary" lesions were 0.11 and 1.84% for males and 0.22 and 2.64% for females.

† The making of boot and shoe machinery in this country is largely in the hands of one company, which not only hires its products to boot and shoe factories but also advises on the lay-out of their workshops.

each occupational group the proportion of male and female operatives tends to be constant. Finally, working arrangements are so static that two years after the completion of the mass radiography survey it was possible to reconstruct the original lay-out of the factories and identify the whole population at risk in terms of sex, occupation, and room distribution.

Armed with this additional information, we have been able to show that tuberculosis carriers constitute a danger to fellow workers, and that the distribution of the cases in boot and shoe factories is such as would be expected with any disease due to droplet infection. Certainly the incidence of overt pulmonary tuberculosis in any industry or occupational group is dependent first of all upon whether the nature of the work is such as to attract or repel tuberculous subjects; but once a number of these have been recruited the further spread of the disease depends upon whether working conditions foster or inhibit its transmission. Owing to the relatively small number of cases in each of the disease categories (newly discovered, previously notified, active, quiescent, and "open" tuberculosis) it is impossible to produce gilt-edged statistics in support of these suggestions. There is, however, strong presumptive evidence to suggest not only that "whatsoever a man soweth, that shall he also reap," but also that the seed so liberally scattered in boot and shoe factories "fell into good ground and brought forth fruit."

In view of these findings it is perhaps worth considering whether we are at present obtaining the maximum amount of value from mass radiography surveys. From a clinical point of view it is impossible to overrate a service which enables us to detect tuberculosis in the earliest stage of the disease, and in this respect it would be difficult to improve the work which is being done. On the other hand, the present investigation does suggest that the potential contribution of mass radiography surveys to epidemiology is not only neglected but actually hampered by preoccupation with matters of clinical interest.

There are several ways in which the Ministry of Health could help to correct this bias. In the first place, it should be possible to formulate a generally acceptable definition of "quiescent pulmonary tuberculosis." Since medical officers in charge of mass radiography units attend a special course of instruction before taking up their duties, it should not be difficult to ensure much greater uniformity of record-keeping than at present exists. Secondly, the Ministry could stress the importance of knowing the exact distribution and interrelationships of all types of tuberculosis, and encourage the inclusion of known tuberculous subjects in mass radiography surveys. Finally, attention might also be drawn to the importance of correlating medical and non-medical data, providing trained workers for collecting the latter, and directing some of the surveys towards more detailed environmental research.

Summary and Conclusions

An investigation is described in which mass radiography statistics have been used to study tuberculosis morbidity rates in different occupational groups in Northamptonshire during 1945–6.

The following findings (already reported elsewhere) are confirmed: (*a*) the incidence of newly discovered active disease in 1945–6 was higher in the boot and shoe factories than in other industries in Northamptonshire; (*b*) in the boot and shoe industry this type of case was found as often among men as among women, but in other occupations women were chiefly affected; and (*c*) the case incidence was higher in large than in small boot and shoe factories, and higher for clickers, lasters, and finishers than for rough-stuff workers.

New facts relating to the incidence of inactive tuberculous lesions, previously notified cases, cases with tubercle bacilli in the sputum, and three subdivisions of the newly discovered active cases (acute, subacute, and chronic) have also come to light.

From the distribution of newly discovered cases of quiescent tuberculosis, it is evident that in 1945–6 Northamptonshire boot and shoe factory operatives were more exposed to infection than workers in other occupations.

In the male section of the boot and shoe industry there were an exceptionally large number of previously notified cases, chronic undiagnosed cases, and acute undiagnosed cases. There were some "open" cases of tuberculosis in each of these disease categories, but these were mainly concentrated in the chronic undiagnosed group. Male rough-stuff workers (mostly sole-cutters) were an exception to the general rule and had relatively low rates for all types of tuberculosis.

Compared with other industries in which women were employed, the female section of the boot and shoe industry (closing- and shoe-rooms) included a large number of previously notified cases; but compared with industries in which men were employed these cases were infrequent and rarely showed signs of active disease. There were many acute undiagnosed cases among female workers, but relatively few chronic undiagnosed cases. In these respects there were no significant differences between female boot and shoe operatives and women in other occupations.

Acute undiagnosed cases usually occurred in association with chronic cases (previously notified and undiagnosed), and the proportion of acute to chronic disease steadily increased with increase in factory size.

An independent survey of the boot and shoe factories included in the mass radiography survey has revealed the following facts: (*a*) room size—that is, workers per room—is a function of factory size—that is, workers per factory; (*b*) workshops in large factories tend to be more congested than workshops in small factories; (*c*) in other respects the internal working arrangements are very similar in all factories; (*d*) with a few exceptions—notably sole-cutting—the operations performed in boot and shoe factories do not entail much physical exertion; and (*e*) there are fewer persons per room and more space per worker in the sole-cutting or rough-stuff departments than in any other department.

There is no evidence that leather dust, in moderate concentration, produces pneumoconiosis.

The final conclusion is that certain types of work suit the requirements of physically handicapped persons, and that in densely populated workshops the transmission of airborne diseases is facilitated. These two factors are responsible for there being more tuberculosis in boot and shoe factories than elsewhere. They do not, however, apply to sole-cutters, partly because their work is relatively heavy, and partly because they are more widely spaced than the other operatives.

In other departments the presence of carriers has led to further spread of the disease, in spite of the workers being relatively resistant to tuberculosis. This further spread is shown by the fact that examples of recently acquired disease were found most often in those factories which had the largest workshops, and in those departments which had the most chronic cases.

We have great pleasure in thanking Dr. M. C. Brough, Dr. W. T. Bermingham, and other members of the Northamptonshire Mass Radiography Unit for their kind co-operation. Our thanks are also due to Dr. C. M. Smith and other members of the Northamptonshire Steering Committee for initiating the investigation; to Dr. W. T. Russell for statistical advice; to Mr. W. E. C. Brooksbank and Miss Daphne Coulthard for

collecting and assembling the data; and to the Medical Research Council for providing the necessary financial assistance.

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ADDENDUM.—Two years after completing its first tour, the Northamptonshire Mass Radiography Unit went round the county again. The final results of this survey are not yet available, but a preliminary inspection of the records suggests that the incidence of newly discovered active pulmonary tuberculosis among male boot and shoe operatives is now no higher than among men in other occupations. The exact significance of this finding cannot be appreciated until it is known how many of these men were examined for the first time; how many were new entrants to the industry; what type of case was discovered; and what was the age distribution of the population examined. It is, however, likely that boot and shoe factories in Northamptonshire are already reaping the benefits of having had a thorough comb-out of chronic carriers during 1945–6.

HAEMOPHILIA ASSOCIATED WITH NORMAL COAGULATION TIME

BY

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Haemophilia is a condition which has attracted considerable interest, and the clinical and laboratory features of the typical syndrome are well recognized. The average case presents no difficulty in diagnosis and can be recognized with a high degree of certainty. The means by which this is accomplished are the family history, the clinical picture, and the laboratory findings.

Family History and Clinical Picture

Haemophilia is "an inherited tendency in males to bleed" (Bulloch and Fildes, 1911). It is transmitted by apparently unaffected females. No other haemorrhagic diathesis with this type of inheritance has yet been described. The absence of such a history need not exclude the diagnosis, as apparently sporadic cases are not uncommon: they accounted for 39% of cases met with in one series (Merskey, 1950b).

The chief symptom is severe and often almost uncontrollable haemorrhage from even minor injuries. These haemorrhages may occur from skin and mucous membranes, into muscles and especially into joints. It is a severely disabling condition, the patients being constantly exposed to the risk of haemorrhage and often being crippled by the ankylosis of joints which so constantly follows the repeated haemarthroses. Very few haemophiliacs are able to lead normal lives, and the mortality rate in childhood and adolescence is considerable.

*Cecil John Adams Travelling Scholar, 1949.

Laboratory Findings

The bleeding time, platelet count, tourniquet test, and plasma prothrombin, factor V, and fibrinogen are all normal. On the other hand, the coagulation time is prolonged and prothrombin is not adequately consumed during coagulation of the blood.

The lengthening of the coagulation time of the blood is the best-known laboratory abnormality of haemophilia. Conflicting views have been expressed about whether a normal coagulation time can occur in haemophilia. Davidson *et al.* (1949) stated that they had never seen it. Birch (1937) stated that in mild haemophilia it might be normal at intervals, and Whitby and Britton (1946) that it might be almost normal between the attacks of bleeding. Quick (1949) reported a series of 24 haemophiliacs, 7 of whom had a Lee and White coagulation time of under 10 minutes, and he commented that in mild haemophilia the coagulation time could be normal; a similar statement was made by Tocantins (1949).

Brinkhous (1939) was the first to demonstrate defective consumption of prothrombin during coagulation of haemophilic blood, and this has since been confirmed (Quick, 1947; Soulier, 1948; Alexander and de Vries, 1949; Merskey, 1950a). By comparing the amount of prothrombin in the plasma with that present in the serum of blood clotted in glass tubes the amount of prothrombin "consumed" during coagulation can be measured. Normally, most of the prothrombin is converted to thrombin and very little remains in the serum. In haemophilia the serum often contains as much as the plasma and, for reasons not at present fully explained, in many cases apparently even more.

Patek and Stetson (1936) showed that there was a substance present in normal blood which was absent or unavailable in haemophilic blood. This substance, sometimes called antihaemophilic globulin, when added in small proportion to haemophilic blood shortened the coagulation time of the latter and also improved its prothrombin consumption defect (Quick, 1947; Soulier, 1948; Alexander and de Vries, 1949; Merskey, 1950a).

The absence of antihaemophilic globulin in haemophilic blood can be used as a diagnostic test for this condition. This can be demonstrated by adding to known haemophilic blood minimal proportions of the blood of a patient suspected of having haemophilia. If the suspected blood proves incapable of correcting the coagulation time and prothrombin consumption defect, the patient probably has haemophilia. If it can correct these defects of haemophilic blood to some extent, but not to that produced by an equal proportion of normal blood, it is probable that the patient has the haemophilic defect, but in less degree.

By the use of this test in a large series of haemophilic patients I was able to show (Merskey, 1950b) that varying grades of the haemophilic defect did exist. At the one extreme there were the classical haemophiliacs with prolonged coagulation time, grossly defective prothrombin consumption, and inability to correct haemophilic blood; at the other extreme patients with normal coagulation time, a much milder prothrombin consumption defect (in some instances no demonstrable defect at