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CORONARY HEART DISEASE AND PHYSICAL ACTIVITY OF WORK

EVIDENCE OF A NATIONAL NECROPSY SURVEY*

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It has previously been shown that the drivers of London's double-decker buses are more likely to die suddenly from "coronary thrombosis" than the conductors, and that Government clerks suffer more often from rapidly fatal cardiac infarction than do postmen.[43] On the basis of these and similar observations a hypothesis has been stated that *men in physically active jobs have a lower incidence of coronary (ischaemic) heart disease in middle-age than men in physically inactive jobs. More important, the disease is not so severe in physically active workers, tending to present in them in relatively benign forms.*

It is a principle of epidemiological research of this type to seek evidence from as many, as various, and as independent sources as possible.[40] The present report deals with the frequency, in relation to occupation, of ischaemic myocardial fibrosis in men dying from causes other than coronary heart disease itself. These myocardial scars are often evidence of early coronary heart disease and of less severe, or at any rate non-lethal, ischaemia. Thus the present study provides a picture of coronary heart disease in one of its simpler forms, and this may help in elucidating social connexions. At the same time another test of the hypothesis is made, using quite different data from the previous inquiries and upon quite another aspect of the condition. The inquiry it was hoped would provide some information on the pathological mechanisms of any differences with physical activity of work that were found; and in particular we sought to learn something about the relationships of occupation to coronary artery disease. In brief, Can the hearts of men be seen to vary with the kind of work they have done? At what phases in the complex of coronary–myocardial disease as a whole can this particular "cause"—physical activity/inactivity—be seen to operate? More generally the inquiry was intended to provide a statistical account of the coronary arteries of the middle-aged British male population, 1954–6.[42]

Method

Through the universities and regional hospital boards we appealed personally to all pathologists in the National Health Service who might regularly be in charge of post-mortem examinations to co-operate in the inquiry, and the pathologists of 206 hospitals or hospital groups—between 85% and 90% of the "possibles"—very kindly agreed. We cannot be more precise about this fraction, because it is not known whether some of those who did not reply at all to our letters were in fact regularly responsible for appreciable numbers of necropsies.

Each pathologist was invited to provide particulars on a standard form of 25 consecutive unselected necropsies on men aged 45–70 years, no matter what the cause of death or how the case came to necropsy. 5,000 reports were sent to us: trial runs with records from 1944 to 1951 in the Pathological Institute of the London Hospital[39 60] had encouraged the hope that with such numbers stable group patterns would emerge. In all cases *macroscopic details* were requested of *disease in the coronary arteries*, its nature, amount, and distribution, with descriptions of any stenosis; and of *fibrosis of the myocardium of the left ventricle* and *interventricular septum*, using lesions of 1 cm. in any dimension as markers; and the *heart weight*. Particulars were also asked about the main causes of death and other important clinical and pathological findings such as valvular heart disease, including especially aortic stenosis. By appealing for detailed descriptions of lesions seen, discouraging evaluations such as "slight" or "much," and giving guidance on terminology if not on technique, we hoped to reduce the variability of such procedures. It was postulated, moreover, that the variability in observation and recording over so many departments of pathology would be "random" in relation to the main factor with which pathology was to be correlated—physical activity of work.

The pathological data on each record relating to disease in the coronary arteries and fibrosis of the myocardium were graded, agreed, and coded by at least two and often three physicians in the unit. It took many months to define appropriate scales; but finally scales emerged that made pathological sense, were simple in use, having no more than five points, and the gradings on which proved highly reproducible by ourselves and by others.

Pathologists were also invited to give details of the *last occupation* of the deceased, but in many cases this information had to be obtained by the unit from the

*Part of this report was included in the Ernestine Henry Lecture delivered by one of us (J. N. M.) before the Royal College of Physicians of London on June 10, 1958.

General Register Office. The last stated occupation, apart from other difficulties,[57] is unlikely to be an exact indicator of men's jobs during their middle-age. The present inquiry, however, is concerned only with *type of job* in terms of its characteristic *physical activity*. Some special categories apart, the last job is probably by and large an adequate indicator of this. (Occupational histories of their national series kindly made available to us by Doll and Hill[14 15] showed on analysis that among 152 fatal cases of lung cancer in men aged 55–64, 80% had been in the same job for more than their last 10 years and a further 10% had changed jobs during the last 10 years of life but remained in the same physical activity category. These proportions over 15 years were 70% and 14% respectively; over 20 years, 61% and 17%.)

The 1,700 different descriptions of occupations included in the 5,000 returns of the present inquiry were classified, in terms of the physical activity habitually involved, by two experts in industrial medicine who first graded all the jobs independently and then presented the unit with an agreed coding. They used a three-point scale: typically "light" jobs (for example, schoolmaster, bus-driver, clerk of any description); "active" jobs (for example, postman, carpenter); or "heavy" jobs (for example, boilermaker, dock labourer). Light jobs, that is, include sedentary; heavy include the heaviest.

The technical problems involved in such studies as the present have already been considered,[37 40 42] and further comments are included in this and will be given in subsequent papers. There are many imperfections in the data on both biological and social sides of the equations to be attempted. The method used, like any other, and more than most, has its limitations as well as its possibilities. In particular, detailed occupational histories could not be obtained, which may be a considerable loss, and more than occupation-wise, since related economic/nutritional standards varied far more widely in the 1930s than in the 1950s.[13 36 51] Moreover, considered agreement on pathological techniques, not to say uniformity, has been sacrificed for numbers. The crucial issue was that of range of occupation: only a countrywide and comprehensive survey gathering large numbers of cases from many different centres could include enough men in the diminishing categories of truly "heavy" workers—coal hewers, farm labourers, men in heavy engineering, and the like. The interest of the questions that can be asked only from the present kind of study will, it is hoped, compensate for what has had to be forgone—and suggest what might next be done.[41]

Material

Necropsy material may be classified for our present purposes as follows[39 42]:

Group A.—Deaths due to coronary heart disease: coronary heart disease itself; or with hypertension, and/or other pathology; and including slow, congestive cardiac failure as well as the more numerous sudden deaths. There were about 1,200 altogether in Group A.

Group B.—Deaths from conditions associated with a specially high prevalence or severity of coronary artery disease—for example, deaths from hypertension and its complications; deaths from vascular disease in sites other than the coronary arteries, with or without hypertension; ("senile") aortic stenosis; deaths from destructive renal disease; the cases of diabetes. In addition to such well-recognized associations it was noticed that deaths from peptic ulcer in the present material showed a significant excess of occlusive coronary artery disease, and these deaths were therefore included in Group B. This group of 1,000 cases was called the *high coronary artery disease group.*

Group C.—Deaths from other conditions, the remainder and majority of necropsies, including injuries, infections, cancers. No disease or disease-group with 100 cases or over included in Group C showed significantly more or significantly less coronary artery disease at the 5% level than the remainder, as judged by the prevalence and amount of mural disease and the frequency of lumen narrowing of 50% or more in a major artery. This group is therefore called the *basal group* as regards coronary artery disease. There were 2,800 cases in it.

The present report deals with the 3,800 cases in Groups B and C. Brief reference is also made to Group A, but these cases will be fully considered on another occasion.

Ischaemic Myocardial Fibrosis

In some 500 of the 3,800 non-coronary deaths fibrosis was reported in the myocardium of the left ventricle and/or septum. All these records were scrutinized, and any subjects with rheumatic heart disease or other possible cause of myocardial fibrosis, the collagen-vascular diseases, for example, or ostial syphilis, were excluded; cases with generalized, "diffuse" fibrosis not otherwise described were also discarded. ("Myocarditis" was rarely mentioned by the pathologists; no microscopical examination was requested.) This left close on 400 cases with scars, commonly in the lower, antero-lateral walls of the left ventricle, in the front of the septum, or high on the posterior wall, which are presumptively ischaemic, will henceforth be regarded as *ischaemic myocardial fibrosis,* and have alone been analysed. In most of these 400 cases there was much coronary artery disease and a report of topical coronary narrowing.* The few scars in the right ventricle were ignored.

Scars were classified on two axes, whether they were single or multiple and large or small. Two main types of ischaemic myocardial fibrosis soon identified themselves, and provided a quick first answer to one of the main questions of the inquiry:

Type 1.—The *large, discrete patch* of fibrosis, over 1.5 cm. in one dimension, and often solitary. These patches were commonly transmural, and they are presumably the healed end-result of major and maybe acute infarction—"large healed infarcts"—or sometimes of confluent lesser infarcts. They were usually associated with occlusion or near-occlusion in the related main coronary artery, often high in it, rather than with lesser coronary narrowing. All aneurysmal dilatations have been included here, and also some large areas of fibrosis which were not clearly circumscribed.

Type 2.—Small, multiple scars, in the left ventricular wall, the septum, or papillary muscles which were usually thinner and less defined than type 1 and were associated in this material mostly with minor degrees of focal narrowing, low in a main coronary artery, for example, or in smaller branches. These scars are commonly regarded as the product of lesser and more slowly developing coronary insufficiency and myocardial ischaemia. However, some of this "focal myocardial fibrosis"[21] may well be the result of very small infarcts.

It was soon apparent that the occurrence of a large patch was strongly related to physical activity/inactivity of occupation, the occurrence of the small multiple scars less so. Discrete patches of 0.5–1.5 cm. in diameter, and some very small scars also regarded as ischaemic, were all found to behave much more like type 2 in relation to occupation, to coronary narrowing (and, as seen later, to hypertension)

*In the minority of scars in which there was no record of topical coronary narrowing the same relationships with physical activity of occupation were observed as among the majority with a record of obstructive arterial disease. Only one tabulation is therefore presented.

than the large healed infarcts of type 1, and they have therefore been classified to type 2. All type 2 scars will, for convenience, be called "focal myocardial fibrosis." Mixed cases with both types of fibrosis were included with type 1.[1 21 47 65 69]

Results

As stated, this report deals mainly with the (presumptively) ischaemic myocardial fibrosis found in a national sample of 3,800 non-coronary deaths in middle-aged men. Table I sets out the findings, first for the 2,800 miscellaneous deaths from injuries, infections, cancers, etc., and, below, for the 1,000 deaths from hypertensive and other vascular disorders, the deaths in diabetics, etc. Throughout, in each line of Table I, the rate among the "light" workers (e.g., *2.0*% in the first line) is substantially higher than in the "heavy" (*0.3*% in the first line). The "active" rates mostly fall between, but occasionally are below the "heavy" (as in the second line of the Table). This trend was repeated time after time in the analysis of Group C, Group B, and various pathological, medical, and social subdivisions of these; it was found in Scotland, Wales, Greater London, and the rest of England, separately; in London teaching hospitals, other teaching hospitals, and non-teaching hospitals when these were distinguished; and it was also the main finding of the trial study of the 1944–51 Woods and Russell London Hospital cases.

The results in Table I can be summarized thus:

1. Disregarding age, cause of death category, and type of scarring (last line of the Table) there is twice as much ischaemic myocardial fibrosis in the "light" workers as in the "heavy"—*13.4*% compared with *6.8*%.

2. There is a stronger gradient with physical activity of occupation in the cases with large fibrous patches—threefold overall, *3.5*% to *1.2*%—than in those with the smaller/multiple scars—*9.9*% to *5.7*% (second and third last lines of Table I).

3. This excess of large healed infarcts among the "light" workers is more evident in the younger age group than at 60–70 years. At 45<60 years, in Groups B and C combined, there are four to five times as many of these scars in "light" workers as in "heavy"; at 60–70, two to three times as many (Table II).

Numbers are often small, but it seemed preferable to set out all the data instead of amalgamating the active and heavy ocupations and comparing these with the light, which was the alternative the data indicated. Table I emphasizes that even among the heavy occupations there is a good deal of ischaemic myocardial fibrosis; though, in fact, large healed infarcts were as common in light workers aged 45–54 (2.0%) as in heavy aged 65–70 (1.9%).

TABLE II.—*Large Healed Myocardial Infarcts. 3,800 Non-coronary Deaths. Men*

Ages	Occupation		
	Light	Active	Heavy
45<60	*2·3%*	*1·3%*	*(0·49%)*
60–70	*4·7%*	*2·6%*	*1·8%*

TABLE I.—*Proportions with Ischaemic Myocardial Fibrosis by Physical Activity of Occupation ("Light," "Active," "Heavy"). 3,800 Non-coronary Deaths. Males Aged 45–70*

Age	Ischaemic Myocardial Fibrosis	Occupation		
		Light	Active	Heavy
	Deaths from Conditions in "Basal" Group			
45<60	No. of cases	509	516	324
	With large fibrous patch	10	5	1
	Rate %	*2·0%*	*1·0%*	*(0·3%)*
	With smaller/multiple scars	21	14	9
	Rate %	*4·1%*	*2·7%*	*2·8%*
60–70	No. of cases	486	518	344
	With large fibrous patch	16	12	3
	Rate %	*3·3%*	*2·3%*	*(0·9%)*
	With smaller/multiple scars	45	34	19
	Rate %	*9·3%*	*6·6%*	*5·5%*
45–70	No. of cases	995	1,034	668
	Total with ischaemic myocardial fibrosis	92	65	32
	Rate %	*9·2%*	*6·3%*	*4·8%*
	Deaths from Conditions in "High" Coronary Artery Disease Group			
45<60	No. of cases	193	189	82
	With large fibrous patch	6	4	1
	Rate %	*3·1%*	*(2·1%)*	*(1·2%)*
	With smaller/multiple scars	33	16	5
	Rate %	*17·1%*	*8·5%*	*6·1%*
60–70	No. of cases	252	206	112
	With large fibrous patch	19	7	5
	Rate %	*7·5%*	*3·4%*	*4·5%*
	With smaller/multiple scars	43	32	16
	Rate %	*17·1%*	*15·5%*	*14·3%*
45–70	No. of cases	445	395	194
	Total with ischaemic myocardial fibrosis	101	59	27
	Rate %	*22·7%*	*14·9%*	*13·9%*
	All Non-coronary Deaths			
45–70	No. of cases	1,440	1,429	862
	With large fibrous patch	51	28	10
	Rate %	*3·5%*	*2·0%*	*1·2%*
	With smaller multiple scars	142	96	49
	Rate %	*9·9%*	*6·7%*	*5·7%*
	Total with ischaemic myocardial fibrosis	193	124	59
	Rate %	*13·4%*	*8·7%*	*6·8%*

National Necropsy Survey, Scotland, England and Wales, 1954–6. Data from 206 hospitals or hospital groups.

The number of non-coronary deaths that were analysed varied slightly around 3,800, depending on the availability of data.

Forty-six cases have been omitted from this and all subsequent tables because information was inadequate, or it was impossible to classify a main cause of death to Groups A, B, or C (e.g., 12 cases of polyarteritis nodosa). In addition 114 non-coronary deaths have been omitted from tables dealing with the physical activity of occupation because the last job was unknown or could not be classified.

Occupations were classified by Dr. R. Murray and Dr. D. Turner.

Throughout these tables rates of ischaemic myocardial fibrosis are printed in italic. Rates based on a numerator of less than 5 cases are bracketed ( ).

45<60 years=45–59 incl. 60–70 years=60–70 incl. 45–70 years=45–70 incl.

Because of the similarity of age distributions crude rates have been used throughout the analysis and tables in amalgamations of 45–70 years inclusive.

Tests of Significance.—The test used in this table (and throughout this paper where relevant) is the test for linear trends in proportions (P. Armitage, *Biometrics*, 1955, **11**, 375). A significant value of p indicates that the trend in the proportions (percentages) from "light" through "active" to "heavy" occupations is unlikely to be due to chance. The p values in separate subgroups—e.g., age groups 45<60 and 60–70—have usually been combined in the total groups—e.g., aged 45–70—the method of combination allowing for the fact that the trend was in the same direction in each subgroup.

Third last line, $p<0{\cdot}001$; 2nd last line, $p<0{\cdot}001$; last line, $p<0{\cdot}001$.

Hypertension

Pathologists were asked to report any clinical or pathological evidence of hypertension, and much detailed information was provided for us. Using one at least of these criteria—(*a*) a clinical history of hypertension with record of diastolic pressure over 110; often there were particulars of treatment; (*b*) "concentric" left ventricular hypertrophy; or (*c*) in younger cases particularly, left ventricular hypertrophy not otherwise described or explained, together with nephrosclerosis—it was possible to distinguish those with "record or evidence of hypertension" from the "others." Close on 10% of the "basal" Group C had incidental hypertension as so defined. In almost half the cases of the "high coronary artery disease" Group B hypertension was present, and considered usually to be a principal factor in the death—for example, in many of the deaths from cerebrovascular disease.

The prevalence of ischaemic myocardial fibrosis in relation to hypertension is summarized in Table III, which shows no difference in the large fibrous patches (large healed infarcts) but substantially more of the smaller/multiple scars (focal myocardial fibrosis) among the hypertensive ($p<0.001$). This latter excess, it may be noted, held for each of the subtypes of small scars and multiple scars included in type 2; whence the use of the term "focal myocardial fibrosis" for all of type 2 scars.

Table IV continues this analysis by occupation, and includes all the cases in Groups B and C—that is, all the non-coronary deaths. There is nothing of interest in the large fibrous patches, both the hypertensive (e.g., 4th line, in italics, left half of the table) and the "others" (e.g., first line in italics, right half of the table) showing the expected

TABLE III.—*Proportions With Ischaemic Myocardial Fibrosis. Factor of Hypertension.* 3,800 *Non-coronary Deaths. Males Aged* 45–70

Ischaemic Myocardial Fibrosis	Cases With Record or Evidence of Hypertension		Others	
No. of cases	759		3,086	
With large fibrous patch	18		74	
Rate %		*2·4%*		*2·4%*
With smaller/multiple scars	122		172	
Rate %		*16·1%*		*5·6%*

TABLE IV.—*Proportions with Ischaemic Myocardial Fibrosis by Physical Activity of Occupation. Factor of Hypertension.* 3,800 *Non-coronary Deaths. Males Aged* 45–70

Age	Ischaemic Myocardial Fibrosis	Cases with Record or Evidence of Hypertension			Others		
		Occupation			Occupation		
		Light	Active	Heavy	Light	Active	Heavy
45<60	No. of cases	135	130	41	567	575	365
	With large fibrous patch	2	2	0	14	7	2
	Rate %	*(1·5%)*	*(1·5%)*	*(0%)*	*2·5%*	*1·2%*	*(0·5%)*
	With smaller/multiple scars	29	12	2	25	18	12
	Rate %	*21·5%*	*9·2%*	*(4·9%)*	*4·4%*	*3·1%*	*3·3%*
	Total with ischaemic myocardial fibrosis	31	14	2	39	25	14
	Rate %	*23·0%*	*10·8%‖*	*(4·9%)*	*6·9%*	*4·3%*	*3·8%*
60–70	No. of cases	194	160	78	544	564	378
	With large fibrous patch	10	3	1	25	16	7
	Rate %	*5·2%*	*(1·9%)*	*(1·3%)*	*4·6%*	*2·8%*	*1·9%*
	With smaller/multiple scars	42	23	11	46	43	24
	Rate %	*21·6%*	*14·4%*	*14·1%*	*8·5%*	*7·6%*	*6·3%*
	Total with ischaemic myocardial fibrosis	52	26	12	71	59	31
	Rate %	*26·8%*	*16·3%*	*15·4%*	*13·1%*	*10·5%*	*8·2%*

Tests of Significance

	Hypertensives	Others
Line 1	—*	0·02>p>0·01
,, 2	0·01>p>0·001	—*
,, 3	0·01>p>0·001	0·02>p>0·01
,, 4	—*	0·02>p>0·01
,, 5	0·05>p>0·02	—*
,, 6	0·01>p>0·001	0·02>p>0·01

This table amalgamates the "basal" and "high" coronary artery disease Groups C and B, and corresponds with Table I. 0 and *0%*=No cases with ischaemic myocardial fibrosis.

Tests were for trends in percentages from "light" through "active" to "heavy" occupations (cf. footnote to Table I). * Trend not significant—i.e., p>0·05.

TABLE V.—*Coronary Artery Disease by Physical Activity of Occupation.* 3,800 *Non-coronary Deaths. Males Aged* 45–70

Coronary Artery Disease		"Basal" Group			"High" Coronary Artery Disease Group			All Non-Coronary Deaths		
		Occupation			Occupation			Occupation		
		Light	Active	Heavy	Light	Active	Heavy	Light	Active	Heavy
No. of cases:		995	1,034	668	445	395	194	1,440	1,429	862
(1) Coronary atherosclerosis present	Rate %	85	82	82	91	90	86	87	84	83
(2) Much coronary atherosclerosis with focal obstruction ("severe disease")	Rate %	10	9	10	24	17	22	14	11	13
(3) Much coronary atherosclerosis without focal obstruction	Rate %	5·7	6·0	4·6	9·0	8·4	9·3	6·7	6·6	5·7
(4) Calcification present	Rate %	19	18	18	32	26	31	23	20	21
(5) Focal obstruction present including	Rate %	21	16	19	34	28	32	25	19	22
(6) Complete or near-complete occlusion of a main coronary artery	Rate %	3·7	3·0	2·5	10·3	7·3	5·7	5·8*	4·2	3·2

The figures in the last panel cannot be used directly as indicators, however crude, of the overall prevalence of coronary artery disease, and of its various manifestations, in the whole middle-aged male population of Britain. Even if the dead can be taken at all to represent the situation in the living, it must be remembered that deaths from clinical coronary heart disease (Group A) have not been considered so far. The great majority of these would of course show severe coronary artery disease, coronary occlusions, etc.; and, whatever proportion of such cases were added to set up a "model" of the total population, the totals of all 6 indicators, except (3), in the last panel would surely be raised. On the other hand, *deaths* from severe hypertension, as in Group B, are very likely *over*-represented. However that may be, it seems probable from what is known of the occurrence of clinical coronary heart disease in different occupations that the excess here reported of coronary occlusions among light occupations may be an underestimate. By the same token, there may well be some excess of severe coronary artery disease among light workers in the population as a whole.

* 0·02>p>0·01.

trend. But the picture is quite different in the smaller/multiple scars. Among the hypertensives the prevalence of this focal myocardial fibrosis was very high in light workers —22% of these patients aged 45–70 (*21.5%* and *21.6%*) showed it. This rate is higher than that found in the active and heavy workers with hypertension, and much higher than in all with no record or evidence of hypertension (Others in Table). The effects are again clearer at 45<60 years; the light occupations showed these small scars almost *three* times more often at this age than the rest with hypertension, and *six* times more than the others without hypertension. At 60–70 years the figures are *one and a half* times, and *three* times, respectively. Indeed, this special excess of small, multiple scars *in light workers* with hypertension is largely responsible for the higher overall rate of such scars seen in hypertensives as a whole (Table III) when they are compared with the "others." (These "others" without record or evidence of hypertension, it is interesting, showed little variation of focal myocardial fibrosis with occupation among themselves, but what trend there was is also in the expected direction.) In brief, however,

The physical activity factor is clearly evident in the occurrence of smaller/multiple scars only in association with hypertension. At ages 45–70, light workers with hypertension showed these scars twice as often as active and heavy workers with hypertension, and five times more than all without record or evidence of hypertension. The excess in light occupations is, again, greater at 45<60 years than at 60–70.

Coronary Artery Disease

The next question, of course, is whether these various occupational differences in the prevalence of ischaemic heart disease are associated with corresponding differences in the prevalence of coronary artery disease and, in particular, of coronary narrowing. The pathogenesis of ischaemic myocardial fibrosis may be regarded for the present as coronary insufficiency, and the basic pathology is "atheroma" or "atherosclerosis" (the terms are interchangeable in Britain —and equally unsatisfactory) with focal coronary obstruction. Most ischaemic scars, it will be recalled, were associated with topical coronary narrowing, the large fibrous patches more commonly with complete or near-complete occlusions, the smaller/multiple scars with lesser degrees of coronary narrowing.

Statistical analysis of the condition of the coronary arteries in the 5,000 reports has only been started, and it will inevitably be on less sure ground than with myocardial fibrosis. Meanwhile, Table V presents some preliminary indices of macroscopic disease in the main arteries and large branches[8 12 16 17 18 22 26 37 38 39 42 47 67] firstly for the basal group C and then for the high coronary artery disease group B, the main classification of the inquiry as a whole. These are the indices:*

(1) The presence of any reported coronary atheroma. Macroscopic intimal disease was reported in 85% of the cases in the light occupations of the basal group, 82% in the active occupations, etc.

(2) The proportion with severe coronary atherosclerosis, using mainly a simple quantitative five-point scale of "none," "little," "moderate," "much," "indefinite" disease. The minimum to qualify as "severe" was (*a*) "much" atheroma throughout the coronary arteries with large or confluent plaque formation—superficial flecking or streaking alone did not count—showing also (*b*) some focal obstruction.

(3) The presence of much mural disease without encroachment upon the lumen. Cases with arterial dilatation were also included here.

(4) The presence of calcification.

(5) The proportion with coronary obstruction—that is, lumen stenosis or narrowing of any degree; and including

(6) Complete occlusion or near-complete (e.g., "admitting fine probe only") of a main coronary artery (left, left anterior descending, circumflex, right). This alone was called "coronary occlusion."

Diffuse intimal fibrous thickening, by itself, was ignored.

There is much in Table V, but attention is here paid only to the frequency of coronary artery disease by occupation. Both in the basal group and in the cases of the high coronary artery disease group—Table V corresponds to Table I but is set out horizontally—gross coronary artery disease (1), (2), (3), and (4) is exceedingly common: however, there is no occupational trend of any interest. Index (5) again reveals no material difference in the overall frequency of coronary obstruction among the occupation groups. In terms of one of the original hopes in the design of the inquiry the stability of these various indices of coronary artery disease is reassuring—if for other reasons disappointing! The first observation of note is in (6), the greater frequency of complete or near-complete occlusions in light occupations (5.8%) compared with heavy (3.2%). The rate of coronary occlusion, as defined, is about the same in light workers aged 45<60 as in heavy workers 10–15 years older (Table VI). Straightaway, however, it is obvious that the excess of occlusion in light workers is less than the excess of large healed infarcts already reported in Table II.

Comparison of the condition of the coronary arteries in cases with *hypertension* and in others showed much more atherosclerosis

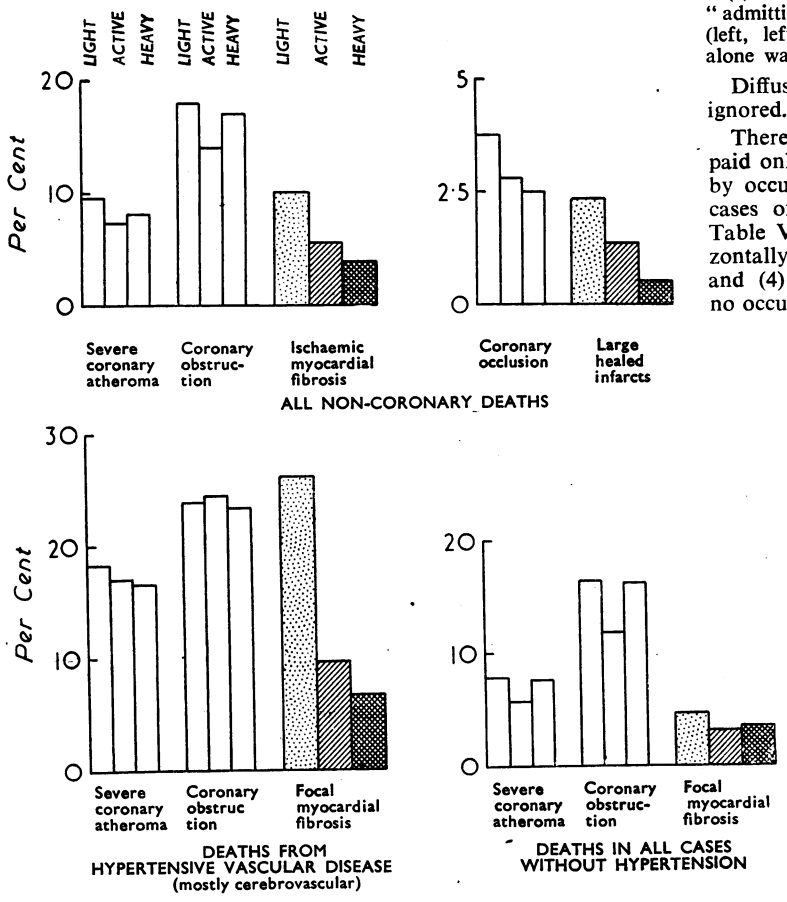

FIG. 1.—Coronary artery disease, ischaemic heart disease, and physical activity of occupation. 1,800 non-coronary deaths. Males aged 45<60 years.

*The Report of the World Health Organization's Study Group on the Classification of Atherosclerotic Lesions (*Wld Hlth Org. techn. Rep. Ser.*, 1958, 143) became available too late for use in this analysis.

TABLE VI.—*Coronary Occlusion.* 3,800 *Non-coronary Deaths. Men*

Ages	Occupation		
	Light	Active	Heavy
45<60	3·8%	2·8%	2·5%
60–70	7·6%	5·5%	3·9%

TABLE VII.—*Severe Coronary Atherosclerosis.* 3,800 *Non-coronary Deaths. Males Aged* 45–70

Cases	Occupation		
	Light	Active	Heavy
With hypertension	22%	19%	19%
No record or evidence of hypertension	12%	9%	12%

in the hypertensive throughout 45–70 years of age.[6 26 54] For example, the proportion with severe coronary atherosclerosis, as previously defined, was as shown in Table VII. The prevalence of coronary occlusions was higher in the hypertensive, and it was greatest again in the light occupations. There was no occupational trend, however, in the frequency of lesser degrees of coronary narrowing among the hypertensives; though, as stated above, these cases showed a strong light-heavy trend in the frequency of focal myocardial fibrosis, and the small/multiple scars are particularly associated with such lesser narrowing.

Fig. 1 illustrates these points in the most interesting cases, men under 60. If all such cases are taken together, there is no particular difference with occupation in the prevalence of severe coronary artery disease, or in the overall prevalence of coronary obstruction, but quite a clear trend in ischaemic scarring. There is a gradient with occupation in the frequency of complete or near-complete coronary occlusions—notice the change of scale—but a steeper one in the large healed infarcts. It is striking how, with similar occupational frequencies of coronary obstruction, the hypertensive cases (the most important cases in Group B have been used for this illustration—the deaths actually from hypertensive vascular disease, mostly cerebral) show a marked occupational difference in the frequency of focal myocardial fibrosis. On the other hand, in the cases without hypertension there are again similar prevalences of arterial obstruction in the occupation groups but, now, very little occupational trend in such scars. (The contrast with focal myocardial fibrosis is the same if the prevalence of lesser coronary narrowing alone is included.) It looks, then, as if much of the variation in ischaemic myocardial scarring with physical activity of work does not depend on occupational differences of, at any rate, *gross* coronary artery disease. Or, another way of looking at the data, there is no suggestion in the present material that habitual physical exertion materially affects coronary atheroma, but an indication that it is related to the frequency of coronary occlusion.*

**Hypertension.* We have shown that focal myocardial fibrosis was commoner in hypertensive cases than in those without record or evidence of hypertension and that, among the hypertensives, light workers showed substantially more of these small scars than did the active and heavy workers. There is another point of interest. In this material, the proportion of cases with hypertension among heavy workers, throughout 45–70 years of age but more so in the younger men, is smaller than among light workers. In Group C, at 45<60, 3% of the men in heavy occupations showed it, compared with 8% in light; in Group B, 39% compared with 50%.[49] "Following through" this observation from the Group C through Group B into Group A, it may be seen in Table XII (next footnote) that the proportion with hypertension in these deaths *from* coronary heart disease, etc., was lower in heavy occupations than the others. Broadly speaking, in the material as a whole the frequency of hypertension in heavy workers aged 60–70 was the same as in light workers of 45<60 years of age.

Two special factors, then, may be operating in relation to hypertension: heavy workers possibly have less of it; and light workers with hypertension may be specially liable to cardiac damage. The suggestion that the combination of high blood pressure and light occupation may be particularly important, may provide a "way in" for the study of the complicated relations of hypertension with coronary heart disease.

Occupation and "Social Class"

The distribution, in Britain, of mortality from coronary heart disease by social class is well known. First established in 1930–2,[56] the most recent figures (Table VIII) relate to 1949–53.

TABLE VIII

Social Class	Scotland[46 59] Males, Aged 15 and Over	England and Wales[33 57] Males, Aged 20–64
I	167	147
II	119	110
III	109	105
IV	85	79
V	79	89
All classes	100	100

The mortality in social class I (Osler's[52] "better classes") when adjusted for age, as in the above, is much higher than in the rest and about twice that in classes IV and V.

"Social class" is intended to reflect "general standing within the community," social class I including the leading professions and business, class III the craftsmen and skilled workers, and class V the unskilled. Classes II and IV are intermediate. It seems clear that, for men in the age range dealt with, "class" also provides an economic grading.

The 3,800 non-coronary deaths of the present inquiry were analysed by social class[58]: the present approach has the advantage that the "level" or "plane" of description and diagnosis is probably the same for all classes. The result in Table IX shows a steady fall in ischaemic myocardial fibrosis from 13.3% to 7.8%. This trend, however, disappears when the social classes are analysed in terms of the physical activity of the occupations in them. Table X(A), read *downwards*, shows that the frequency of the fibrosis in these light workers of similar ages is about the same in social classes I, II, III, and IV—that is, there is no

TABLE IX.—*Proportions With Ischaemic Myocardial Fibrosis by Social Class.* 3,800 *Non-coronary Deaths. Males Aged* 45–70

Social Class	No.	Proportion with Ischaemic Myocardial Fibrosis
I	98	*13·3%*
II	510	*12·1%*
III	1,847	*10·5%*
IV	605	*9·2%*
V	683	*7·8%*

The trend of the proportions with ischaemic myocardial fibrosis is statistically significant ($p < 0.01$).

Occupations were allocated to social class in accordance with the General Register Office *Classification of Occupations*, 1950.[58] 102 cases could not be so allocated because of insufficient information.

TABLE X.—*Proportions with Ischaemic Myocardial Fibrosis by Social Class and Physical Activity of Occupation.* 3,800 *Non-coronary Deaths. Males Aged* 45–70.

Social Class	Light Occupations %	Active Occupations %	Heavy Occupations %	All %
(A) Ischaemic Myocardial Fibrosis by Social Class and Physical Activity of Occupation:				
I	*13·7*	*(0)*	—*	*13·3* } *12·3*
II	*13·4*	*9·2*	*(0)*	*12·1* }
III	*13·8*	*8·0*	*8·2*	*10·5*
IV	*13·5*	*10·1*	*4·9*	*9·1*
V	*8·9*	*9·0*	*7·1*	*7·8*
All	*13·4*	*8·7*	*6·8*	*10·0*
(B) Large Healed Infarcts by Social Class and Physical Activity of Occupation:				
I and II ..	*4·3*	*(2·1)*	*(0)*	*3·8*
III	*3·2*	*1·8*	*(1·2)*	*2·3*
IV	*(3·6)*	*2·1*	*(1·5)*	*2·3*
V	*(2·2)*	*(2·2)*	*(1·0)*	*1·5*
(C) Focal Myocardial Fibrosis by Social Class and Physical Activity of Occupation:				
I and II ..	*9·1*	*6·9*	*(0)*	*8·6*
III	*10·6*	*6·2*	*6·9*	*8·2*
IV	*9·9*	*8·0*	*3·4*	*6·8*
V	*6·7*	*6·7*	*6·1*	*6·3*

*No cases at all.

variation with social class and, incidentally, no indication of the particular excess seen in the national mortality data among social class I. There is again no class trend in the active occupations (middle column of Table X(A)) and less than none in the heavy. But reading Table X(A) *across*, the light-heavy trend previously reported is pretty clear *within* each social class, the light occupations showing more with scars than the active in class II, and the light in class III and class IV a higher prevalence than the active and heavy in these classes. That is to say, among men of comparable social-economic circumstances, those in light occupations showed a clear excess of ischaemic myocardial fibrosis.[9 43] As would be expected—Tables X(B) and (C)—the reduction in the frequency of fibrosis that occurs with physical activity of occupation *within* the social classes is more evident for the large healed infarcts; though the numbers in Table X(B) are impossibly small.

The irregularities in these tables are also interesting. Social class V stands out on its own, both in showing low rates among light workers and in showing little trend with occupation. It is just in these men that the classification of occupations by "activity" is at its weakest. On the one hand, the light occupations—for example, lift attendant, night watchman—are reserved mostly for disabled persons; therefore the last and "light" job, more than in other classes, is apt to be an inaccurate indicator of the main or usual job during working life. On the other hand, all "general labourers" were perforce graded as "heavy" workers, though, as is well known, many an elderly "labourer," officially or unofficially disabled, does little more than odd jobs on a building site and the like, and may have been so occupied for years before his death. There is an irregularity in social class III because some very heavy workers—for example, stonemasons and boilermakers—have a high prevalence of scars, high for heavy workers; a hint here, perhaps, of the dangers of *too much* physical activity.[48] The rate for heavy occupations in class IV is particularly low because agricultural workers show little ischaemic fibrosis—little even for heavy workers. These special features of classes III and IV persist when the prevalence of scarring in these particular occupations is compared also with that of other heavy workers in the same

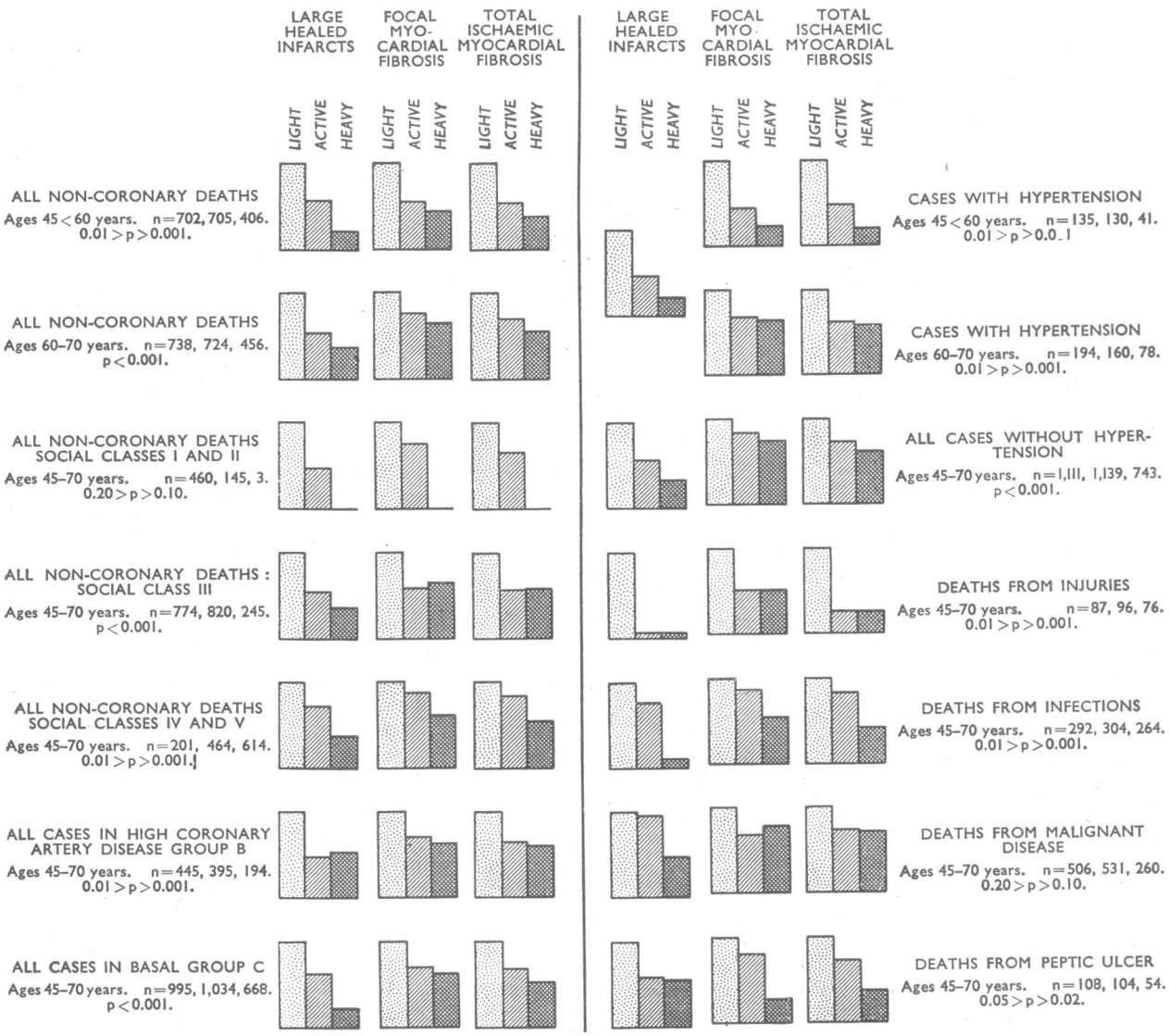

FIG. 2.—Frequency of ischaemic myocardial fibrosis, by physical activity of occupation. 3,800 non-coronary deaths. Males aged 45–70 years. In each block of three columns the first column is the rate among light occupations regarded as 100%. In the second column (active occupations) and the third column (heavy) the rates have been recalculated as proportions of the rate among light occupations.

In each line the first block represents the large fibrous patches; the second block represents the smaller/multiple scars; and the third is the total of ischaemic myocardial fibrosis.

n gives the numbers of cases in light, active, and heavy occupations in that order. The test of significance applies to the total of ischaemic myocardial fibrosis. In deaths from injuries active and heavy occupations have been amalgamated.

sets of necropsy reports, the kind of internal "control" that is so important in this type of study.[40]

In brief, *in this material* there is no evidence of any important "class" factor. Most of the social class trend in ischaemic myocardial fibrosis seems to arise from the distribution of "light" and "heavy" workers among the classes (Table XI), though there is evidence also of other and it may be more specific occupational factors affecting the class rates. The association of ischaemic myocardial fibrosis with physical activity of work in these data seems to be independent of standards of living, including obviously in the present instance levels of education and skill and possibly also of responsibility.

TABLE XI.—*Distribution of Occupations Within the Social Classes*

Social Class	Percentage of			Total
	Light Occupations	Active Occupations	Heavy Occupations	
I	97	3	—	98
II	72	28	1	510
III	42	44	13	1,847
IV	18	47	34	605
V	13	26	60	683

Summing up the 3,800 Non-coronary Deaths

Fig. 2 sums up the main findings. In each block the rate of ischaemic myocardial fibrosis in the light occupations is regarded as 100%, and the rates in active and heavy occupations are calculated as proportions of this. In each line the first block illustrates the prevalence of the large fibrous patch, the middle block that of the smaller scars, and the third is the total of ischaemic myocardial fibrosis. (In the first two lines of the second column dealing with hypertensive disease the data have been amalgamated for 45–70 years of age in the large healed infarcts, but distinguished by the two age groups in focal myocardial fibrosis.) There is, of course, considerable overlapping in these various extracts from the data, and some of the numbers—the total is given in each line for light, active, and heavy in that order—are small. The tests of statistical significance apply to the total with scars in each line.

The consistency of the pattern is striking and makes it unlikely that the association of ischaemic myocardial fibrosis, and particularly the large healed infarcts, with physical activity of occupation is the product of some gross bias in this necropsy material. There is quite conceivably an association between ischaemic myocardial fibrosis and the chances of dying and/or undergoing necropsy. But it is less conceivable that such an association could be systematically greater in light occupations than heavy, so that with equal real prevalence of fibrosis among occupations the rate would appear higher in the light. And it is difficult to conceive how such a bias could be effective in the wide variety of disease (and other categories) illustrated in Fig. 2. But, of course, bias can be "built-in" in goodness knows how many ways, and no individual study can deal with all of even the recognized sources. Other studies will need to be done, and also on large numbers, to repeat these observations and to permit still further and quite different subdivisions of the data.

Evidence from 1,200 Deaths from Coronary Heart Disease

As stated before, about 1,200 of the 5,000 reports in the inquiry were on deaths in which coronary heart disease was the main cause—coronary heart disease by itself, or coronary heart disease with hypertension or with other pathology (for example, the post-operative cases)—together with a small number of less-defined though related cardiac conditions. These 1,200 will be described elsewhere. Much less can be made of them because they raise acutely the intractable problem of selection of cases; problems that are of less moment, as just discussed, in conditions like ischaemic myocardial fibrosis which are not the main cause of death and are incidental and often chance findings at necropsy. Moreover, no base or denominator can be defined for the estimation of frequency *rates* of coronary heart disease—for example, by type of occupation. Less effort was therefore made to obtain a good national sample. Thus no request for co-operation was made to the coroners' pathologists in Greater London; though in the provinces many coroners' cases were included in the series of 25, and there were a fair number also, as a matter of fact, in the Metropolitan hospitals' series. However, the 1,200 deaths from coronary heart disease can be classified by occupation and ratios comparing the actual number of cases in each of the three occupation groups can be calculated. This was done.

There were 482 deaths from coronary heart disease and related conditions in light workers, 436 in active workers, and 230 in heavy workers, a ratio of 1.0:0.9:0.48; and there is little doubt, from previous inquiries by the unit,[39 43 45] that if the London area had been fully represented the excess of light occupations among deaths from coronary heart disease would have been greater still. Meanwhile it may be noted that the trend with occupation in deaths from coronary heart disease is greater in the cases with hypertension than in the others.

Fig. 3 sets out the occupational ratios of the coronary heart disease and related deaths (Group A), and for completeness the ratios of the cases with ischaemic myocardial fibrosis in the high coronary artery disease group B, then of the cases with such fibrosis in the basal group C. Fig. d gives the ratio (using again the numbers in light, active, and heavy occupations) of all these cases with evidence of ischaemic heart disease in Groups A, B, and C added together—that is, in the whole series of 5,000. This is 1.0:0.84:0.43. Fig. 3e is for the rest of the 5,000 reports, those showing no evidence of ischaemic heart disease—1.0:1.05:0.64; and this ratio is plainly not of a kind with the previous ($p<0.001$). For what such evidence is worth, then—and this is by no means the right way of asking this particular question—there is indication of higher mortality from clinical coronary heart disease among light workers.*

Discussion

An association has been demonstrated between physical activity/inactivity of work and one form of coronary heart disease, ischaemic myocardial fibrosis. Explanation of this may be attempted along several lines. First, that light occupation increases the incidence of ischaemic myocardial fibrosis, heavy jobs are protective. Second, that the association is effect rather than cause; on account of disability from myocardial ischaemia men give up heavy jobs for light ones and a higher prevalence of scarring is thereby created among light workers. Third, that the association is indirect:

*Other sums can be done with the data if required:

TABLE XII.—*Number of Cases of Ischaemic Heart Disease in a National Sample of 5,000 Necropsies. Males Aged 45–70*

Occupation	"Coronary" Deaths, Etc.		Non-Coronary Deaths, with Ischaemic Myocardial Fibrosis		Non-Coronary Deaths, With *No* Ischaemic Myocardial Fibrosis	Total
	Hypertension Present	Others	Large Healed Infarcts	Focal Myocardial Fibrosis		
Light (No.) ..	145	337	51	142	1,247	1,922
Active (No.) ..	127	309	28	96	1,305	1,865
Heavy (No.) ..	51	179	10	49	803	1,092
Total ..	1,148		376		3,355	4,879

160 cases were excluded for one reason or another, cf., Table I.

for example, susceptibility to coronary heart disease and individual choice of job may both be the product of host factors in constitution (and previous experience); or physical activity/inactivity may be reflections merely of the nervous strain of jobs, and it is this that really matters in coronary heart disease. All these processes, it could reasonably be proposed in the present state of knowledge, contribute to the community picture of coronary heart disease; but, of course, the first is the most interesting.

The present study sheds no light on personality factors, though we hope other inquiries in which we are engaged—on somatotype and occupation, for example—will do so.[44] No attempt has yet been made to classify the 1,700 different job descriptions in terms, say, of responsibility, of nervous strain—and emotional support. This might be done; but it is an appalling prospect, and the similarity of the rate of fibrosis among the professional and business men of class I to that found in the semi-skilled light workers of class IV does not encourage us to try. The study of psychological stress in relation to coronary heart disease still lacks an appropriate method (we have long thought that a forward-looking study among doctors from their late thirties or early forties is the most hopeful). The possibility that the high prevalence of fibrosis in light jobs is the result of transfer by men into these *because* of coronary insufficiency has not been directly considered. It can only be said that the evidence available gives no hint that such transfer, which must surely be common, explains all or even much of the occupational distribution found. Thus the excess of scarring among light workers is no greater at 60–70 years of age than at 45<60, and, indeed, for the large patches it is more evident in the younger men. Moreover, it may again be pertinent that the rate among the light occupations of social classes I and II, drift into which from heavy jobs in unlikely, is just as high as that in class III, where such drift is more likely, and class IV, where it is very likely. In social class V itself there was little if any excess among the light occupations, which is as reassuring as it was unexpected; because, as already said, it is just these jobs—messenger, lift attendant, night watchman, and the like—that "disabled" manual workers so often select, and drift into, which for lesser impairment is also very likely. But this difficult and important problem needs to be tackled in other ways: an attempt is now being made in this unit, for example, to determine the prevalence of quite silent coronary heart disease by electrocardiographic study of workers with contrasting physical activity of jobs.

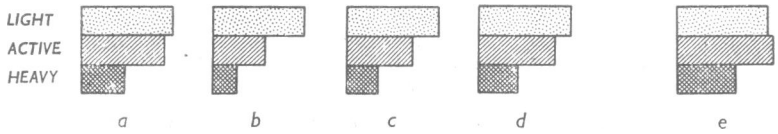

FIG. 3.—Ratios of the number of cases of ischaemic heart disease in the three occupational groups, the number in light occupations being regarded as 1. National sample of 5,000 necropsies. Males aged 45–70. Scotland, England and Wales, 1954–6. (*a*) Group A: Deaths from ischaemic heart disease, etc. (*b*) Ischaemic myocardial scars in cases of Group B. (*c*) Ischaemic myocardial scars in cases of Group C. (*d*) Showing *a*, *b*, and *c* added together. (*e*) All the cases without ischaemic heart disease.

Restatement of Hypothesis

Another piece of evidence has thus been provided in this report that confirms the general hypothesis, and using on this occasion quite different material from before. In the present data as a whole, and in every sizable category of it, *there was a lower prevalence of ischaemic myocardial fibrosis among men who had been in physically active and heavy jobs than among those in sedentary and light jobs.* Study of the detailed morbid anatomy of this social difference supports the second part of the original hypothesis. It is particularly in the prevalence of the large, often and for obvious reasons solitary, patch of fibrosis, the probable result it may be said of major and acute infarction (and homologue of sudden death in the bus driver ?) that light workers shows an excess. The heavy workers had less ischaemic fibrosis altogether, and relatively more of it took the form of smaller patches and small, often very small, scars. That is to say, in this material *ischaemic myocardial fibrosis is not so severe in physically active and heavy* workers. But the prevalence of these minor forms of myocardial fibrosis also was lower in active and heavy than in light occupations; which rather suggests that the excess of angina previously noted in physically active men (bus conductors and postmen) is more likely to be a matter of symptom formation, of the disease being elicited and made manifest in them by their physical effort, rather than of an absolute excess of any particular pathology in active workers.[43]

Evidence can now be advanced relating physical activity of occupation to the incidence of coronary heart disease, to sudden death and other rapidly fatal cardiac infarction, to the prognosis in the survivors of the first clinical episode, to the prevalence of the disease, to total coronary mortality in middle-age, and to several forms of ischaemic myocardial fibrosis. The time seems to have come, in view of the convergence of such varied and independent evidence, for a restatement of the general hypothesis in causal terms: *Physical activity of work is a protection against coronary (ischaemic) heart disease. Men in physically active jobs have less coronary heart disease during middle-age, what disease they have is less severe, and they develop it later than men in physically inactive jobs.*

It must be emphasized, however, that, overall, the evidence on this problem is quite conflicting.[2 5 7 9 11 22 23 24 27 34 45 62 63 64 66 69] In several studies coronary heart disease has been found to be associated with physical activity/inactivity of occupation in the expected way. In as many, no relationship was demonstrated, or an equivocal or opposite one; and why this is so is still quite unclear. Different methods are being used by different investigators and different aspects of the disease are being studied. Moreover, the "epidemic constitution" may be different in the U.S.A. from the U.K. —the important causes may be present in different degrees and in different combinations.[22]

Some *speculations* may be worth airing here. The diminishing physical activity of work during the present century may be one of the causes of the increasing incidence of coronary heart disease that seems to be occurring, and, if the increase is as modest as is now often suggested, a principal cause. This question might be studied through the historical experiences of "underdeveloped" populations becoming "westernized." If it is argued that constitution and mesomorphy is the crucial variable, unexpressed mesomorphy, the disuse of large-muscle masses, may be said to be one of the characteristic biological consequences of industrialization. Then, it may be asked whether regular physical activity *outside* work protects against coronary heart disease in middle-age. There is no information, meanwhile, on the relations, if any, between physical exertion in leisure, for example, and the incidence or prevalence of coronary heart disease; but plainly this is the main implication of observations such as the present for preventive medicine, and means of testing such a hypothesis must be found. Typical of to-day's problems in epidemiology, this will involve *ad hoc* studies of large numbers of individuals; and even preliminary indirect studies of coronary heart disease and leisure activities in ready-made social groups such as the social "classes" cannot be made.

A final speculation may be advanced that *habitual physical activity is a general factor of cardiovascular health in middle-aged men* since it may be related to blood lipid levels, to clotting and to fibrinolysis, to diabetes, to hypertension and its complications, to coronary occlusion, and to ischaemic heart disease.[3 10 20 25 28 29 30 31 35 40 50 52 68] Regular physical exercise could be one of the "ways of life"

that promote health in middle-age, and ischaemic heart disease may be in some degree a deprivation syndrome, a deficiency disease.

Mechanisms of the Occupational Difference

Nothing corresponding to the differences with physical activity which have been found in experimental atherogenesis[31 50] were observed in the present material. Clearly the main causes of coronary atherosclerosis in man have to be sought elsewhere—for example, in hypertension and, the principal field of interest at present, in diet and lipid metabolism. There is more coronary occlusion among the light occupations, which is particularly interesting because the factor of intracoronary thrombosis may be particularly associated with these complications of atheroma[16 17 18 38] and the present findings may be another indication of the relationship between physical activity and intravascular clotting.[5 28 29 50] If, as many would argue, the pathogenesis of all degrees of coronary obstruction is the same, then, it would appear, the capacity to cope and to resolve such obstructions must vary with occcupation so that actual occlusion of large coronary vessels is less common in active and heavy workers than in sedentary and light workers. However that may be, the excess of coronary occlusion is inadequate to explain the excess of large healed infarcts in light occupations; and the other indicators of coronary artery disease so far studied do not help at all to account for the occupational distribution of the scarring. Mechanisms of the occupational differences in ischaemic myocardial fibrosis need therefore to be postulated that operate additionally to those of gross coronary artery disease,[10 25 32 55 62] in general and local haemodynamics, it may be, in neuro-hormonal mechanisms, in special relationships with hypertension, in the physiological capacity of the main arteries and branches, in intercoronary collateral circulation.[4 19 20 61 70] Recently it has been observed that effective collateral vessels in dogs with coronary obstruction develop more profusely if the dogs are exercised; functional myocardial hypoxia might be the mechanism relating physical activity to collateral formation.[19 20]

Distinction of Ischaemic Heart Disease from Coronary Artery Disease

In the first report of the present series[39] it was suggested that the recent history of coronary thrombosis/myocardial infarction on the one hand, and that of coronary atheroma on the other, are different. The former, there is good reason to believe, have increased during this century; there is no evidence whatever in Britain that the latter has, and, indeed, coronary atheroma may have declined here during the past 40 years.[59 60] The historical material, that is to say, suggests that ischaemic heart disease is not a simple, proportional function of coronary atherosclerosis. The evidence now presented goes further in dissociating the heart disease from the arterial disease, because it suggests that even when the latter is analysed into obstructive and non-obstructive processes nothing like a 1:1 relationship emerges between myocardial damage and the *obstructive* arterial disease. Social grouping of the pathological data (by occupation) shows substantial differences in the frequency of myocardial fibrosis which correspond only moderately to the frequency of coronary occlusions and correspond not at all to the frequency of lesser narrowing of the coronary lumen. Such identification of syndromes from undifferentiated clinical material—in this instance of ischaemic heart disease from coronary artery disease—is one of the uses of epidemiology, and theoretically is of much interest.[40]

A Word on the Method

Finally, it may be remarked that post-mortem reports are just about the most difficult medium for epidemiological analysis: many sources of bias in the material are known; as many, it must be assumed, are quite unknown. The use of necropsy data finds its main warrant in asking questions, such as the present report illustrates, that cannot be asked by any other method. But the limitations of any one set of data, with its inevitably imperfect "population" samples and incomplete ascertainment of disease, make it very necessary that studies are repeated in quite different situations.

Summary and Conclusions

This report is one of a series on the epidemiology of coronary disease, and it continues the study of coronary (ischaemic) heart disease in relation to physical activity of work.

The hypothesis was previously stated that *men in physically active jobs have a lower incidence of coronary heart disease in middle-age than men in physically inactive jobs. More important, the disease is not so severe in physically active workers, tending to present in them in relatively benign forms.* The investigation now reported deals with the relations between physical activity of work and the frequency of ischaemic myocardial fibrosis in a sample of 3,800 middle-aged men dying from causes other than coronary heart disease.

All departments of morbid anatomy in the hospitals of the National Health Service of Scotland, England, and Wales were invited to take part in a national necropsy survey during 1954–6 by sending particulars in standard form of the naked-eye findings on the coronary arteries, the myocardium, and other specified items for a consecutive series of 25 males aged 45–70 years coming to necropsy. 206 departments co-operated, more than 85% of those eligible. About 5,000 reports were received, made up in round numbers thus: 1,200 deaths from coronary heart disease, etc. (Group A); 1,000 deaths from conditions with a specially high prevalence of coronary artery disease—for example, deaths caused by hypertension and its complications, deaths in diabetics, deaths from arterial disease in other sites (Group B); and, the remainder, 2,800 deaths from miscellaneous conditions, their main causes having no particular association with coronary artery disease—for example, injuries, infections, cancer (Group C). Groups B and C comprise 3,800 non-coronary deaths.

Two broad types of *ischaemic myocardial fibrosis* in the left ventricle and interventricular septum are described: (1) the large, discrete, often solitary patch which is probably the end-result of major and acute infarction and is associated particularly with complete or near-complete occlusion in a main coronary artery (90 cases among the 3,800 non-coronary deaths); and (2) smaller, commonly multiple scars, the result, it may be, of more chronic and less severe ischaemia, and occurring in hearts showing usually lesser focal narrowings of coronary arteries or branches (290 cases).

Cases were classified as "*hypertensive*" or "*other*" on the basis of the clinical and pathological information provided. About half the cases in Group B and 10% of those in Group C were thus regarded as hypertensive. The large healed infarcts—type 1 fibrosis above—were found equally in hypertensive and other cases; focal myocardial fibrosis of type 2 was commoner in hypertensive cases than in those without record or evidence of hypertension.

The last *occupation* of each man was graded on a three-point scale in terms of the physical activity the job typically involved as "light," "active," or "heavy."

Relation of Fibrosis to Occupation.—Ischaemic myocardial fibrosis in these 3,800 necropsies was commoner in the light occupations than in the active and heavy. Scarring among light workers aged 45<60 was as common as in heavy workers 10 to 15 years older.

The two main types of ischaemic fibrosis were differently related to physical activity of occupation:

The *large healed infarcts,* type 1 above, showed a strong gradient with occupation, being *three* times commoner in light workers than in heavy workers overall; *four to five* times commoner at 45<60 years of age, and *two to three* times commoner at 60–70 years. The excess of these severe ischaemic lesions in light workers was evident in Group B and in Group C, in hypertensive cases as in others, in every sizable medical and social category that was identified.

Focal myocardial fibrosis, type 2, was strongly associated with occupation only in hypertensive cases. Under 60 years of age, the light occupations among the hypertensives showed these small, multiple scars almost *three* times more often than active and heavy workers with hypertension, and about *six* times oftener than all without record or evidence of hypertension. The corresponding figures at 60–70 years of age were *one and a half* and *three* times.

In brief, ischaemic myocardial fibrosis was commoner in light occupations and it appeared earlier in them. It was also more severe among light workers, particularly at younger ages.

Coronary Artery Disease.—The pathological basis of ischaemic myocardial fibrosis is coronary "atheroma" or "atherosclerosis" with impairment of the coronary circulation. In the present data the overall prevalence of coronary atheroma was exceedingly high, and, little, moderate, or much, it did not vary with physical activity of occupation. Coronary narrowing was similarly common in all occupation groups. But actual occlusion of a main coronary artery, complete or near-complete, was commoner in sedentary and light workers than in the active and heavy. This excess of coronary occlusion was seen in the younger men and older, in hypertensive cases as in those without record or evidence of hypertension. In general, the frequency of coronary occlusion in light workers aged 45<60 was the same as that in heavy workers aged 60–70.

The main results of the inquiry may therefore be stated as follows: atheroma of coronary walls, no relationship with physical activity of occupation; occlusion of coronary lumen, some relationship; ischaemic myocardial fibrosis, much relationship.

Ischaemic Heart Disease and Coronary Artery Disease. — The excess of coronary occlusion among the light occupations was smaller than the excess of large healed infarcts found in them. Among hypertensive cases there was no trend with occupation in the frequency of lesser degrees of coronary narrowing, although, as stated, the frequency of focal myocardial fibrosis was greater in light workers with hypertension than in active and heavy workers with hypertension. That is to say, in the presence of coronary narrowing and occlusion light occupations showed more ischaemic lesions of the myocardium than did active and heavy workers. Analysis of this sample of pathological data by social (occupation) categories thus discloses only very limited correlation between the frequency of myocardial scarring and the condition of the coronary arteries. This is a further suggestion that ischaemic heart disease is not a simple function of coronary artery disease.

Hypertension was less common and occurred at later ages (10–15 years later) in the heavy occupations than in the rest; the excess of coronary occlusions in light workers was seen in hypertensive cases as in the others; a specially high prevalence of small ischaemic myocardial scars in light workers with hypertension has been described. There are suggestions thus of multiple connexions between physical activity of occupation and the blood pressure which need to be followed up.

The expected trend of ischaemic myocardial fibrosis with *social class* was found, the rate falling from 13.3% in class I through 10.5% in class III to 7.8% in class V. This trend, however, disappeared when the social classes were broken down into categories of physical activity, and the occupations of which each class is composed were graded as "light," "active," or "heavy." Light workers in classes I, II, III, and IV all had similar prevalence of ischaemic scarring, and there was no class trend in the fibrosis among active workers or in heavy workers. On the other hand, the relationship of fibrosis to physical activity of occupation was independent of social-economic circumstances, being evident within single social classes: light occupations in class II showed more ischaemic fibrosis than the active in that class, light skilled workers a higher rate than the active and heavy occupations in class III, the light occupations of class IV more scarring than the active and heavy in that class. The overall trend with social class in this material is largely a function of the different proportions of light and heavy workers in the different classes.

Evidence has now been produced relating several aspects of clinical and subclinical coronary heart disease to physical activity of work. The general *hypothesis* may therefore be restated in *causal* terms that *physical activity of work is a protection against coronary (ischaemic) heart disease. Men in physically active jobs have less coronary heart disease during middle-age, what disease they have is less severe, and they develop it later than men in physically inactive jobs.* Since there are suggestions of other connexions between physical activity of work and cardiovascular disease of middle-age, and multiplying evidence from laboratory experiment of the beneficial effects of exercise on relevant cardiovascular physiology and pathology, the *speculation* may be advanced that habitual physical activity is a general factor of cardiovascular health in middle-age, and that coronary heart disease is in some respects a deprivation syndrome, a deficiency disease. In the present material the hearts of sedentary and light workers showed the pathology of the hearts of heavy workers 10–15 years older.

Perspective.—Coronary heart disease among heavy workers, though less common, less severe, and occurring later than among light workers, is nevertheless common enough to constitute a major health problem in them: absolutely; and in comparison with the greater freedom from the disease heavy workers, like the rest of the population, seem to have enjoyed earlier this century and in many countries apparently still enjoy.

We are greatly obliged to many for their participation and help in this inquiry: to the pathologists, and their medical and lay colleagues, of the hospitals listed in the Appendix, with associated hospitals, for a prodigious amount of painstaking work, carried out often, we know, in circumstances of considerable difficulty; to Dr. K. Ball, Professor T. Crawford, Dr. I. Doniach, Professor J. Duguid, Professor G. L. Montgomery, Dr. M. F. Oliver, Professor D. S. Russell, and Dr. C. S. Treip for advice on the design of the Report Form and/or pilot work; Dr. R. Murray, formerly H.M. Medical Inspector of Factories and now of the I.L.O., and Dr. D. Turner, of the Medical Research Council's Environmental Hygiene Research Unit, for the classification of occupations; the Factory Department of the Ministry of Labour and Dr. E. R. Bransby, of the Ministry of Health, for advice on this problem; Dr. Richard Doll and Professor A. Bradford Hill for access to

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APPENDIX: PRINCIPAL PARTICIPATING HOSPITALS

SCOTLAND

NORTHERN REGION:
Royal Northern Infirmary, Inverness.

NORTH-EASTERN REGION:
Teaching Hospitals: Aberdeen Royal Infirmary; Woodend General Hospital, Aberdeen.

EASTERN REGION:
Teaching Hospitals: Dundee Royal Infirmary; Maryfield Hospital, Dundee; Perth Royal Infirmary.

SOUTH-EASTERN REGION:
Teaching Hospitals: Royal Infirmary, Edinburgh; Western, Northern, and Eastern General Hospitals; Leith Hospital.
Cameron Hospital, Windygates, Fife.

WESTERN REGION:
Teaching Hospitals: Western Infirmary, Glasgow; Royal Infirmary, Glasgow; Victoria Infirmary, Glasgow; Southern General Infirmary, Glasgow; Stobhill Hospital, Glasgow.
Kilmarnock Infirmary; Royal Infirmary, Dumfries; Stirling Royal Infirmary.

ENGLAND

Teaching Hospitals.—Manchester Royal Infirmary; Liverpool Royal Infirmary; Royal Victoria Infirmary, Newcastle upon Tyne; Queen Elizabeth Hospital, Birmingham; Accident Hospital, Birmingham; the General Hospital, Birmingham; Bristol Royal Infirmary; Addenbrooke's Hospital, Cambridge; Radcliffe Infirmary, Oxford.

Manchester Region.—Royal Lancaster Infirmary; Westmorland County Hospital, Kendal; Royal Infirmary, Blackburn; General Hospital, Burnley; Bolton Royal Infirmary; Hope Hospital, Salford; Salford Royal Hospital; Crumpsall Hospital, Manchester; Park Hospital, Davyhulme; Withington Hospital, Manchester; Stockport Infirmary; Macclesfield Hospital.

Liverpool Region.—County Hospital, Whiston; Walton Hospital, Liverpool; Sefton General Hospital, Liverpool; General Hospital, Birkenhead; Chester Royal Infirmary.

Newcastle Region.—Newcastle General Hospital; General Hospital, South Shields; Preston Hospital; Hexham General Hospital; Royal Infirmary, Sunderland; Shotley Bridge General Hospital; Dryburn Hospital, Durham; Bishop Auckland General Hospital; Sedgefield General Hospital; Darlington Memorial Hospital; West Hartlepool General Hospital; Cumberland Infirmary, Carlisle.

Birmingham Region.—Selly Oak Hospital, Birmingham; Dudley Road Hospital, Birmingham; Staffordshire General Infirmary; City General Hospital, Stoke-on-Trent; North Staffordshire Royal Infirmary; Walsall General Hospital; West Bromwich and District General Hospital; the Royal Hospital, Wolverhampton; Royal Salop Infirmary, Shrewsbury; Warwick General Hospital; General Hospital, Burton-on-Trent; Worcester Royal Infirmary; County Hospital, Hereford.

Leeds Region.—Scarborough Hospital; County Hospital, York; Hull Royal Infirmary; Clayton Hospital, Wakefield; Huddersfield Royal Infirmary; Royal Halifax Infirmary; St. James Hospital, Leeds; Victoria Hospital, Keighley; Otley General Hospital; Harrogate General Hospital.

Bristol Region.—Southmead General Hospital, Bristol; Frenchay Hospital, Bristol; Cheltenham General Hospital; Manor Hospital, Bath; Musgrove Park Hospital, Taunton; Royal Devon and Exeter Hospital; North Devon Infirmary; Torbay Hospital, Torquay; Royal Cornwall Infirmary, Truro; St. Martin's, Bath; Redruth Miners' and General Hospital, Camborne; West Cornwall Hospital, Penzance.

Sheffield Region.—City General Hospital, Sheffield; St. Helen Hospital, Barnsley; Doncaster Royal Infirmary; Chesterfield Royal Hospital; Derbyshire Royal Infirmary; Nottingham General Hospital; Leicester Royal Infirmary; Lincoln County Hospital; Grimsby General Hospital; Leicester General Hospital; Victoria Hospital, Worksop.

Oxford Region.—Royal Berkshire Hospital, Reading; Kettering General Hospital; Victoria Hospital, Swindon.

East Anglia Region.—Newmarket General Hospital; West Suffolk General Hospital; Ipswich and East Suffolk Hospital; Borough General Hospital, Ipswich; Norfolk and Norwich Hospital.

London Teaching Hospitals.—Charing Cross Hospital; Guy's Hospital; London Hospital; King's College Hospital; Royal Free Hospital; St. Bartholomew's Hospital; St. George's Hospital; St. Mary's Hospital, Paddington; St. Thomas's Hospital; University College Hospital; West London Hospital; Royal Marsden Hospital; Hammersmith Hospital.

North-west Metropolitan Region.—Bedford General Hospital; Luton and Dunstable Hospital, Luton; Lister Hospital, Hitchin; Canadian Red Cross Memorial Hospital, Taplow, Bucks; King Edward VII Hospital, Windsor; Barnet General Hospital; St. Albans City Hospital; Peace Memorial Hospital, Watford; Hillingdon Hospital, Uxbridge; West Middlesex Hospital, Isleworth; King Edward Memorial Hospital, Ealing; Central Middlesex Hospital; Willesden General Hospital; Royal Northern Hospital; the Royal London Homoeopathic Hospital; Whittington Hospital.

North-east Metropolitan Region.—Chase Farm Hospital; Prince of Wales Hospital; Bethnal Green Hospital; Hackney Hospital; Mile End Hospital; St. Andrew's Hospital, Bow; Queen Mary's Hospital, Stratford; Whipps Cross Hospital; Oldchurch Hospital; Southend General Hospital; Rochford General Hospital; St. Margaret's Hospital, Epping; St. John's Hospital, Essex; Essex County Hospital, Colchester; Black Notley Hospital, Braintree.

South-east Metropolitan Region.—St. Olave's Hospital; Miller General Hospital; St. Alfege's Hospital, Greenwich; Lewisham Hospital; Brook General Hospital; Dreadnought Seamen's Hospital; Queen Mary's Hospital, Sidcup; West Hill Hospital, Dartford; St. Bartholomew's Hospital, Rochester; Kent and Canterbury Hospital; Ramsgate and Margate General Hospital; Buckland Hospital, Dover; Pembury Hospital, Kent; Queen Victoria Hospital, East Grinstead; Orpington Hospital; Farnborough Hospital; Bromley Hospital; Princess Alice Memorial Hospital, Eastbourne; St. Mary's Hospital, Eastbourne; Cuckfield Hospital, Haywards Heath.

South-west Metropolitan Region.—Lambeth Hospital; St. Mary Abbots Hospital; Kingston Hospital; St. Helier Hospital, Carshalton; St. Peter's Hospital, Chertsey; St. Thomas's Hospital, Godalming; Royal West Sussex Hospital; Worthing Hospital; Portsmouth and Isle of Wight Area Pathological Service, Central Laboratory, Portsmouth; Royal South Hants Hospital, Southampton; Poole General Hospital; Royal Hants County Hospital; Salisbury General Infirmary; County Laboratory, Dorchester; Royal Portsmouth Hospital; Royal Isle of Wight County Hospital; Southampton General Hospital.

WALES

Teaching Hospital.—Royal Infirmary, Cardiff.

Welsh Region.—Royal Gwent Hospital, Newport, Mon.; St. Woolos Hospital, Newport, Mon.; St. James Hospital, Tredegar; Caerphilly District Miners' Hospital; St. David's Hospital, Cardiff; St. Tydfil's Hospital, Merthyr Tydfil; East Glamorgan Hospital; Neath General Hospital; Morriston Hospital, Swansea; General Hospital, Swansea; West Wales General Hospital, Carmarthen; Pembroke County War Memorial Hospital, Haverfordwest; the Llandudno General Hospital; Royal Alexandra Hospital, Rhyl; Denbigh Infirmary; War Memorial Hospital, Wrexham; North Wales Mental Hospital, Denbigh.

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