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Morbidity Patterns Among Heavy Equipment Operators Exposed to Whole-Body Vibration-1975 (followup to a 1974 study)

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MORBIDITY PATTERNS AMONG HEAVY EQUIPMENT OPERATORS EXPOSED TO WHOLE-BODY VIBRATION - 1975

Followup to a 1974 Study

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ABSTRACT

At present, there are an estimated 2.5 million workers in the United States whose major occupational responsibilities include operating heavy vibrating equipment in the construction industry. The study reported here is a follow-up to a 1974 study on the effects of long-term whole-body vibration conducted under contract (No. HSM-099-71-29) entitled "Relationship Between Whole-Body Vibration and Morbidity Patterns Among Heavy Equipment Operators" (HEW Publication No. (NIOSH) 74-131).

The 1974 study, which examined the issue among members of a construction union in California, revealed that workers exposed to such vibration displayed an increase in the number of medical claims for several major diseases (e.g., ischemic heart disease, obesity of a non-endocrine origin, and certain musculoskeletal diseases such as displacement of the intervertebral discs), but that this trend did not increase continuously with exposure as expected. The trend of the morbidity ratio versus time suggested that selection out of vibrated jobs may have been responsible for the failure to observe increased morbidity with long exposure. The follow-up study reported here was designed to test the extent to which selection out of jobs proving whole-body vibration exposure (vibrated) could account for the observed decreases in claims for the following major diseases among the longest exposed workers: ischemic heart disease, metabolic diseases, bone and joint diseases, and male genital diseases.

Approximately 1376 work histories of workers in the construction industry for the period December 1972 to December 1974 were analyzed with particular emphasis being placed on comparisons between jobs involving exposure versus no exposure to whole-body vibration.

A logistic analysis was used to control for the effects of age and work experience among the entire group of workers. Evidence was found of an increased risk of leaving the construction industry for those workers who had experienced disease. Although there was no significant association between the number of workers leaving vibrated jobs and the number of workers leaving non-vibrated jobs, there was an association, although not statistically significant, between the number of workers with claims for ischemic heart disease and bone and joint diseases and the number of workers leaving vibrated jobs.

In relating these results to the 1974 study data on morbidity patterns in this occupational group, it is concluded that differential selection probably influenced the results for some diseases, but that it is unlikely to have accounted for the unusual frequency of a pattern of increasing then decreasing morbidity versus work experience observed in that study. These findings suggest that there may be some disease conditions whose onset is hastened by exposure to whole-body vibration but whose overall incidence differs little between exposed workers and their unexposed coworkers in the construction industry.

ACKNOWLEDGMENT

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INTRODUCTION

An estimated eight million people in the United States are exposed to one or both of the two recognized kinds of occupationally related vibration: segmental vibration and whole-body vibration (1). While segmental vibration, transmitted mainly via hand tools, has been associated with a definite disease entity, Raynaud's syndrome or "white fingers," whole-body vibration has not. Segmental vibration, however, is not the type of vibration to which the majority of people are exposed. Of those persons exposed to occupationally related vibration, conservative estimates state that six and one-half million are in the transportation industries where whole-body vibration is the primary source of exposure. Farm tractor drivers (2.8 million), heavy equipment operators in construction (2.5 million), truck drivers (1 million), railroad operators (300 thousand), and bus drivers (52 thousand) comprise a rough breakdown of those workers in the transportation industries who operate vehicles or machinery which expose them to whole-body vibration.

Numerous studies have been conducted in European countries and the U. S. on various aspects of whole-body vibration (WBV) (2). These studies have established that WBV, characterized by low frequencies (less than 20 Hz) and high amplitude, can produce effects in nearly every system of the human body, and that many of these physiological and psychological changes are undesirable and possibly damaging. Research in European countries has concentrated on laboratory experiments which define short-term WBV effects, including a specification of frequencies at which target organ systems such as the viscera and spinal cord resonate; field studies aimed at ergonomic considerations of vibrating vehicles, especially those of seat design which will reduce the exposure to WBV; and, particularly in Germany, development of standards for occupational exposure. Investigations in the U. S. have been carried out mainly by military and space agencies concerned with the acute effects of WBV of varying amplitude, frequency, intensity, and duration on task and sensory performance, subjective and physiological responses, and short time tolerances of humans as well as pathological responses of experimental animals. To date, very little research in the U. S. has been directed towards discovering the effects of WBV on average worker groups who are exposed, often over their entire working careers; although, given the magnitude of the occupationally exposed workforce, the need for such research is clear.

STUDY GROUP

In recognition of the need for data, NIOSH, with their responsibility for developing criteria for occupational standards, included longitudinal morbidity studies as part of Phase 1 of their vibration program (3). In order to initiate these epidemiological studies, they needed an accessible data base on morbidity experience among large populations of workers exposed to WBV. The International Union of Operating Engineers, Local No. 3, headquartered in San Francisco, had long been interested in occupational health problems, had an automated membership and health plan record-keeping system for which meaningful morbidity data might be extracted, and was interested in cooperating with our group at the University of California, Berkeley, in a morbidity study of its heavy equipment operators. Accordingly, under NIOSH funding, such a study was begun in August of 1971.

Over a 20-month period, this study (4)(5) examined insurance claims for medical services submitted to the Union's health plan by two groups of construction workers. Workers were assigned to an exposed or control group on the basis of their recorded job class. The exposed group was made up of heavy equipment operators whose jobs subject them to WBV. Workers in the control group held jobs which were performed under similar environmental working conditions to those of the exposed group, but which did not expose them to WBV (see Table I). The control group was, therefore, an internal control group. At the time of this study, a work history survey of its membership was begun by the Union. The results of this survey were most useful to the University's research team in determining the accuracy of recorded job class in representing actual exposure to WBV from operation of heavy equipment. The results showed that misclassification of controls was somewhat greater than misclassification of exposed workers, but that both rates were very low overall.

Comparing the morbidity experience of exposed and control workers, and using a Mantel-Haenszel adjustment for age and work experience, we found a significantly elevated relative risk among the exposed group in three of the thirty disease categories studied. One of these, diseases of the male genital organs, especially prostatitis, was thought to be particularly important. In no disease category did the control group possess a significantly higher risk of requiring medical services.

In addition, we found that even when the relative claims experience among vibrated workers was no greater than that for nonvibrated workers, there was a work experience related trend in the claims data. We identified four possible trend types as follows:

TABLE I

Job Classes Comprising Exposed and Control Groups

Exposed Group (Operators)

NUMBER	NAME
2361	Dozers
5051	Multi-Engine Earth Machine
5501	Pavement Breaker
5531	Pavement Breaker Truck Mounted
5801	Power Blade Operator
5821	Power Blade Operator
6081	Push Track-Type Dozer
6471	Rubber Tired Scraper Self Loading
6481	Rubber Tired Earth Moving
6491	Rubber Tired Earth Moving 2
6501	Rubber Tired Dozer
6521	Rubber Tired Earth Moving 2
6911	Self Propelled Compactor Single Engine
6941	Self Propelled Compactor
7011	Self Propelled Compactor with Dozer

Control Group

3221	Gradesetter Grade Checker
3311	Heavy Duty Repairman
3373	Heavy Duty Repairman Helper
3401	Heavy Duty Repairman and/or Welder
3731	Inspector Technician
3761	Instrument Man
3771	Instrument Man Technician
5173	Oiler
5383	Partsman Heavy Duty Repair Shop
7123	Signalman
7491	Soil Tester
7501	Soil Tester Technician

I - Increasing relative risk

II - Decreasing relative risk

III - Increasing followed by decreasing relative risk

IV - Decreasing followed by increasing relative risk.

Of these, more than half of the disease categories showed trend type III, wherein the relative risk of making claims increased for the exposed group, compared to the control group with increasing work experience, and then, with more work experience, the relative risk decreased (Figure 1). This "peaking" trend can create statistical difficulties in detecting an elevated relative risk when the whole range of work experience is combined.

We proposed, as a possible explanation for these findings, that workers suffering from certain diseases were selected out of job classes requiring exposure to WBV and into other job classes in the construction industry. Thiis-Evensen (6) has suggested that a selection process may have occurred among shift workers in the Norwegian chemical industry based on an elevated and increasing morbidity rate from duodenal ulcers among shift workers up to age 40, followed by a decline after age 40. Since comparable rates among other workers continued to rise with age, Thiis-Evensen interpreted this as indicative of a selection out of shift work (into day work) for those workers who were unable to adjust to the stress of shift work. The peaking trend observed in the data of the WBV study, since it has been adjusted for age and is therefore even more directly related to work experience (i.e., length of exposure), is consistent with this type of selection process.

Selection has been cited in epidemiological research as a confounding process which can introduce bias and imprecision into the formation of case and control groups and error, in both the direction of spurious association and that of nonassociation, during the interpretation of results. An issue

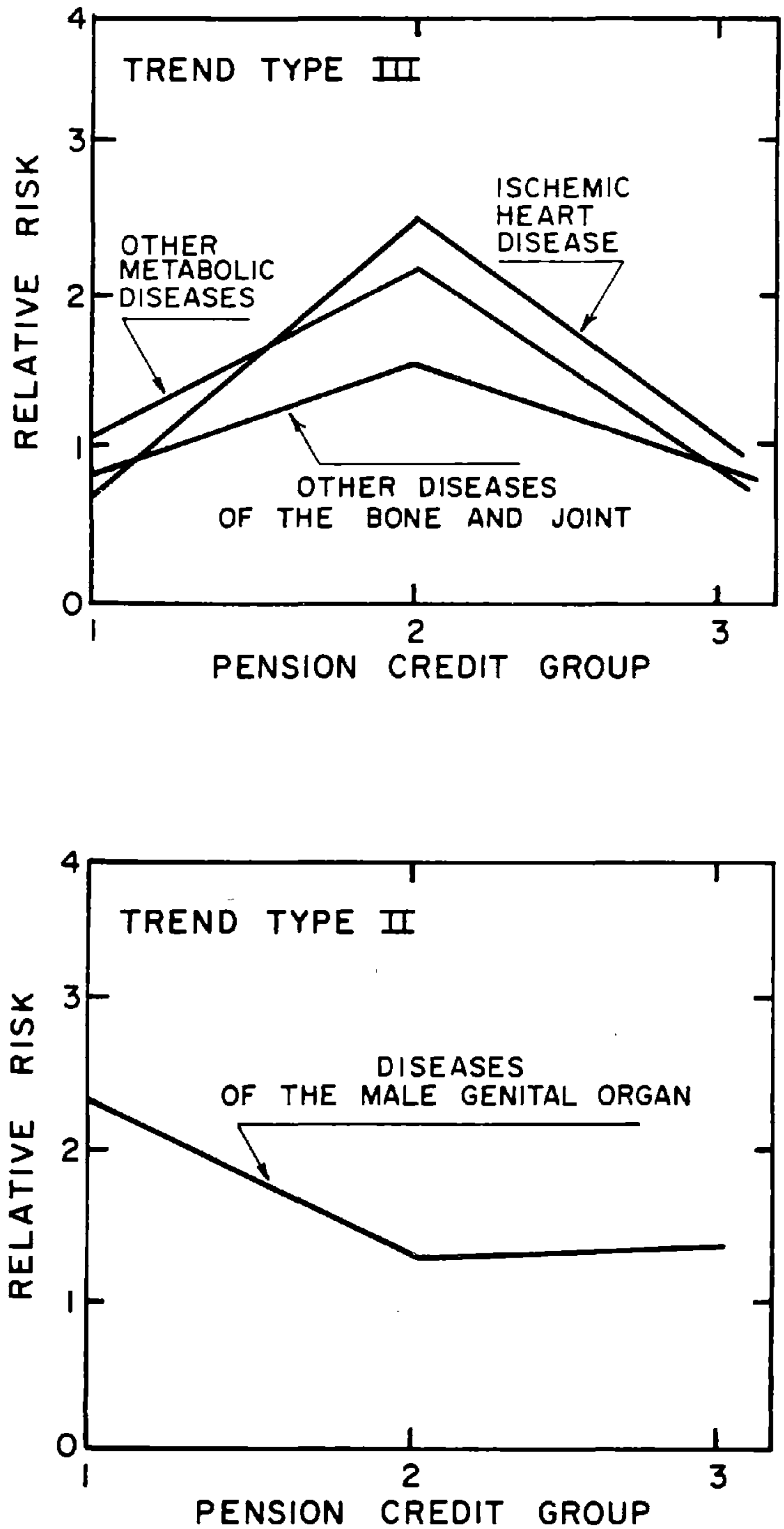
TREND TYPE III
ISCHEMIC HEART DISEASE
OTHER METABOLIC DISEASES
OTHER DISEASES OF THE BONE AND JOINT
RELATIVE RISK
PENSION CREDIT GROUP
TREND TYPE II
DISEASES OF THE MALE GENITAL ORGAN
RELATIVE RISK
PENSION CREDIT GROUP

Figure 1

which seems specifically worrisome is that of preselection. The basic problem in pre-selection seems to be that people, before the initiation of disease, are selected, or self-select, into comparison or risk factor groups on the basis of some unspecified personal characteristic(s) which are linked to the future onset of disease. Thus, there is a need to specify and qualify the factors in selection by direct search, and thereby render them more amenable to adjustment.

But the complexity of the selection issue does not end here. Consider the selection of subjects after exposure to a variable thought to be associated with morbidity. People can select out of a risk factor group into control groups and back again, from control groups to risk factor groups and back again, or out of both groups entirely, before the onset of disease. This situation would produce a change in status, over time, of subjects with respect to the exposure variables of interest and result in innumerable problems of misclassification. People can also select in and out of groups in the same manner after the onset of disease. From this situation there would be change, over time, in the distribution of cases in risk factor and control groups. One of the effects of these movements of people would be to create difficulties in demonstrating statistically that the rate of disease increases with increasing exposure to the variables of interest.

Due to these statistical limitations, one way to detect the operation of selection in already collected data would be to examine variable-specific rates. But trends revealed in specific rates and masked in summary rates are not themselves indicative of the operation of selective processes. Therefore, based on the trends observed in the first study, the present study was conceived to determine the actual existence and possible causation of a selection process among workers exposed and not exposed to WBV and with and without certain diseases.

STUDY DESIGN

The principal question to be answered by this study is whether workers exposed to WBV and making claims for certain diseases are more likely to leave their jobs than workers not exposed to WBV and making claims for the same diseases. We chose, then, to focus the investigation on selection after entry into the vibrated or nonvibrated groups and after the onset of disease. In the results of the previous WBV study, the low misclassification of the overall population of workers assigned to the exposed and control groups suggested that selection between the healthy portion of these two groups was also probably low. Further, the trend data suggested that there was selection out of the exposed groups for diseased workers during some stage of their work experience. For the purposes of this study, selection out of a group is called leaving.

The important comparison, then, would be between vibrated and nonvibrated workers suffering from the same diseases. To make this comparison it was necessary first to examine whether the likelihood of leaving the diseased group was greater than the likelihood of leaving the nondiseased group, while holding the exposure variable constant and, second, whether the likelihood of leaving the vibrated group was significantly different from the likelihood of leaving the nonvibrated group for nondiseased workers. Here recognition can be given to the fact that we were working with three variables: 1) disease, 2) exposure, and 3) leaving. The following four study groups were thus formed for which the rates of leaving could be ascertained and compared:

1. Exposed Cases - Workers exposed to WBV and having made claims for certain diseases.
2. Control Cases - Workers not exposed to WBV and having made claims for certain diseases.

3. Exposed Noncases - Workers exposed to WBV and not having made claims for certain diseases.

4. Control Noncases - Workers not exposed to WBV and not having made claims for certain diseases.

DATA BASE

Information pertaining to worker characteristics was obtained from the records of: 1) the previous WBV study, 2) Local No. 3 of the International Union of Operating Engineers, and 3) C. W. Sweeney and Company, the firm which administers the Union's health and welfare plan. This plan covers Northern California. Questionnaire information was previously gathered independently by Local No. 3, prior to the initiation of the NIOSH sponsored study.

DISEASE

Workers for the exposed and control case groups were selected from the computer files of the previous WBV study. All claims for diseases of interest were listed and the individual workers making these claims were included in the case groups. We decided to examine workers making claims for diseases in the following categories: 1) ischemic heart disease (ICDA codes 410.0 - 414.9), 2) other metabolic diseases (ICDA codes 270.0 - 279.9), 3) osteomyelitis and other diseases of the bone and joint (ICDA codes 720.0 - 729.9), and 4) diseases of the male genital organs (ICDA codes 600.0 - 607.9).

The disease categories "ischemic heart disease" and "other metabolic diseases" were chosen because: 1) they had shown a trend type III, 2) the number of claims for exposed and control groups indicated that sufficient sample sizes of workers could be formed (see Table II), and 3) they were biologically consistent with a selection process occurring after the acquisition of disease. In other words, the diseases included in the ischemic heart disease and other metabolic disease (mainly gout and obesity) categories are chronic, long-term, and frequently incurable. If, as we supposed, diseased workers exposed to WBV are more likely to leave their jobs than are exposed, nondiseased workers, then certain disease states could be viewed as a stress towards selection. Successful treatment and cure of these disease states should remove the stress and selection would not be observed. In contrast, "diseases of the male genital organs" had shown a trend type II (Figure 1) and did not indicate operation of a selection process; yet it had significantly elevated relative risk for the exposed group and a sufficient number of claims. "Osteomyelitis and other diseases of the bone and joint" was chosen because it had large sample sizes, a trend type III, and other studies, especially those initiated by NIOSH (7), had indicated an association between bone disorders and WBV.

To establish the absence of disease in the exposed and control non-case groups, a claims history check for diseases falling into the four above-mentioned categories was performed for each worker selected for these non-case groups. Since all claims made by members of the Union from August 1971 through March 1973 had been recorded in the files of the previous WBV study, it was simply necessary at first to eliminate from those selected for the noncase groups all those chosen for the case groups. Three medical records technicians were employed to examine the claims files at C. W. Sweeney and Co. for the period January, 1973 through April 1975. A potential noncase making a claim for the diseases under study during this period was eliminated from the noncase list.

TABLE II

Morbidity Experience: Exposed and Control Groups
(from Spear et. al. (8))

Disease Category	n_e	n_c	N_e	N_c	Relative Risk	X^2	Trend Type
Ischemic Heart Disease	84	67	48	42	1.25	2.03	III
Other Metabolic Diseases	75	57	60	46	1.35	3.26	III
Osteomyelitis and Other Diseases of Bone & Joint	116	128	89	95	1.06	.23	III
Diseases of Male Genital Organs	75	55	47	41	1.47	4.80	II

n_e - Number of Claims for the Exposed Group

n_c - Number of Claims for the Control Group

N_e - Number of Exposed Workers Making Claims

N_c - Number of Control Workers Making Claims

EXPOSURE

Workers for the case and noncase groups were classified as vibrated or nonvibrated on the basis of recorded job class. The exposed (vibrated) and control (nonvibrated) job class groups used in the previous WBV study (Table I) were retained for the present study. For cases, the job class recorded with their claims on the computer files of the previous study was used to determine if they belonged to the exposed or control group. Although some cases made multiple claims for the same diseases over the entire 20-month period (August 1971 - March 1973) of the previous study, their job class rarely changed. Job class can be described as a good indicator of the most probable occupation of a worker but, due to time lags in the recording methods, a poor indicator of change in occupation. For noncases, the job class as of December 1972, on file at C. W. Sweeney and Co., was used to determine membership in exposed or control groups. Of course, potential cases and noncases without job classes in the two exposure groups were not included in the study.

LEAVING

A work history questionnaire* (Figure 2), had previously been sent to a large number of workers in Local No. 3 and these were made available to us. The information from this questionnaire was used to determine if workers in our four study groups had remained in their vibrated or nonvibrated jobs, had left their vibrated jobs for nonvibrated jobs, or vice versa, or had left their jobs completely and for what reason. The methods instituted to make this determination are discussed in the next section. The time period of follow-up, during which workers were queried for changes in occupation, was defined as starting at the end of December 1972 and terminating on December 31, 1974.

*Independently obtained and funded by Local No. 3 prior to NIOSH participation.

FIGURE 2. LOCAL #3 QUESTIONNAIRE

WORK HISTORY SURVEY

1. Are you currently working in the construction industry? _____ yes _____ no.
   If you are not working in the construction industry now, when did you last do so?

   ____.

2. Below is a list of job classes. For the jobs you have worked on, please mark, to the best of your recollection, how many weeks you spent on each job. The total number of weeks you worked during each time period should not add up to more than 13.

		1973				1974		
Job Class		April May June	July Aug. Sept.	Oct. Nov. Dec.	Jan. Feb. March	April May June	July Aug. Sept.	Oct. Nov. Dec.
2361	Operator - Dozer							
3221	Gradesetter Grade Checker							
3311	Heavy Duty Repairman							
3373	Heavy Duty Repairman Helper							
3401	Heavy Duty Repairman and/or Welder							
3731	Inspector Techn.							
3761	Instrument Man							
3771	Instrument Man Tech.							
5051	Operator-Multi-Engine Earth Machine							
5173	Oiler							
5383	Partsman Heavy Duty Repair Shop							
5501	Operator - Pavement Breaker							
5531	Operator - Pavement Breaker Truck Mounted							
5801	Operator - Power Blade - Single Engine							
5821	Operator - Power Blade - Multi-Engine							
6081	Operator - Push Track-Type Dozer							
6471	Operator - Rubber Tired Scraper Self Loading							
6481	Operator - Rubber Tired Earth Moving							
6491	Operator - Rubber Tired Earth Moving 2 (up to & including 75 cubic yds)							
6501	Operator - Rubber Tired Dozer							
6521	Operator - Rubber Tired Earth Moving 2 (over 75 cubic yds)							
6911	Operator - Self Propelled Compactor Single Engine							
6941	Operator - Self Propelled Compactor							
7011	Operator - Self Propelled Compactor with Dozer							
7123	Signalman (equipment)							
7491	Soil Tester							
7501	Soil Tester Tech.							
	TOTAL:	13wks	13wks	13wks	13wks	13wks	13wks	13wks

3. Are you presently working on one of the above jobs? ____ yes ____ no. If your answer is "yes", write down which one:

   ____

   If your answer is "no", write down what job you are doing: ______________________

   ____

PENSION CREDITS AND AGE

Since heavy equipment operators tend to work about nine months or less out of the year, due to slowdowns in construction and/or severe weather conditions, it was decided early in the previous study to find some other index of duration of exposure other than years worked in the construction industry. Fortunately, the Union, through its trust fund, had set up a pension plan whereby one quarter of a pension credit is earned for every 300 hours worked. Roughly, from three-fourths to one and one-fourth pension credits are earned by a full-time worker each year. From the trust fund, we obtained information on the age and total pension credits of workers in the four study groups, with appropriate protection of confidentiality, as of the end of December 1972. Later, statistical adjustments were made for both age and pension credits from these data.

Work experience related trends, mentioned earlier, were found by examining age adjusted, pension credit specific rates for three pension groupings, since pension credits was used as an index of work experience (or duration of exposure when referring to WBV exposed workers).

STATISTICAL ANALYSIS

Much of this study was designed and executed before the methods of statistical analysis were finalized. Early in the study, we envisioned that a matched pair analysis would be performed. From this thought, exposed cases were loosely pre-matched to exposed noncases and control cases to control noncases on the basis of age and pension credits at the time the entire noncase group was selected. Later, we decided that a more significant match would be between exposed and control cases and between exposed and control noncases, and we planned to employ not only a McNemar matched pair analysis,but also a Mantel-Haenszel and a multiple logistic analysis of the data. Generally, these three methods would test if the rate of leaving were significantly greater between any two groups we wished to compare. Later on it became obvious that the method best suited to our data, with its two constant and three variable factors, was based on the multiple logistic model and, for other reasons discussed in the next section, only this type of test was performed.

DATA COLLECTION AND ANALYSIS

DATA COLLECTION

Workers selected from the files of the previous WBV study,and classified as cases,were listed according to the disease category in which they had made claims. Each combination of exposure group and disease category was called a disease grouping and given an identifying number (for example, exposed ischemic heart disease cases were designated as 1, control ischemic heart disease cases as 2 and so on). These lists of cases, along with their social security numbers and recorded job classes, were handed over to the programming department at C. W. Sweeney and Co. Using social security number as an identifier, they found the age and pension credits of these cases as of December 1972. The programmer noticed, at this time, that some cases were listed in more than one disease grouping. For example, an exposed case had made claims for both male genital and ischemic heart disease, and a control case had made claims for other metabolic, ischemic heart,and other bone and joint diseases. In all, 45 cases had made claims in two disease categories and three cases in three disease categories,while no cases had made claims in all four disease categories. These cases making claims in multiple disease categories have been scrutinized carefully and no nonrandom distribution between exposed and control cases can be observed in regard to many factors of interest,including response rate to the Union's questionnaire, absence of address on the Union's address list (see below), the particular combination of multiple disease categories, rate of leaving, type of leaving,and many others. Since we intended to analyze disease categories separately, identical records, differing only in the disease grouping number, were retained in each of the multiple disease categories in which these cases had made claims.

When the noncases were selected (by matching a maximum of five Union workers, active as of 1972, with each case on the basis of exposure, age, and pension credits) the programmer assigned each study subject a code number by social security number. In order to maintain confidentiality, these codes were assigned at random. After the list of noncases had been pared down by eliminating those who had made claims for the diseases under study, a list of cases and noncases was returned to us with only code numbers attached to age, job class, disease grouping (for cases only), and pension credit information. This precaution of confidentiality was used in order to satisfy the requirements of the Committee for the Protection of Human Subjects at the University of California at Berkeley.

A list of all study subjects selected was also sent to Local No. 3 showing code number, name, and social security number. The programming department at the Union obtained the questionnaire responses from their files, assigned appropriate code numbers, and forwarded the questionnaires to us.

By matching social security numbers, all deaths among study subjects as of December 31, 1974 were obtained from the deceased files at the trust fund, along with the deceased subject's code number. Deceased cases and noncases were classified as leaves (i.e., having left their job entirely). Except for this death information, all other followup data on subjects pertaining to leaving was obtained from the questionnaires (see Table III).

Once data from the questionnaire had been received from the Union, the next step was to interpret the responses to the questionnaires such that responding study subjects could be classified as having left or as not having left the jobs they occupied as of December 1972. A first pass through the questionnaires revealed two facts: 1) most of the leaves were due to retirement and 2) a wider definition of exposed and control occupations was needed

TABLE III

Number of Responses to Local #3 Questionnaire

Study	Number Responding to Questionnaires			Number Not Responding to Questionnaires	
	Number	(*)	%	Number	%
Exposed Noncases	511	(7)	58	366	42
Control Noncases	554	(4)	62	344	38
Exposed Cases (all diseases)	156	(11)	64	88	36
Control Cases (all diseases)	153	(5)	68	71	32
Ischemic Heart Disease					
Exposed	33	(6)	69	15	31
Control	26	(3)	62	16	38
Other Metabolic Diseases					
Exposed	38	(1)	63	22	37
Control	33	(1)	72	13	28
Other Bone and Joint Diseases					
Exposed	56	(3)	63	33	37
Control	60	(0)	63	35	37
Male Genital Diseases					
Exposed	29	(1)	62	18	38
Control	34	(1)	83	7	17

*Number in parenthesis denotes the number of deceased subjects in each category for which data was available.

if much of the data from the questionnaires was not to be lost. In regard to this second point, many of the exposed workers spent much of their time operating vibrating machinery not included in the exposed job classes and many of the control workers had left the listed control job classes, but their new jobs still did not expose them to WBV. Therefore, we decided to classify a change in occupation (i.e., a leave) among exposed workers as changing to jobs that did not expose them to WBV. Leaving either vibrated or nonvibrated jobs due to retirement, permanent disability, or death was also classified as a leave for both exposed and control workers.

The second problem arose from the erratic nature of changes in occupation from vibrated to nonvibrated jobs, and vice versa, among all workers over time. It was recognized that, conceptually, there were four pieces of information for four time intervals for which we could classify workers as engaging in vibrated or nonvibrated jobs: 1) the recorded job class as of December 1972; 2) the occupations for April 1973 through December 1973; 3) the occupation for January 1974 through December 1974; and 4) the occupation at the time the questionnaire was filled out. The last three pieces of information were from the questionnaire (Figure 2). For all possible combinations of vibrated and nonvibrated jobs in these four time intervals we decided upon an outcome of leave or not leave. Since information for the first time interval was always available, it was possible for three pieces, two pieces, or one piece of information to be missing due to incomplete answering of the questionnaire. When three pieces of information were missing, the respondent's questionnaire was rejected as having insufficient information.

When one or two pieces of information were missing for the corresponding time intervals, we had to decide if the information given was sufficient to assign an outcome of leave or not leave. All possible combinations of three and two pieces of information available were tabulated and, extending the outcome scheme for four completed intervals (i.e., four pieces of information available), we ascertained whether the missing information could determine the outcome. If substitution of either vibrated or nonvibrated jobs for the missing information did not affect the outcome of leaving or not leaving, then the questionnaire was retained in the study and the indicated outcome was assigned to that combination. If the substitution could swing the outcome to either leave or not leave, then the questionnaires with this combination were rejected as having insufficient information for deciding upon an outcome. These combinations of completed and missing information are given in the Appendix with the number of respondents in each study group whose questionnaires had these kinds of combinations. This table also shows the number of respondents who can be classified as simultaneously performing vibrated and nonvibrated jobs. These workers were considered unclassifiable and their questionnaires were also rejected. In all, questionnaires were rejected for 10% of exposed noncases, 11% of control noncases, 11% of control cases, and 5% of exposed cases. Table IV shows the number of rejected responses by disease category for exposed and control cases. Table V shows number of rejected responses for exposed and control noncases.

In addition to the types of leaves described above and shown in the Appendix, there were leaves due to retirement, permanent disability, and death. These conditions were classified as leaves only if they occurred as of December 31, 1974, the end of the follow-up period. A breakdown of study subjects into classifications of leave, not leave, and type of leave is given in Tables VI and VII. Table VIII contains data pertaining to the age and pension credit status of the various groups studied.

TABLE IV

Number of Rejected Questionnaires for Cases by Disease Category

Disease Category	Exposed Cases	Control Cases
Ischemic Heart Disease	0	3
Other Metabolic Diseases	1	3
Other Bone and Joint Diseases	4	4
Male Genital Diseases	0	6
TOTAL	5	16

TABLE V

Number of Rejected Questionnaires for Noncases

Exposed Noncases	46
Control Noncases	53

TABLE VI

Number of Leaves, Not Leaves, and Type of Leaves for Four Study Groups

Study Group	Not Leave	Leave	Type of Leave: Ret.	P.D.	E-C	C-E	D.
NONCASES							
Exposed	386	79	52	6	14	---	7
Control	420	81	63	4	---	10	4
CASES - ALL DISEASES							
Exposed	107	44	23	2	8	---	11
Control	100	37	26	3	---	3	5
CASES - BY DISEASE CATEGORY							
Ischemic Heart Disease							
Exposed	16	17	10	0	1	---	6
Control	16	7	3	1	---	0	3
Other Metabolic Diseases							
Exposed	31	6	3	0	2	---	1
Control	21	9	6	1	---	1	1
Other Bone and Joint Diseases							
Exposed	35	17	7	2	5	---	3
Control	44	12	9	1	---	2	0
Male Genital Diseases							
Exposed	25	4	3	0	0	---	1
Control	19	9	8	0	---	0	1

Ret. - Retirement
P.D. - Permanent Disability
E-C - Change from Vibrated to Nonvibrated Job
C-E - Change fron Nonvibrated to Vibrated Job
D. - Deceased

TABLE VII

Questionnaire Results in
Contingency Table Format

		Not Leave	Leave
Vibrated	Diseased	107	44
	Non-Diseased	386	79
Non-Vibrated	Diseased	100	37
	Non-Diseased	420	81

DATA ANALYSIS

After the results from the questionnaires and other data on study subjects were coded for computer input and keypunched on cards, the first statistical tests were performed by the computer program using multiple logistic analysis (8)(9). The multiple logistic method was our first choice since it used all of the available data. The McNemar matched pair method does not use all the data since the number of pairs which can be formed is limited by the number of subjects in the study group of smallest size. For example, only 23 pairs could be formed for a comparison of exposed and control cases in the ischemic heart disease category since the control group had only 23 subjects with useful data, while the exposed group had 33; thus, data on 10 subjects would be lost during a matched pair analysis. We knew that the number of subjects for which data were available was meager, so, to further reduce the number of subjects, due to limitations of the statistical method, would, in turn, irreparably reduce the power of any statistical tests. A weighted combination of contingency tables, such as are found in Mantel-Haenszel, was also dropped from our analysis scheme since the small size of disease groupings would give small numbers or zeros in some subclassifications, thereby making adjustment difficult or meaningless. We thus decided to use solely the multiple logistic model for statistical analysis of the data. The principal disadvantage of the multiple logistic analysis is that it has not yet found widespread application in epidemiological studies and is somewhat difficult for non-mathematically oriented people to follow. For these reasons, a step-by-step explanation of the multiple logistic method, as it applies to this study, is given here.

The logistic model has been used for a fairly long time in bioassay studies, usually with only one variable. Recently, the properties of this model which lend themselves to multivariate analysis have been recognized and applied. In the univariate case, the logistic model is structured such that the probability that the event of interest occurs increases with increasing levels of the risk factor, yielding an S-shaped curve. In this study the variable of interest is "leaving." The probability of leaving, P(LE), is defined as:

$$P(LE) = \frac{1}{1 + e^{-(b_0 + b_1x_1 + b_2x_2 + \cdot \cdot \cdot \cdot + b_{k-1}x_{k-1} + b_kx_k)}}$$

where x_1, x_2, x_{k-1}, x_k, etc. are levels of risk factors which may be adjusted as required by the study design. The parameters b_1, b_2, b_{k-1}, b_k, etc., are the coefficients of the risk factors and are conceptually analogous to the beta coefficients of multiple regression analysis. In this study, the variables that need to be adjusted for are age (x_1) and pension credits (x_2). x_k is a discrete indicator variable defined by two states or conditions. This indicator variable represents the risk factor of interest or study. In this study it represents either diseased or nondiseased (i.e., case or noncase) for one set of tests; or it represents vibrated (V) or nonvibrated ($\bar{V}$) for another set of tests (i.e., exposed or control). If P(LE) is the probability of leaving, then the natural logarithm of the quantity P(LE)/(1 - P(LE)) is defined as the logit of that probability, i.e.:

$$\text{Logit (LE)} = \ln \frac{P(LE)}{1 - P(LE)}$$

It follows from the definition of P(LE) that:

$$\text{Logit (LE)} = \ln \frac{P(LE)}{1 - P(LE)} = b_0 + b_1x_1 + b_2x_2 + \cdot \cdot \cdot \cdot + b_{k-1}x_{k-1} + b_kx_k$$

Each study subject has his own x_1, x_2, and x_3 values which are read into the multiple logistic computer program. The program first uses the procedure for discriminant analysis (10) to get initial estimates of the coefficients, and then an iterative method (11) to arrive at finer estimates, ($\hat{b}_0$, $\hat{b}_1$, $\hat{b}_2$, $\hat{b}_3$).

Imagine that we have run the program for all study subjects and we wish to compare the risk of leaving of exposed subjects vs. control subjects. We have designated x_3 to be zero for subjects in the nonvibrated ($\bar{V}$) or control group, and x_3 to be one for subjects in the exposed or vibrated (V) group. If we set age and pension credits at fixed values, then the Logit $(LE)_V$ (the logit of the probability of leaving for the vibrated group) is:

$$\text{Logit } (LE) = b_0 + b_1x_1 + b_2x_2 + b_3$$

since $x_3 = 1$ for vibrated, and the Logit $(LE)_{\bar{V}}$ (the logit of the probability of leaving for the nonvibrated group) is:

$$\text{Logit } (LE)_{\bar{V}} = b_0 + b_1x_1 + b_2x_2$$

since $x_3 = 0$ for nonvibrated.

If we subtract Logit $(LE)_{\bar{V}}$ from Logit $(LE)_V$ we get:

$$\text{Logit } (LE)_V - \text{Logit } (LE)_{\bar{V}} = b_3 \quad \text{(Equation I)}$$

but Logit $(LE)_V$ and Logit $(LE)_{\bar{V}}$ are by definition:

$$\text{Logit } (LE)_V = \ln \frac{P(LE/V)}{1 - P(LE/V)}$$

where $P(LE/V)$ = Probability of leaving given membership in the vibrated group and

$$\text{Logit } (LE)_{\bar{V}} = \ln \frac{P(LE/\bar{V})}{1 - P(LE/\bar{V})}$$

where $P(LE/\bar{V})$ = Probability of leaving given membership in the nonvibrated group. From basic probability it follows that:

$$1 - P(LE/V) = P(\overline{LE}/V)$$

and

$$1 - P(LE/\bar{V}) = P(\overline{LE}/\bar{V})$$

where $\overline{LE}$ = <u>not</u> leaving.

Substituting into Equation I we have:

$$b_3 = \ln \frac{P(LE/V)}{P(\overline{LE}/V)} - \ln \frac{P\ (LE/\bar{V})}{P\ (\overline{LE}/\bar{V})}$$

and from the rules of subtraction of logarithms:

$$b_3 = \ln \frac{\dfrac{P(LE/V)}{P(\overline{LE}/V)}}{\dfrac{P(LE/\bar{V})}{P(\overline{LE}/\bar{V})}}$$

Rearranging, we have:

$$b_3 = \ln \left[\frac{P(LE/V)}{P(LE/\bar{V})} \quad \frac{P(\overline{LE}/\bar{V})}{P(\overline{LE}/V)}\right] \qquad \text{(Equation II)}$$

But the quantity in brackets is the familiar measure of statistical association used often by epidemiologists: the odds ratio or cross product ratio. Recall that for the following two by two table:

	LE	$\overline{LE}$
V	P_{11}	P_{12}
$\bar{V}$	P_{21}	P_{22}

$P_{11} = P(LE/V)$, $P_{12} = P(\overline{LE}/V)$, $P_{21} = P(LE/\bar{V})$, and $P_{22} = P(\overline{LE}/\bar{V})$.

The odds ratio is:

$$\text{Odds Ratio} = OR = \frac{\dfrac{P_{11}}{P_{12}}}{\dfrac{P_{21}}{P_{22}}}$$

and by rearranging again we have the cross product ratio:

$$OR = \frac{P_{11}P_{22}}{P_{12}P_{21}} = \frac{P(LE/V)}{P(\overline{LE}/V)} \quad \frac{P(\overline{LE}/\bar{V})}{P(LE/\bar{V})}$$

Therefore, b_3 is an estimate of the natural log of the odds ratio. Thus:

$$OR = e^{b_3}$$

Thus, by finding b_3 we can arrive at an estimate of the odds ratio for leaving, i.e., the risk of leaving for the vibrated compared to the non-vibrated group, for this example, or for diseased vs. nondiseased if we designated disease as the indicator variable. The odds ratio is greater than one if the risk of leaving is greater for the vibrated group, and less than one if the risk of leaving is greater for the nonvibrated group. The odds ratio equals one if there is no association between leaving and exposure to vibration (or disease). The multiple logistic program also yields a set of significance probablities (p-values) for the corresponding estimates of the coefficients. A p-value for any particular b is obtained under the hypothesis $b = 0$. Since $b = 0$ is equivalent to $e^b = 1$, it can be tested whether the estimated odds ratio, e^{b_3}, is significantly different from one.

RESULTS AND DISCUSSION

BACKGROUND

The raw data on leaving shown in Table VII indicate that the majority of leaves in all groups are classified as retirements or deaths. Few workers leave by changing from exposed to control group jobs. or vice versa. The possibility of changes from exposed to control jobs after the onset of disease was regarded at the conclusion of the first study as a pattern which might explain the observed trend type III curves. Various members of Local #3. with whom this issue was discussed, stated that such job transitions were uncommon and the results of this study confirm their observations.

Since most of the leaves are due to retirement or death, it follows that both age and pension credits should be predictors of leaving. Although age and pension credits are correlated, age is the dominant predictor variable in virtually all of the analyses that were carried out. For example, consider the effect of heart disease on leaving among the vibrated group. In this case the predictor variables are heart disease, age, and pension credits;and the probability of leaving* is:

$$P(L) = \frac{e^{-y}}{1 + e^{-y}}$$

where the exponent, y, is

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3$$

and x_1 = 1 for heart disease cases	b_0 = 5.608
2 for noncases	b_1 = 1.565
x_2 = age	b_2 = -.125
x_3 = pension credits	b_3 = -.027

*For computational purposes it was convenient to compute the probability of not leaving $P(\bar{L}) = 1/(1 + e^{-y})$ and then obtain the probability of leaving as $P(L) = 1 - P(\bar{L})$.

TABLE VIII

Mean Age and Pension Credits for Cases, Exposed and Control and Disease Groups and for Noncases, Exposed and Control

CASES	AGE	PENSION CREDITS
Control		
Mean	50.60	14.86
S.D.	8.93	12.54
Exposed (Vib)		
Mean	51.23	17.21
S.D.	8.44	15.28
Heart		
Mean	53.39	17.21
S.D.	6.67	15.26
Male Genital		
Mean	53.77	16.96
S.D.	8.19	15.78
Metabolic		
Mean	50.55	16.85
S.D.	8.38	15.43
Bone and Joint		
Mean	48.39	14.59
S.D.	9.28	11.41
NON-CASES		
Control		
Mean	49.78	13.68
S.D.	9.22	10.83
Exposed (Vib)		
Mean	50.44	16.45
S.D.	9.06	14.84

If, for example, an individual member of the vibrated group is 50 years old, possesses 20 pension credits, and has heart disease, the exponent is:

$$y = + b_0 + b_1(1) + b_2(-.125) + b_3(-.027)$$

$$y = + .608 + 1.575 - 6.250 - .540 = + .393$$

with the associated probability of leaving of 0.403. A comparison of the relative importance of age vs. pension credits in these cases can be obtained by inspection of the ratio of the standard deviation of age times b_2 to the standard deviation of pension credits times b_3. In the above example, this ratio is 5.08, which confirms the impression that age is relatively more important, as suggested by the calculations for the "typical" case given above. Similar results are obtained for the effects of pension credits vs. age for all diseased vs. nondiseased comparisons.

Although the principal use of the logistic model in this study was to adjust for age and pension credit effects on leaving, the coefficients of the logistic model are presented for the eight individual diseased vs. non-diseased comparisons and the two overall diseased-nondiseased comparisons in Table IX. The probability of leaving is calculated, as in the previous example, with the disease variable being $x = 1$ for disease and $x = 2$ for no disease, and results pertain only to the sample included in the present study. If the proportion of leavers is unequal between the sample and entire population, a correction factor must be applied to the coefficient b_0.

PRIMARY RESULTS

The basic issue addressed by this study concerned the degree to which selection out of jobs involving exposure to whole-body vibration might explain the pattern of morbidity vs. experience observed in our previous study

TABLE IX

Logistic parameters for diseased vs. nondiseased comparisons where $P(L) = e^{-y}/(1 + e^{-y})$ and $y = b_0 + b_1x_1 + b_2x_2 + b_3x_3$.

	HEART	OTHER METABOLIC	MALE GENITAL	BONE & JOINT	ALL DISEASES
EXPOSED					
Constant (b_0)	5.608	8.230	10.327	5.242	6.202
Disease (b_1)	1.575	.103	.714	1.156	.713
Age (b_2)	- .125	- .118	- .126	- .105	- .107
Pension Credits (b_3)	- .027	- .030	- .029	- .022	- .020
CONTROL					
Constant (b_0)	9.322	9.560	9.231	8.133	8.042
Disease (b_1)	.685	.595	.773	.737	.690
Age (b_2)	- .157	- .159	- .152	- .135	- .135
Pension Credits (b_3)	- .037	- .036	- .056	- .047	- .037

of the morbidity patterns in workers exposed to whole-body vibration. In the present study, selection was defined as selection out of exposed or control group job classes after the onset of disease. As explained previously, the multiple logistic model is useful in this case because it allows efficient use of the data set and also allows one to adjust for both age and experience.

As a first step, it was important to ascertain if, in the absence of disease, a difference existed in the probability of leaving for the exposed vs. the control group. The odds ratio for the exposed vs. control noncases was found to be 0.91 with a significance probability of 0.620, i.e., there appears to be no difference in the probability of leaving exposed vs. control jobs for workers free of the diseases of concern in this study.

Table X contains the odds ratio and significance probabilities for diseased vs. nondiseased members of the control and exposed groups separately. As in the former case, these figures are age and experience adjusted. As might be expected, these results show that workers with disease generally leave their jobs at about twice the rate of nondiseased workers in both exposed and control groups. However, for the control group the odds ratio for each of the four disease groups, although never significantly different from unity, shows remarkably little variation from the overall value of 1.99. The odds ratio for the exposed workers, on the other hand, shows considerable variability as a function of disease, with a value of 0.49 for male genital disease vs. 4.83 for ischemic heart disease, the latter being highly significant.

TABLE X

Results of Statistical Analysis
for Diseased vs. Nondiseased Workers

	Odds Ratio*	Significance Probability
Control Workers Only		
Cases (all diseases) vs. Noncases	1.99	.00739
Ischemic Heart Disease Cases vs. Noncases	1.98	.213
Other Metabolic Disease Cases vs. Noncases	1.81	.217
Other Bone and Joint Disease Cases vs. Noncases	2.09	.062
Male Genital Disease Cases vs. Noncases	2.17	.124
Exposed Workers Only		
Cases (all diseases) vs. Noncases	2.04	.00210
Ischemic Heart Disease Cases vs. Noncases	4.83	.0000665
Other Metabolic Disease Cases vs. Noncases	1.11	.838
Other Bone and Joint Disease Cases vs. Noncases	3.18	.00117
Male Genital Disease Cases vs. Noncases	0.49	.207

*The odds ratio is defined on page 27.

The results given in Table X for ischemic heart disease and for bone and joint disorders among the exposed group are consistent with the selection hypothesis, whereas, the result for male genital disease is counter-intuitive since it suggests that workers afflicted with such conditions preferentially remain in exposed group jobs. In the latter case, however, the result is not significant, nor was a trend type III curve seen in the original study. Such a trend type was observed, however, in the case of other metabolic diseases, and there is no evidence of selection among exposed workers for these diseases.

Although there is no clear pattern in this set of results, there is the suggestion of two different selection forces. Recalling that the original choices of the control group were dictated by a desire that the type of job site be matched as closely as possible with that of the machine operators, it can be hypothesized that the life styles of the two groups are reasonably similar. For example, a proportion of both groups work on job sites distant from their homes and, as a result, these men often spend a considerable portion of the year living separate from their families and the amenities of home. It seems quite plausible that workers might find such a life style unacceptable, or even untenable, when afflicted with a debilitating and/or painful chronic disease. It may be that this life style selection accounts for the uniform odds of leaving for those afflicted with any of the four diseases among the control population.

The second type of selection pressure is that associated with the rigors of the job itself. It was this form of selection pressure that was originally hypothesized to contribute to the type III trend curves observed in the former study. Because the control group used in this study is composed of the same group of job classes as in the former study, comparisons between subgroups of exposed and control workers with disease can be expected to control for life style selection to whatever degree it actually exists. Therefore, the odds ratios given in Table X are of considerable interest since they include the effects of both types of post-disease selection pressure.

The data of Table X clearly indicate that post-disease selection exists but they do not directly bear on the question of the trend types seen in the former study. This can be accomplished by inspecting the odds ratios for diseased individuals only when classified by exposed or control group job categories. Table XI shows the odds ratios for each of the four disease groups. These results describe the differential tendency to select out of the exposed vs. the control groups, given that the worker has been diagnosed as being afflicted with the disease in question. Only in the case of male genital diseases does the odds ratio differ from unity at a reasonable level of significance. However, the odds ratio is 0.14, which indicates a strong tendency to select out of the control group with higher probability than from the exposed for this disease category. This result is thrown into some doubt, though, by the fact that the odds ratio within the exposed group for cases vs. noncases was 0.49, which suggests that workers afflicted with male genital diseases are more likely to continue operating vibrating equipment than are their nondiseased colleagues. It is difficult to construct a plausible reason for this to be true, and, therefore, it would seem prudent to consider this finding in the case of exposed vs. control workers with caution.

TABLE XI

Results of Statistical Analysis for Diseased Workers: Exposed vs. Control

	Odds Ratio*	Significance Probability
Cases Only		
Ischemic Heart Disease Exposed vs. Control	2.44	.169
Other Metabolic Diseases Exposed vs. Control	0.92	.904
Other Bone and Joint Diseases Exposed vs. Control	1.77	.214
Male Genital Diseases Exposed vs. Control	0.14	.0186

*The odds ratio is defined on page 27.

For the other three disease groups the suggestion of selection exists for ischemic heart disease and bone and joint diseases, but in neither case are the significance probabilities adequate to conclude that the odds ratios truly differ from unity. It seems likely that a larger sample would show that the odds ratios exceed unity in these two cases, but whether their magnitude is in the neighborhood of two, as suggested by the present data, is more speculative. The fact, however, that there is no suggestion of differential selection in the case of other metabolic diseases suggests, even if heart disease and bone and joint diseases were significant, that not all trend type III curves seen in the previous study are likely to be due to post-disease selection.

FURTHER COMMENT ON IMPLICATIONS FOR PREVIOUS STUDY

Recalling the results of the diseased-nondiseased comparisons of Table X, there are only two diseased groups for which the odds ratio is significantly different from unity at the 5% level or better. These are heart disease (ICDA 410-414.9) and bone and joint disorders (ICDA 720-729.9), both in the exposed population. Also, it was found that, for these two diseases, the odds ratios for exposed vs. control cases exceed one but in neither case at an acceptable level of significance. Because of this lack of significance, nothing definitive can be said about the effect of post-disease selection on the results of the previous study. Nevertheless, it is valid to inquire into the implications of the observed odds ratios had they been significant. In order to accomplish this goal, it is necessary to make an assumption regarding the functional relationship between leaving and time after the onset of disease.

We assume this relation to be of an exponential type in which the proportion of individuals afflicted with a specific disease at time $t = 0$ who remain in their jobs by time t is given by $e^{-\gamma t}$. Then the proportion leaving is $1 - e^{\gamma t}$. If, then, we estimate the odds of leaving at any time t_1 by comparing the proportion of leavers among the exposed and the proportion among the controls after appropriate age and experience adjustments, the odds ratio is

$$O\ R = \frac{1 - e^{-\gamma_e t_1}/e^{-\gamma_e t_1}}{1 - e^{-\gamma_c t_1}/e^{-\gamma_c t_1}} = \frac{e^{\gamma_e t_1} - 1}{e^{\gamma_c t_1} - 1}$$

It is somewhat easier to deal with this relationship on an intuitive basis if the appropriate half lives, t_e and t_c, are substituted for the parameters γ according to the relation $t_e = .693/\gamma_e$ and $t_c = .693/\gamma_c$. Then,

$$O\ R = \frac{e^{.693t_1/t_e} - 1}{e^{.693t_1/t_c} - 1}$$

In the case of ischemic heart disease, the odds ratio was 2.44 at the end of two years. Substituting these values, and noting that t_e is also on the order of 2 years (Table VI), it can be shown that $t_c \approx 2\ t_e$. That is, whatever the exact value of t_e between about 1.5 and 2.5 years, t_c is about twice as long. In different terms, this result suggests that in 4 years after the onset of ischemic heart disease, 50% of the control group so afflicted would have left their jobs. In the same interval, 75% of the exposed group would leave their jobs. Recalling that the former study dealt with the prevalence of claims for various diseases, rather than the incidence of these diseases, it can be seen that a true difference in the values of t_e and t_c of this amount would have materially affected the relative risk of making claims where an appreciable degree of post-disease selection occurred. In the cases of ischemic heart disease and diseases of the bone and joint, appreciable selection appears to have occurred, but the lack of significance of the corresponding odds ratios between exposed and control cases precludes a defensible estimation of t_e and t_c with the ensuing calculation of a relative risk correction.

One is left with a strengthened suspicion that a differential post-disease selction rate exists between exposed and control workers for some disease conditions showing a trend type III in the original studies and, at least in part, accounts for this morbidity pattern. However, there was no suggestion of differential selection in the case of other metabolic diseases, which indicates that selection did not underlie all trend type III curves. The unusually frequent occurrence of trend type III curves in the original study may indicate that exposure to whole-body vibration hastens the onset of certain diseases but does not increase the overall incidence over that observed among the control subjects.

CONCLUSIONS

This study was undertaken to investigate the extent to which selection out of jobs in the construction industry after the onset of certain diseases might have influenced the results of a previous study of morbidity patterns among workers in this industry. It has been shown that:

(1) for the set of disease groups studied, the overall probability of leaving is higher by a factor of two for both exposed and control group workers afflicted with these diseases, as compared with their nondiseased colleagues.

(2) among the diseased vs. nondiseased members of the control group, the odds of leaving are very similar for all four disease groups, whereas there is considerable variation in the odds of leaving as a function of disease among the exposed workers.

(3) in comparisons of exposed vs. control workers with disease, there are suggestions of differences in the probability of leaving which are consistent with the selection hypothesis of the earlier study. However, there is no evidence of differential selection in at least one disease grouping (Other Metabolic Diseases) in which it was expected, based on the results of that previous study.

From these findings, we conclude that there are some diseases which probably lead to a higher probability of leaving jobs exposing workers to whole-body vibration than of leaving control group jobs. However, the lack of statistical significance of the corresponding odds ratios precludes a definitive conclusion that such a differential selection process exists. It should be recalled that, because of the control group used in these studies, differential selection would most likely be due to the greater rigors of jobs exposing workers to whole-body vibration than of control group jobs. That is, any selection due to lifestyle among these workers should be adequately controlled in the exposed-control comparisons among the diseased population.

There was no evidence, suggestive or otherwise, that differential selection existed among workers afflicted with "other metabolic diseases," although this disease grouping showed a strong trend type III curve in the earlier study. This finding suggests that factors in addition to differential selection might be responsible for the trend type III curves seen in the former study, and that in some cases this morbidity pattern may reflect an early onset of disease rather than a higher incidence overall among workers exposed to whole-body vibration.

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APPENDIX

TABLE A-1 - NONCASES

All Possible Combinations of Completed and
Missing Information and Number of Questionnaires
with These Combinations for Exposed and Control Noncases

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Noncases	Control Noncases
V	V	V	V	NL	185	----
V	NV	V	V	NL	0	----
V	V	NV	V	NL	2	----
V	V	V	NV	NL	8	----
V	NV	NV	V	NL	1	----
V	NV	V	NV	L	0	----
V	V	NV	NV	L	3	----
V	NV	NV	NV	L	11	----
NV	NV	NV	NV	NL	----	276
NV	V	NV	NV	NL	----	1
NV	NV	V	NV	NL	----	0
NV	NV	NV	V	NL	----	7
NV	V	V	NV	NL	----	1
NV	V	NV	V	L	----	0
NV	NV	V	V	L	----	1
NV	V	V	V	L	----	6

TABLE A-1 - NONCASES (cont.)

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Noncases	Control Noncases
V	V	V	MI	NL	165	----
V	V	NV	MI	?	1	----
V	NV	V	MI	?	3	----
V	NV	NV	MI	?	4	----
V	V	MI	V	NL	7	----
V	V	MI	NV	?	1	----
V	NV	MI	V	NL	1	----
V	NV	MI	NV	L	0	----
V	MI	V	V	NL	4	----
V	MI	V	NV	?	1	----
V	MI	NV	V	NL	0	----
V	MI	NV	NV	L	0	----
NV	NV	NV	MI	NL	----	87
NV	NV	V	MI	?	----	2
NV	V	NV	MI	?	----	0
NV	V	V	MI	?	----	5
NV	NV	MI	NV	NL	----	2
NV	NV	MI	V	?	----	1
NV	V	MI	NV	NL	----	0
NV	V	MI	V	L	----	2

TABLE A-1 - NONCASES (cont.)

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Noncases	Control Noncases
NV	MI	NV	NV	NL	----	5
NV	MI	NV	V	?	----	0
NV	MI	V	NV	NL	----	0
NV	MI	NV	NV	L	----	1
V	V	MI	MI	?	10	----
V	MI	V	MI	?	5	----
V	MI	MI	V	NL	13	----
V	NV	MI	MI	?	0	----
V	MI	NV	MI	?	0	----
V	MI	MI	NV	?	8	----
NV	NV	MI	MI	?	----	5
NV	MI	NV	MI	?	----	4
NV	MI	MI	NV	NL	----	41
NV	V	MI	MI	?	----	1
NV	MI	V	MI	?	----	2
NV	MI	MI	V	?	----	7
Both V and NV for Entire Followup Period					6	18
No information given although questionnaire returned					7	8

V - Vibrated NV - Not Vibrated L - Leave NL - Not Leave MI - Missing Information
? - No Decision as to Outcome Possible

TABLE A-1 - CASES

All Possible Combinations of Completed and Missing Information and Number of Questionnaires with These Combinations for Exposed and Control Cases

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Cases	Control Cases
V	V	V	V	NL	61	----
V	NV	V	V	NL	0	----
V	V	NV	V	NL	0	----
V	V	V	NV	NL	0	----
V	NV	NV	V	NL	1	----
V	NV	V	NV	L	0	----
V	V	NV	NV	L	4	----
V	NV	NV	NV	L	4	----
NV	NV	NV	NV	NL	----	64
NV	V	NV	NV	NL	----	0
NV	NV	V	NV	NL	----	0
NV	NV	NV	V	NL	----	1
NV	V	V	NV	NL	----	1
NV	V	NV	V	L	----	0
NV	NV	V	V	L	----	0
NV	V	V	V	L	----	3
V	V	V	MI	NL	42	----

TABLE A-1 - CASES (cont.)

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Cases	Control Cases
V	V	NV	MI	?	0	----
V	NV	V	MI	?	0	----
V	NV	NV	MI	?	0	----
V	V	MI	V	NL	1	----
V	V	MI	NV	?	0	----
V	NV	MI	V	NL	0	----
V	NV	MI	NV	L	0	----
V	MI	V	V	NL	1	----
V	MI	V	NV	?	0	----
V	MI	NV	V	NL	0	----
V	MI	NV	NV	L	0	----
NV	NV	NV	MI	NL	----	25
NV	NV	V	MI	?	----	2
NV	V	NV	MI	?	----	2
NV	V	V	MI	?	----	1
NV	NV	MI	NV	NL	----	2
NV	NV	MI	V	?	----	0
NV	V	MI	NV	NL	----	0
NV	V	MI	V	L	----	0

TABLE A-1 - CASES (cont.)

Recorded Job Class as of Dec. 1972	Type of Job 4/73-12/73	Type of Job 1/74-12/74	Type of Job Date of Quest.	Outcome	Exposed Cases	Control Cases
NV	MI	NV	NV	NL	----	0
NV	MI	NV	V	?	----	0
NV	MI	V	NV	NL	----	0
NV	MI	NV	NV	L	----	0
V	V	MI	MI	?	1	----
V	MI	V	MI	?	0	----
V	MI	MI	V	NL	1	----
V	NV	MI	MI	?	0	----
V	MI	NV	MI	?	0	----
V	MI	MI	NV	?	2	----
NV	NV	MI	MI	?	----	2
NV	MI	NV	MI	?	----	1
NV	MI	MI	NV	NL	----	7
NV	V	MI	MI	?	----	0
NV	MI	V	MI	?	----	0
NV	MI	MI	V	?	----	0
Both V and NV for entire Followup Period					1	5
No information given although questionnaire returned					1	1

V - Vibrated NV - Not Vibrated L - Leave NL - Not Leave MI - Missing Information
? - No Decision as to Outcome Possible

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