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Morbidity Studies of Workers Exposed to Whole Body Vibration

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ABSTRACT

Insurance claims for medical services submitted on behalf of a group of workers in the construction industry were collected over a 20-month period. The morbidity experience of those workers exposed to whole body vibration was contrasted with that of an unexposed control group eligible for benefits under the same plan. Using Mantel-Haenszel adjustment for age and experience, a significantly elevated relative risk was found among the exposed group in three of the thirty disease categories studied. In no disease category did the control group possess a significantly higher risk of requiring medical services. A striking proportion of the disease categories showed an initial increase in risk for exposed workers followed by a decrease with experience. This pattern suggests a selection process in which workers leave exposed-group jobs as they become afflicted with certain disease conditions.

IT HAS BEEN recognized that exposure to vibration can produce various undesirable physiological and psychological effects on the human body.[1] The nature and extent of these effects depend upon the amplitude, frequency, intensity, and duration of the vibration. The military and space agencies have developed a good deal of basic knowledge about acute vibrational effects, but little is known about the effects of long-term or "chronic" vibration. This is especially true in the case of low frequency (i.e., $\leqslant 100$ Hz), high amplitude vibration of the type experienced by operators of heavy construction equipment.

During the past several years, Local No. 3 of the International Union of Operating Engineers, headquartered in San Francisco, has modernized and automated its membership and health plan record-keeping systems to the point where it appeared possible to extract informative data on the experience of their members by both age group and job classification.

The availability of these data and the Union's long standing interest in occupation health problems led us to plan and propose to the National Institute for Occupational Safety and Health a study of morbidity patterns in this occupational group.[2] The general plan was to compare morbidity of workers exposed to whole body vibration (machine operators) to a control group selected from among eligible workers not subject to whole body vibration but otherwise working at sites generally similar to those of machine operators. Division of workers into exposed and control groups was made on the basis of recorded job classification. The specific goal of the study was to identify any unusual morbidity that might be associated with chronic exposure to whole body vibration.

All of the basic information for the period August 1971 to March 1973 reported in this study was gathered from the records of Local No. 3 or from the firm that administers their health and welfare plan. This particular plan covers Northern California. Eligibility for medical benefits through the program depends on time worked per month under the collective bargaining agreements.

Experimental Procedure

Every month each employer submits a contribution to the health plan for workers in his employ. This report lists each man employed, the hours worked, and the job class of each worker. The job classification system was started in 1969 and includes approximately four hundred separate titles. Seventy percent of eligible men were so classified during the study. From occupational reports an estimate was made of the number of man-months at risk in each job classification during the study period. During the 20 months covered in the study, the exposed group accumulated 2,496 man-years (29,952 man-months) of eligibility for health and welfare benefits, while the control group accumulated 2,849 man-years (34,188 man-months). Because eligibility is accrued on a monthly basis, both the number of eligible workers and the individuals comprising

this total vary from month to month. In an average month during the interval of study, the exposed and control groups totaled 3,207 workers.

The claim-handling process was the source of morbidity data for the study. When an eligible member receives medical attention, his personal physician fills out the health plan's standard claim form, which includes the data of the occurrence of the problem, the physician's diagnosis, and the treatment given. This form is then submitted for processing and payment. Since the claim-handling process does not include coding of medical records or other compilation of diagnostic data, accredited record technicians trained to code from the eighth revision of the *International Classification of Diseases, Adapted,* (ICDA) were added to the claim-handling process during the study.[3] All claims by all Union members for personal medical services during the study period were coded; the total number of these claims was 3,892. Compensation cases are handled separately from those covered under the health and welfare plan and were not included in the study.

Thus, the claims data provided the numerator information and the record of the employer's monthly contribution to the plan for each employee supplied the denominator. The basic measure of morbidity was then the number of claims per man-month at risk for the various disease categories.

The adequacy of current job classification as an indicator of work history was investigated in a preliminary study conducted by Local No. 3 in which a detailed work history questionnaire was mailed to randomly selected members in a number of current job classes. One hundred sixty-nine questionnaires were returned. Since this survey was limited to work history information, these data were used to compare current job class with individual work history only. It was thus possible to determine which current job classes represented either continuous exposure to vibrating equipment or no such exposure throughout the work experience of the individual. We were then able to refine our definition of exposed and control group job titles.

Duration of exposure to the occupational stresses of the construction industry was measured for both vibrated and control groups by pension credits. Under the pension plan one quarter of a pension credit is earned for each 300 hours worked, a procedure that has been in effect since 1959. Credit is given for work done prior to 1959 based on initiation date and work history.

Comparison of the morbidity experience for vibrated and control groups was made by the Mantel-Haenszel procedure for summarizing relative risks over several groups.[4] Adjustment was made for both age and length of exposure as measured by pension credits, and χ^2 tests appropriate for this procedure were applied.

Results

Work History Survey

The age and experience of the respondents were representative of the exposed and control groups as reflected by the eligibility data, except that no response was received from men under 24 years of age.

As a result of the work history survey, the following job classes were confirmed as encompassing a majority of the notable whole body vibration exposures and control categories of the study population:

Exposed Group (Operators)

- Dozers
- Multi-engine earth machine
- Pavement breaker
- Pavement breaker, truck mounted
- Power blade
- Push track-type dozer
- Rubber-tired scraper, self loading
- Rubber-tired earth mover
- Rubber-tired dozer
- Self-propelled compactor, single engine
- Self-propelled compactor
- Self-propelled compactor with dozer

Control Group

- Gradesetter grade checker
- Heavy duty repairman
- Heavy duty repairman helper
- Heavy duty repairman and/or welders
- Inspector technician
- Instrument man
- Instrument man technician
- Oiler
- Partsman, heavy duty repair shop
- Signalman
- Soil tester
- Soil tester technician

Figure 1 shows the summed years of exposure on all vibrating machines vs. years in the industry. This figure illustrates the clear difference between the two groups. There are some men in the control group who have had substantial exposure, but virtually no men classified as exposed have had under 5 years of exposure. The few controls (*open circles*) on the diagonal line represent vibrating equipment operators who were misclassified as controls. The single exposed worker (*solid circle*) near the bottom horizontal axis represents the even lower rate of misclassification of controls as being in the exposed group.

Fig. 1. Number of years spent operating heavy equipment by 169 exposed and control respondents.

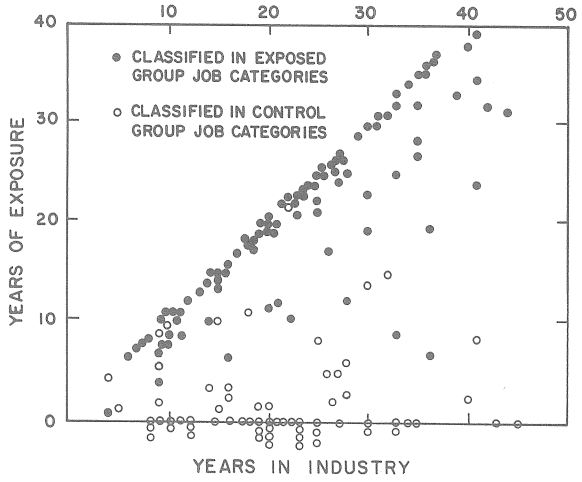


Fig. 2. Number of months worked per year by 169 exposed and control respondents.

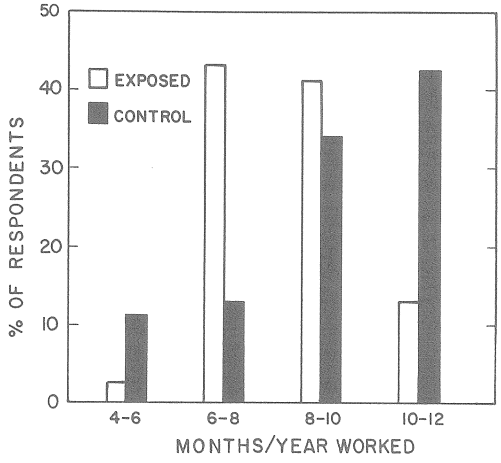


Figure 2 shows the months per year worked by the respondents. A substantial proportion of the control group respondents work a 12-month year, whereas few of the exposed group appear to do so. This result substantiates the choice of pension credit as an index of exposure time to the occupational stresses relevant to this study.

The final issue investigated via the survey concerned the variety of machines operated by a man throughout a career in the industry. It had been suggested that men tended to operate a single type of machine, and responses to the questionnaire indicated that operators did work the greatest proportion of their time on a single type of equipment. However, time spent on other types was usually substantial and there appeared to be little difference in the number of machines operated as a function of experience. This result confirmed our prior judgment that it would be impossible to partition the exposed group on the basis of type of machine operated and investigate their morbidity experience separately.

Principal Results

The principal results, contrasting the morbidity experience of the exposed (vibrated) and control groups, and consisting of an average of 3,207 workers, are presented in the table. Disease groupings are based on two-digit categories from the eighth revision of the ICDA. Although there were some claims from almost all categories so classified, those associated with gynecological conditions and those containing fewer than twenty claims from the vibrated group have been excluded. The table shows, for each disease category, the number of claims in the exposed (n_e) and control (n_c) groups, the relative risk of making a claim among the vibrated group compared to the control group, and the corresponding χ^2 value. As stated above, the values for the relative risks and χ^2 were based on the Mantel-Haenszel procedure and were adjusted for age and pension credit group.

Among the thirty disease categories tested, there were only three that indicated an increased relative risk with a probability of less than 5% ($\chi^2 > 3.86$), and one that was close to this level of significance. While it can be expected that three or four significant values would be found by chance in a series of thirty, one of the categories, "diseases of the male genital organs" (ICDA codes 600.0–607.9, primarily prostatitis) has previously been associated with whole body vibration. (In the United States Armed Services, medical personnel often refer to prostatitis as "jeep drivers disease" [oral communication, Col. Walter Barnes, M.D., July 1973]).

Even when the relative claim experience among vibrated workers was not greater than that of workers in nonvibrating jobs, there may have been an experience-related trend in the claims data. In order to examine this issue, the claimants were allocated to three pension credit groups corresponding to increasing levels of job experience. These three groups included workers with 0 to 9.75, 10 to 19.75, and 20 or more total pension credits respectively.

Again using Mantel-Haenszel adjustment for age and pension credits within these broader groups, the relative risks were computed for the three job experience groups for each of the disease categories. From these data it is possible to identify the trend in relative risk (for each disease category) with increasing work experience. Four possible trend types can be described as follows:

I – Increasing relative risk
II – Decreasing relative risk
III – Increasing followed by decreasing
IV – Decreasing followed by increasing relative risk.

These trend types for each disease category are included in the table. The overwhelming majority in Trend Types II and III is striking. Figure 3 shows several examples of the change in relative risk with job experience characteristic of Trend Types II and III. Examination of the χ^2 values in the table and of the trend patterns in Figure 3 reveals why some disease categories did not show a significantly elevated relative risk when the whole range of experience was combined.

Comments

Among the thirty disease categories for which there were sufficient claims filed for analysis, there were twenty-one in which the value for the adjusted relative risk was greater than 1 for workers exposed to whole body vibration, compared with workers not exposed (controls). While only three of the thirty had a relative risk significantly different from 1 at the 5% level, all three of these indicated an elevated risk among exposed workers, as did all of the other categories with χ^2 values greater than 2. Plausible hypotheses might be formulated to explain the elevated risk for several of these disease categories, but others are almost certainly due to chance alone. The overall impression, however, is that workers in job classes which involved exposure to whole body vibration were at higher risk of making claims for medical service than were workers in control group job classes.

If these data result from a process in which exposure to whole body vibration leads to an increase in disease requiring medical attention, one might expect to find an increase in the relative risk of making such claims as the duration of exposure in vibrating jobs increases. The paucity of

disease categories showing Trend Type I, representing such an increase with increasing exposure, was surprising. Moreover, the large number of disease categories showing Trend Type III was further evidence that the different trend types did not occur at random. Although we would not expect each of the trend types to occur with equal frequency, it can be shown that Trend Type I occurred much less often and Trend Type III much more often than expected by chance.

One explanation for these findings is that workers suffering from certain diseases selected out of job classes requiring exposure to whole body vibration and found employment in other job classes in the construction industry. Thiis-Evensen[5] has suggested that a selection

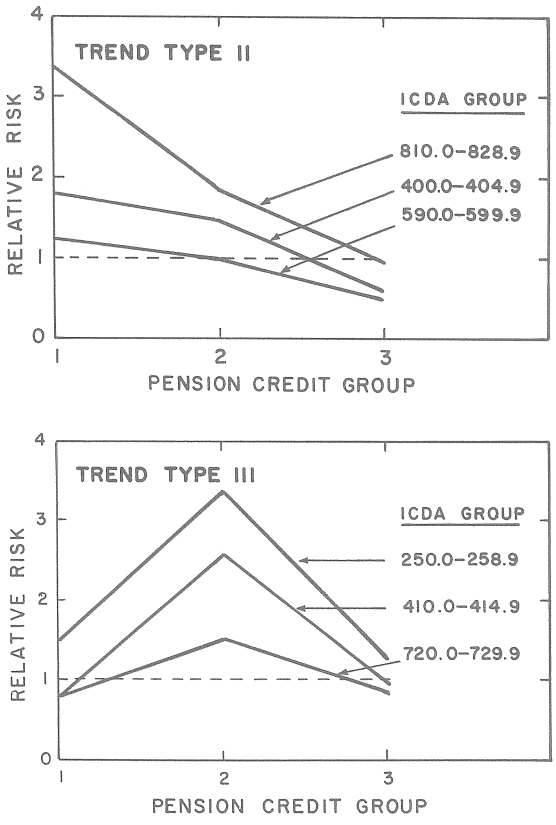
Morbidity Experience for Exposed and Control Groups

ICDA Code	Description	n_e*	n_c†	Relative Risk	χ^2	Trend Type
0.1 - 136.9	Infective and parasitic diseases	201	228	1.07	.47	III
210.0 - 228.9	Benign neoplasms	31	31	.94	.07	III
250.0 - 258.9	Diseases of other endocrine glands	46	31	1.71	6.05	III
270.0 - 279.9	Other metabolic diseases	75	57	1.35	3.26	III
350.0 - 358.9	Diseases of nerves and peripheral ganglia	40	37	1.08	.11	III
400.0 - 404.9	Hypertensive disease	51	57	1.10	.31	II
410.0 - 414.9	Ischemic heart disease	84	67	1.25	2.03	III
420.0 - 429.9	Other forms of heart disease	32	42	.76	1.54	III
450.0 - 458.9	Diseases of veins and lymphatics, and other diseases of circulatory system	35	34	1.04	.04	III
460.0 - 466.9	Acute respiratory infections, except influenza	49	57	.97	.03	III
470.0 - 474.9	Influenza	22	16	1.79	3.55	II
480.0 - 486.9	Pneumonia	20	23	.98	.01	III
490.0 - 493.9	Bronchitis, emphysema, and asthma	73	76	1.15	.68	I
500.0 - 508.9	Other diseases of upper respiratory tract	43	56	.97	.02	III
530.0 - 537.9	Diseases of esophagus, stomach, and duodenum	73	68	1.27	2.28	II
550.0 - 553.9	Hernia of abdominal cavity	37	34	1.28	1.06	IV
560.0 - 569.9	Other diseases of intestine and peritoneum	31	28	1.36	1.53	II
590.0 - 599.9	Other diseases of urinary system	28	38	.79	1.04	II
600.0 - 607.9	Diseases of male genital organs	75	55	1.47	4.80	II
680.0 - 686.9	Infections of skin and subcutaneous tissue	19	22	.95	.03	II
690.0 - 698.9	Other inflammatory conditions of skin and subcutaneous tissue	30	46	.76	1.28	III
700.0 - 709.9	Other diseases of skin and subcutaneous tissue	54	67	.83	.89	I
710.0 - 718.9	Arthritis and rheumatism, except rheumatic fever	108	103	1.14	.91	III
720.0 - 729.9	Osteomyelitis and other diseases of bone and joint	116	128	1.06	.23	III
730.0 - 738.9	Other diseases of musculoskeletal system	52	58	1.08	.20	III
810.0 - 828.9	Fracture of limb	75	48	2.11	17.43	II
830.0 - 845.9	Dislocations, sprains, and strains of joints	75	87	1.17	1.04	II
850.0 - 877.9	Intracranial injuries, internal injuries, lacerations of head, neck, trunk	31	23	1.50	2.42	II
880.0 - 887.9	Laceration and open wound of upper limb	90	103	1.08	.30	III
910.0 - 929.9	Superficial injuries, contusions	167	163	1.23	3.76	III

* No. of claims in exposed (vibrated) group.

† No. of claims in control group.

Fig. 3. Examples of Trend Types II and III.



process may have occurred among shift workers in the Norwegian chemical industry, based on an elevated and increasing morbidity rate from duodenal ulcer among shift workers up to age 40 which is followed by a decline at older ages. Since comparable rates among other workers continued to rise with age, he interpreted this as indicative of a selection out of shift work (and into day work) for those workers who were unable to adjust to the stress of shift work. In our data, a Trend Type III represents a relative increase in risk of making a claim for medical service followed by a decrease. This pattern, which has been adjusted for age and is therefore even more directly related to length of exposure, is consistent with such a selection process.

Kleinman[6] reported that construction machinery workers had high proportionate morbidity ratios (and thus an excess of these conditions) for osteomyelitis, displacement of intervertebral disc, and deformities of bones and joints. These results were derived from Social Security Administration data concerning disabling conditions for which benefits were claimed.[7] In our data, these conditions are included in the categories "osteomyelitis and other diseases of bones and joints," and "other diseases of musculoskeletal system." Both of these categories display a Trend Type III pattern, while neither shows a significantly elevated relative risk at the 5% level.

Thus, while there was a tendency for construction workers exposed to whole body vibration to make more claims for medical service than construction workers not so exposed during the period of the study, there were few disease categories with statistically significant elevated risk. This may result from selection out of exposed job classes by some workers suffering from certain of these diseases. Our data suggest that this has occurred for at least several disease conditions. The strong implication of such a selection process has resulted in further direct study of this issue, which is now being carried out by our group.

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