

***Mortality, morbidity and health selection
among metal workers***

by Riitta-Sisko Koskela

Institute of Occupational Health
Topeliuksenkatu 41 a A
FIN-00250 Helsinki
Finland

5	Preface
5	Summary
7	I. BACKGROUND OF THE STUDY AND PREVIOUS FINDINGS
7	1. Historical review of ideas on health selection
8	2. Problem of health selection in earlier mortality studies
8	2.1. Health-based selection
11	2.2. Methodological factors
11	2.3. Additional problems in the study of health selection
12	II. OBJECTIVES OF THE STUDY
13	III. HYPOTHESES
14	IV. MATERIAL
14	1. Study design and criteria for the definition of the study population
14	2. Empirical study population
15	V. METHODS
15	1. Source of information
17	2. Exposure
20	3. Confounders and modifiers
23	4. Comparison groups
24	5. Methods of analysis
25	6. Significance testing
25	VI. OCCUPATIONAL MORTALITY AND MORBIDITY
25	1. Mortality
33	2. Disability
36	3. Morbidity
47	4. Combined results for mortality, disability, and morbidity
48	5. Turnover
50	VII. SELECTION
50	1. Social selection
51	2. Health selection
55	3. Chain of selection and life cycle
58	VIII. DISCUSSION
58	1. Validity of the study
61	2. Concluding remarks
64	IX. FOLLOW-UP OF MORTALITY AND MORBIDITY
64	1. Objective of the follow-up
64	2. Material and methods
65	3. Mortality
69	4. Disability
69	5. Chronic diseases
70	6. Discussion
70	7. Concluding remarks
71	References
76	Appendix

PREFACE

This study has been carried out in the Finnish Institute of Occupational Health. It comprises a retrospective cohort study of foundry workers, metal product workers, and electrical workers. The report consists of two phases: the basic phase for the years 1950-1978 and the follow-up until the end of 1987.

Parts of the basic phase of the study have been published earlier. The publications concerned the main hypotheses of the study, health selection, effect of cohort definition and follow-up length on occupational mortality rates, different stages of disease, heaviness of work and life cycle, and completeness of occupational history and occurrences of work-related diseases.

Many people have contributed to this study in one way or another. I particularly wish to thank Sven Hernberg, MD, former Director of Research of the Institute, for his expert guidance in epidemiology and constructive discussions during the many phases of this work. He was a continuous source of support and encouragement even through the most difficult times. Erkki Järvinen, MSc, and Pertti Mutanen, MSc, were especially important with respect to their valuable advice on statistical analyses and their scientific collaboration throughout all stages of the study. A for innumerable others in the Institute, Erkki always unselfishly found time to listen patiently to many problems and help find solutions. I wish to thank Antti Tossavainen, DTech, for his help with the classification of exposures.

I also wish to express my sincerest thanks to my co-workers Hannu Korhonen, MSocSc, Pertti J Kolari, MSc, Juha-Antti Sorsa, MSc, and Satu Simonen, MSc, for their valuable contributions to the data processing and their stimulating teamwork during the different phases of the study.

My warmest thanks are also expressed to Ms Eira Böhm, Ms Hillevi Tötterman, Ms Raija Vuorela, Ms Marja-Liisa Laine, and Ms Riitta Lukinmaa for their skillful assistance in collecting and handling the register and questionnaire data. I wish to express my cordial thanks to Ms Merja Jauhiainen, PhD, Information Scientist, for the literature search. I also wish kindly to thank Ms Pirkko Halme for the word processing and layout of this work, and Georgianna Oja, ELS, for revising the English language of this issue.

The register-based data were obtained from the Social Insurance Institution, from Statistics Finland, and from the Population Register Centre, I want to thank them all.

SUMMARY

Workers are selected into and out of physically demanding jobs with regard to their health. The study of occupational mortality and morbidity is hampered by this selection. Furthermore, social selection and rapid turnover are involved in health selection. Because different stages of disease form only one continuum (dissatisfaction - death), the correct interpretation of the results also requires measures softer than mortality. Earlier studies have concluded that soft and hard measures of health follow one another as explanations for the termination-of-employment rate.

The aim of this study was to determine which age and exposure categories are the most prone to health selection. Mortality and morbidity were studied on three different exposure levels defined primarily according to the physical demands of the work: heavy level (iron foundries); medium level (manufacture of metal products); and light level (manufacture of electrical devices). The population comprised 15 714 men hired in 1950-1976 to work in the three branches of the metal industry. Another cohort, a cross-sectional one, of 1292 workers (who had been hired earlier and were still working in 1950) in the three industrial branches was used to clarify selection due to disability and mortality. Data for the mortality and disability analyses were obtained from national death and disability registers. The period of follow-up was 1950-1978. A questionnaire on occupational history, morbidity, and the causes of turnover was sent to 400 current and 600 former workers from each industrial branch. A questionnaire concerning occupational history was also sent to the nearest relatives of a total of 450 decedents.

The occupational histories of the current and former workers were compared for changes in the exposure level throughout their complete occupational histories. The occupations during the workers' lifetimes were also classified into three exposure levels on the basis of physical demands (heavy, medium, and light).

The three exposure levels showed different patterns of change according to age throughout the workers' complete occupational histories. Selection into and out of jobs within and between different exposure levels appeared to be a continuous process, a chain of selection. This conclusion was ascertained when the complete occupational histories were analyzed according to the exposure levels (heavy, medium, light) of the occupations from which the workers came and to which they transferred.

The foundry workers entered the industry from either heavy or medium-level occupations, and most

of them sought lighter work in medium-level occupations. The metal product workers either began their work lives within the metal product industry or they transferred to it from work that entailed the same exposure level. After leaving a job, the metal product workers generally moved to medium (ie, the same level) or light occupations. The electrical workers switched from medium-level work, or they began their worklives within that industrial branch. When they left a job, they chose medium or light work in the metal industry.

Due to the chain of selection from one exposure level to another, the mortality and morbidity rates for a certain exposure level can be underestimated or overestimated if complete occupational histories are not available.

The selection process was different for different diseases and was manifested as different stages of disease.

Ache or pain in the musculoskeletal system within the last 12 months was more frequent among the foundry and metal product workers than among the electrical workers. Both the currently employed and former foundry workers had significantly more earlier-diagnosed musculoskeletal diseases than the electrical workers. The younger age classes of foundry workers (<45 years) had a higher occurrence of musculoskeletal diseases than the metal product workers; in the older age classes the opposite was true. The former foundry workers had more diagnosed musculoskeletal diseases than the current workers; there was no such difference among the metal product workers. The results indicate that musculoskeletal diseases clearly lead to selection away from heavy work. This conclusion was also supported by the rate of disability due to musculoskeletal diseases, which showed a greater excess in the cross-sectional cohort than in the longitudinal one.

Both the current and the former foundry workers (in different smoker categories) had higher rates of chronic bronchitis than the corresponding groups of metal product and electrical workers. Selection away from heavy exposure was indicated by the finding that former foundry workers had higher occurrences of chronic bronchitis than current foundry workers from the age class of 45–54 years on. A similar trend was found for the metal product workers, but the rates were lower. Diagnosed lung diseases were also more frequent in heavy than medium and light work. Health selection during employment was also suggested by the disability rates for respiratory diseases. Respiratory diseases were more frequent than expected in both the cross-sectional and the longitudinal cohorts, but the excess was greater in the cross-sectional one. Negative health selection was shown as

higher occurrences of diagnosed emphysema and bronchitis in the youngest age class of electrical workers than among the foundry and metal product workers of the same age.

Angina pectoris (irrespective of smoking habits) was more prevalent among both the current and former foundry workers than among the electrical workers, whereas the corresponding differences between workers and metal product workers were not significant. The former foundry workers had somewhat higher occurrences than the current workers. The same was true for the metal product workers. The current electrical workers had higher occurrences than the former electrical workers. This result may reflect negative health selection to light from heavy and medium work. Analysis according to complete occupational history showed that workers at the heavy level had more diagnosed cases of cardiovascular diseases in the younger age classes while workers at the medium level had more diagnosed cases of cardiovascular diseases in the older age classes; both the findings which can be interpreted as the result of selection. Disability due to all cardiovascular diseases and also to coronary heart disease alone were significantly lower for the foundry workers than for the active male population. This finding can be explained both by health selection into and out of heavy-level exposure and by the mortality from cardiovascular diseases in the older age groups.

The use of complete occupational histories and the combination of similar exposure levels throughout the lifetime produced clearer differences in the occurrences of musculoskeletal, respiratory, and cardiovascular diseases between the three exposure levels.

The heavy level had significantly higher occurrences of any previously diagnosed musculoskeletal disease which had prevented work for at least one month (45%) than the medium (34%) or the light (22%) exposure level. The medium level had higher occurrences than the light exposure level.

The prevalences of all diagnosed lung diseases were the highest (42%) at the heavy level, the second highest (36%) at the medium level, and the lowest (32%) at the light exposure level. The differences between the branches were not statistically significant.

This analysis of previously diagnosed heart diseases according to the exposure level did not reveal great differences between the exposure levels. The medium level had the highest prevalence (16%), the heavy level the second highest prevalence (14%), and the light level the lowest prevalence (10%). However, workers 45 years or older on the medium exposure level had significantly more previously diagnosed heart diseases than workers of the same age on the

light level.

Just as changes in the heaviness of the work formed a chain of selection during the workers' lifetimes, changes in the workers' health also formed a chain through their life cycles.

The combined results (with the life-tables technique) for mortality, disability, and morbidity indicated that different stages of disease decreased the cohorts on the heavy, medium, and light exposure levels in different ways. The cohort of workers on the heavy level decreased because of decreased work capacity, disability and death. The cohort of workers on the medium exposure level was reduced mainly through disabling diseases and disability in the older age classes. Workers on the light exposure level had the smallest decrement attributable to different stages of disease; however, they had an increased decrement due to death in the older age classes, a finding which indicates negative health selection.

The life-table technique was also used to show the points of inflection according to the age at which the measures of different stages of disease turned from soft measures into hard ones. The occurrences of excellent work capacity, as well as soft measures of disease (dissatisfaction, discomfort, disease) were calculated for the workers still active, whereas hard measures (disability, death) were considered complementary. The points of inflection in age varied according to the exposure level.

Comparisons of the three industrial branches revealed that the proportion of foundry workers with excellent work capacity decreased the most rapidly with age. The highest point of dissatisfaction (low pay) was found before the age of 30 years and turned to discomfort (heavy work) at the age of 30–34 years. Discomfort again changed to disease at about the age of 40 years. Since heavy work and different symptoms led to selection out of heavy-level jobs, disease did not change to disability until near the age of 50 years. Thereafter hard measures of disease were the most prominent.

Low pay was more important throughout the age classes among the metal product workers than among the foundry workers. Correspondingly, the proportion of workers who experienced the work as heavy was clearly smaller than among the foundry workers and turned to disease later (at about the age of 44 years). Nevertheless, disease changed to disability early in the next age class (45–49 years).

The electrical workers retained "excellent" work capacity until older ages than the foundry workers and metal product workers. They also had the highest occurrences of dissatisfaction (low pay) throughout all the age classes. The proportions of heavy work and illness were low. Because light-level work is not

physically demanding and because there was negative health selection, the occurrence of disease was slightly higher than that of discomfort. Discomfort and disease turned to disability in the age class of 50–54 years.

Hard and soft measures thus formed a continuum (dissatisfaction - death) and followed each other as explanations for the termination of employment. Consequently, a chain of selection was not only formed during workers' lifetimes by changes in the heaviness of the work, but also by health changes during their life cycles.

I. BACKGROUND OF THE STUDY AND PREVIOUS FINDINGS

The complexity of occupational mortality differentials and especially the importance of methodological factors in the interpretation of results have been acknowledged throughout this study. The health effects of various factors of work and the work environment are distorted by different mechanisms of selection into and out of jobs and by methodological factors associated with the measurement of exposure and outcome (mortality or morbidity). The formation of study and reference groups is problematic, the length of follow-up must be optimal, and the methods of analysis must be correct.

Some results of the present study have been published earlier, mainly in connection with international congresses (1-5).

1. Historical review of ideas on health selection

The need for information on occupation has been recognized ever since the first cause-specific mortality statistics were produced in the middle of the 19th century (6, 7). The problem of health selection was first presented by William Oggle in 1885 (7). According to Fox & Collier he described two difficulties encountered in calculating death rates in different industries: "(i) consequence of the considerable standard of muscular strength and vigour to be maintained by those who pursued various trades and occupations, (ii) a very serious flaw due to the fact that industries did not start on equal terms." [p 225] Oggle's comments suggest that three properties of occupational cohorts should be measured: selection, survival, and length of follow-up.

The occupational codes written on the death certificates used in mortality statistics were sufficient as long as social structure remained stable (until the 1940s). Social mobility increased as industrialism expanded and private social insurance systems were set up in the 1950s. These new developments required more accurate records on occupations and diseases. In addition, improved methods were developed for calculating mortality and morbidity statistics, and it became possible to compare different subcategories of the population (6, 8-11).

The problem of health selection emerged not only in comparisons of the mortality rates for different occupational groups, but also in individual studies on occupational morbidity and mortality (11-13). Investigations on older people and heavy work and occupational differences in termination ages received special attention in the 1950s and 1960s (14-19).

The development of national social security systems in the 1960s created the conditions necessary for a more precise registration of mortality and morbidity (20-24). It also improved the accuracy of calculation methods for vital statistics and special studies (12, 25-31).

The number of occupation-specific epidemiologic studies on morbidity and mortality, especially cohort studies, increased sharply in the 1970s (32-40). Despite the better accuracy of the methods, however, these studies suffered from the same difficulties of interpretation mentioned by Oggle in 1885 (7). Several reports discussed the question of health selection in the middle of the 1970s (7, 23, 34, 35, 41-44). Thereafter attempts have been made to separate the effect of selection, survival, and the length of follow-up (7, 42, 45-48) on occupational mortality and morbidity rates. The complexity of the question makes it impossible to find any uniform solution that excludes the healthy worker effect. But nowadays the problem can be specified and considered via different stratification and modeling methods (49-54).

2. Problem of health selection in earlier mortality studies

2.1. Health-based selection

Healthy worker effect. The term selection is used in a broad sense to describe the social circumstances, behavior, or way of life of persons with the characteristic in question. It can even be used about their genetic characteristics (ie, biological selection). In occupational epidemiology selection is used to refer to the "healthy worker effect" (comparison bias).

The healthy worker effect is usually defined as an employed population's tendency to have lower mortality than the general population. This tendency is reflected by standardized mortality ratios (SMR) of less than one (7, 23, 36, 46, 54-57). But the healthy worker effect has also been used to refer to employed populations' lower morbidity (reflected in the frequency of different stages of disease) and longer life expectancy, for which the terms "active worker effect" (46) and "health-related mobility" (58) have been used. Fox & Goldblatt (59) analyzed different selection processes in the Office of Population Censuses and Surveys' longitudinal study. The study focused on health-related mobility, which the authors defined as the relation between artificial improvement or deterioration of the average health of people with a particular characteristic and the processes of selection by which that characteristic is acquired or lost. Mortality was interpreted to be affected by health-related mobility if the health of people acquiring or losing a particular characteristic differed systematically from the health of others with that characteristic. Analyses of the relation between mortality and duration of follow-up confirmed that health-related mobility is an important factor that contributes to the mortality levels of the employed population and immigrants. Selection that affected social class implied differences in mortality.

The healthy worker effect was first reported by William Ogle in 1885 (7). He described three factors that contribute to the low mortality rates in industrial cohorts: (i) healthy persons' selection for employment, (ii) healthier persons staying employed, and (iii) the length of follow-up - the longer the follow-up, the more similar the observed number of deaths to the expected numbers.

Many attempts have been made to calculate or estimate a corrected value for an unbiased SMR due to the healthy worker effect (23, 54, 55, 60). Goldsmith (23) suggested calculating proportional mortality instead of SMR values as a less biased cause-specific mortality. He proposed the application of a constant correction factor (90%) to total male mortality across all ages and causes as another approach. Sterling & Weinkam. (61) estimated that a healthy worker effect of 20% to 40% reduced the mortality of veterans over the entire age range for various causes in the United States. Wen et al (55) pointed out that the proportion of active workers in a cohort is one of the most important determinants of the healthy worker effect. They showed that low SMR values gradually increase as the proportion of active workers decreases in a cohort. The relationship was expressed by a regression equation. Any uniform solution has been the object of much criticism (45, 46, 56, 62), since the

healthy worker effect varies according to many factors.

The healthy worker effect is different for each cause of death. It is known, for example, to be smaller (or nonexistent) for cancer than for cardiovascular and respiratory diseases (7, 36, 42, 63-66). It also varies according to exposure. Epidemiologic studies have commonly faced the problem of a particular exposure in connection with physically heavy work, a factor which also correlates with low social class. Causal conclusions between exposure and excess mortality may be misleading.

The healthy worker effect is also affected by several modifiers. Besides exposure and occupation or work category, other demographic factors (eg, age, gender, and race) determine the healthy worker effect. Young age groups show a greater healthy worker effect than older ones (7, 45). Young workers have better initial health status than the general population of the same age, which includes persons with a congenital defect or a chronic disease that prevents employment. As their age increases, unhealthy persons tend to remain in less demanding jobs or retire due to disability (45, 62, 66, 67). According to McMichael (45) the healthy worker effect disappears by the age of 75 years.

The healthy worker effect is different for men and women. This difference has been explained by the fact that the proportion of women in the economically active population is smaller than that of men. Thus the general female population (as a reference population) includes more healthy persons than the general male population (68, 69).

In the United States the healthy worker effect is stronger for nonwhites than for whites (44, 45, 63, 64), compared with the white population, the non-white population has a higher unemployment rate and higher proportions of persons indigent, disabled, or working in hazardous occupations. In addition, the quality of the comparison is different for the two race groups: working-class whites are compared with the national average middle-class white population, whereas working-class non-whites are compared with the national average non-white population, which has a greater proportion of lower social classes than the white population.

Several studies have reported mortality differences between social groups or other sociodemographic categories (eg, marital status, geographic area, occupation) (69-77). Occupation-specific mortality by socioeconomic categories has been analyzed by Ott et al (78), Shindell et al (54), and Gilbert (62). They found that causes of death other than cancer increased with decreasing socioeconomic status. Cancer mortality was substantially lower for the highest socioeco-

nomic level than for other workers. The higher overall mortality in lower social classes means that the healthy worker effect becomes more evident among well-paid and skilled worker groups (74, 75). Valkonen (79) reported the difference in life expectancy between Finnish upper white-collar employees and manual workers to be about six years among men. He considered two causal possibilities: socioeconomic position affects morbidity and mortality through the influence of social and physiological risk factors or there are factors that directly or indirectly affect both the socioeconomic position and the health of individuals. A Swedish study on twins reared apart and reared together indicated that social causation, childhood, childhood experiences, and health selection may all be important for the association between socioeconomic status and health (80).

Socioeconomic status also affects life-style. Variations in life-style (smoking, drinking, diet, health education, use of medical services, etc) may increase or decrease the differences in health between social classes (22, 68, 69, 78, 81, 82).

Unemployed people are a special group with increased health risk. Mortality statistics (69, 75) and specific studies (72, 83-85) indicate that the unemployed suffer from various diseases (eg, mental disorders) and have a shortened life expectancy (they are especially prone to violent deaths).

Social selection and health selection are intermingled and therefore difficult to distinguish. Fox & Adelstein (70) analyzed mortality differentials and tried to estimate the extent to which mortality is affected by the work environment on one hand and the way of life on the other. They standardized social class to study the variation in mortality between occupations. Observed and expected deaths were compared, in the standard manner with χ^2 values, for each of 25 occupations. The sum of these values measures the total variation between occupation orders. The calculation was then repeated, with the expected deaths based on social class-specific death rates in order to measure the variations associated with direct occupational influences. The difference between this calculation and the total variation was thought to be due to variation reflecting differences in the way of life. The results suggested that some 18% of the variation between occupations was work-related. Thus more than 80% of the variation was explained by the standardization of social class. Only 12% of the variation in cancer mortality rates appeared to be associated with work. For some other diseases (eg, circulatory and respiratory diseases) the work-related variation was higher, ie, nearly 30%. The authors concluded that selective factors associated with entry to different occupations may be more

strongly associated with work than life-style and that such factors may explain some of the differences. Alternatively, certain occupations may be associated with a different life-style than that of men in the same social class.

Selection into and out of jobs. In comparison with the general population, active workers have a better average health status and thus lower mortality and morbidity rates. Economically inactive populations contain several special groups (the institutionalized, the ill, the unemployed, and asocial persons) with a shorter life expectancy (72, 75, 86).

The most important reason for the healthy worker effect is selection of the work force (21, 46, 65). It comprises both self-selection by the employee and selection by the employer. The choice of job depends foremost on the worker's interest, education, family, residence, etc, and on job openings. On the other hand workers are selected into and out of jobs on the basis of their health (62, 87-91). Especially cohorts or workers doing physically heavy work (eg, granite workers, foundry workers, dock workers) have exhibited health-based preselection due to cardiovascular and musculoskeletal diseases (92-97). Negative health selection into physically light occupations causes biased excess morbidity and mortality. The overestimation of morbidity is the most apparent for musculoskeletal disorders and circulatory diseases (98).

Different industries place different demands on workers' health and other factors connected with employability (age, gender, occupational training, social prerequisites). Healthier persons are more easily selected for jobs than less healthy persons. Health screenings and psychological tests are used to select persons fit for work.

Similarly, healthier workers tend to remain in the sector, whereas the work of ill workers may be terminated for health reasons. Bias from healthy worker selection hampered the detection of a true work-related health effect in a study based only on a survivor population (99).

Self-selection out of various jobs has been shown to occur due to symptoms of cardiovascular, respiratory, and musculoskeletal diseases (93, 94, 100-104).

Vinni & Hakama (60) followed a random sample of the total Finnish population for changes in occupation over a 10-year period. They later studied the mortality of the same population for deaths over a five-year period. The healthy population selection effect (ie, selection when persons entered the work force) was found to be about 30%. The mortality of persons entering the work force was 50% of the mortality of those who retired before the age of 65 years. The study also showed a survivor population effect (ie, the mortality of persons entering the work force,

staying employed, and retiring compared with that of the total Finnish population). The mortality of persons who remained working in the same occupational category was 60% of the mortality of those who retired before the age of 65 years. The mortality of persons who changed from one occupational group to another was only 90% of the mortality of persons who remained working in the same occupational group. Thus persons who retired had a high mortality, whereas those who changed occupation were healthier than the total population. The survivor population effect was reduced when these two inverse components were combined. The mortality of persons who remained in the working population was 80% of the mortality of those who changed occupational group.

Knox (105) showed that industrial populations with moderate to high turnover rates cause a form of extended dose-sharing. Nonlinearity of the exposure-response relationship then results in substantially more deaths than would be the case if the turnover rate were lower.

Occupations which require skills (higher social status) also tend to increase health-based selection. Negative health selection may also be found in these occupations, as workers with certain handicaps are able to get sheltered jobs.

In addition, fluctuations in the environment (such as economic growth or recession) to some extent regulate the criteria for workers' health and social selection. For example, the study on the relationship between mortality and the economic cycle revealed a tendency for ischemic heart disease to increase during economic recessions (106-109). Little attention has been paid to mortality differences between workers who are hired during economic growth and those who are hired during recessions (37, 94).

Definition of the cohort and length of follow-up. Different cohort formation criteria and variations in the follow-up modify the results of occupational mortality studies. A cross-sectionally based cohort (workers employed in a certain year or years) will produce results different from those for a longitudinal (entry) cohort (new workers hired during a certain period of time) even though the cohorts are formed from the same workplaces. The former cohort design is affected, like cross-sectional study designs in general, by health selection out of jobs, and the latter cohort design is liable to weaken the possible effects of exposure, especially in occupations with rapid turnover (37, 110-112). Weiss (51) studied bias in cohort definition. The results indicated that a more valid assessment of an epidemic would be obtained from a study of an inception cohort than from a study of a cross-sectional cohort. Even if the direction of the results in the designs are the same, the total mortality

rates may vary and may cause differences in cause-specific figures.

In addition, restricting a cohort, sampling, or orientation toward, for example, certain age groups, matching, or the requirement of a minimum length of exposure modify the results of occupational mortality studies.

The length of the period of entry similarly causes variations in mortality rates (7, 42, 51, 62). As the period of follow-up becomes longer, the cohort ages and the probability of death increases. The higher SMR values which result are then interpreted to mean that the healthy worker effect has decreased or disappeared (7, 45, 46, 55, 113). Goldblatt et al (114) confirmed by statistical modeling that the healthy worker effect did not entirely disappear as follow-up progressed.

When the general population is used as a comparison group for an occupational cohort, the healthy worker effect is unlikely to have any substantial influence on the process of assessing causality for any observed association (115). Wen and his co-workers (46, 55) have remarked that the healthy worker effect is exaggerated by the way the SMR is calculated. The proportion of active workers determines the magnitude of the SMR. Shindell et al (54) considered the healthy worker effect to be an artefact of the underascertainment of deaths (54). Wang & Miettinen (56) criticized Shindell's conclusion because the healthy worker effect is a reflection of a biased comparison of two populations and not a result of the incomparability of the effects or information.

A stratified analysis by the years since entry for different causes of death has been recommended to show variations in SMR values according to the length of follow-up. As measured by relative comparison, the SMR, the healthy worker effect is seen to have a dynamic phase and a plateau phase in relation to the length of follow-up (116). Analysis according to the length of follow-up is important when the latency period of a disease is studied (29, 117-120). Such analysis is also needed when the period of entry varies in the subcohorts (46, 51).

2.2. Methodological factors

Comparison group. Occupational mortality studies face the difficulty of finding a proper reference group (ie, a cohort as similar as possible in all relevant respects other than the exposure under study). Because of these difficulties the general population is generally used for comparison. The drawbacks of using this reference population are well known. Because of health-based selection and in the absence of strong

life-shortening exposures, occupational cohorts generally produce lower mortality rates than the general population. An occupationally active population would be a more valid comparison group (7, 36, 42, 100).

However, suitable mortality statistics (concerning retrospective time periods, since 1940 or 1950) for the general active population do not exist (75, 86). Better validity may be achieved if several occupational cohorts are used or if internal comparisons are done between different subgroups of the cohort in addition to the use of general mortality statistics.

Methods of analysis. The methods of analysis appropriate for a study depend on the study design and the problem under consideration. Crude or adjusted rates, direct or indirect standardization, proportional mortality ratios (PMR), and standardized mortality ratios (SMR), as well as the mortality odds ratio (MOR), may produce different estimates of occupational mortality (41, 43, 44, 46, 56, 113, 120). Thus the methods of analysis can also modify the results of an occupational mortality study and should be considered when the results of different studies are interpreted and compared and when their inconsistencies are considered.

2.3. Additional problems in the study of health selection

Measures of exposure. Quality, intensity, fluctuations, and duration are the main measures of occupational exposure. Retrospective occupational mortality studies encounter difficulties in obtaining reliable data about past exposures (8, 9, 121-124). Even exact and reliable measurements in the present are seldom representative of past exposures. Hence retrospective studies must rely on crude and inexact information. Exposure classifications for the past are based on general knowledge of the hygienic conditions and on changes caused by technical improvements. Employers' and employees' evaluations collected via interviews or questionnaires are also used for exposure classification.

The classification of individual exposures necessitates knowledge of the workers' complete occupational histories in order to measure the duration of exposure. The lack of central registers on exposures and employments makes it essential to gather data on occupations from the personnel records kept by workplaces. Alternatively interviews and questionnaires can be used to obtain complete occupational histories from the workers themselves or the closest relatives of deceased workers. Retrospective cohort studies often include such large populations that

complete occupational histories can be acquired only from samples.

The collection of exposure data suffers from defects in validity that are similar to those of interviews and questionnaires in general (125, 126). Additional difficulties are faced when the respondent is the closest relative of a deceased worker (127-129).

Several studies have shown significant agreement between the self-reporting of employment in a specific industry and employer records of such employment (128, 130). Rosenstock et al (131) designed and tested a questionnaire for a comprehensive occupational health history which also yields information about work and exposure histories. They concluded that information on health history was feasibly obtainable from a self-administered format. The questionnaire results correlated with a separate assessment of occupational exposure and correctly identified worker groups with known high and low hazardous exposures. Tockman (132) and Axelson (133) pointed out the problems of misclassification caused by the fact that not all workers within a particular job classification have the exposure in question. Another reason for misclassification is that too few cases may be found in the unexposed job category because of the tendency to exaggerate exposure.

As a whole, occupational mortality studies have paid too little attention to the completeness and correctness of occupational histories. Thus the discovery of associations between effects and exposures is hampered. For instance, if an increased cancer risk is suspected, unreported early exposure makes the estimation of correct latency periods difficult. Ignorance about confounding exposures may deter the clarification of causal relations.

Measures of outcome. Different stages of disease are defined as measures of outcome (figure 1). The terms hard and soft measures are often used for

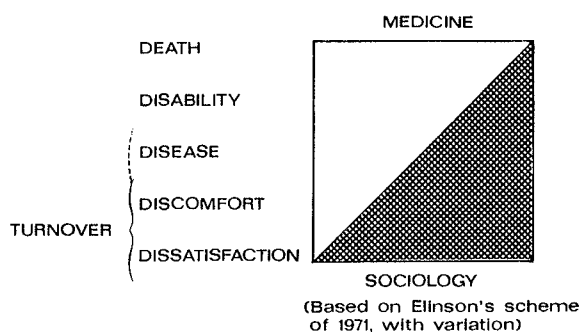


Figure 1. Different stages of disease (adapted from reference 135).

different stages of disease, death being the hardest and subjective opinions the softest measures (36, 134). A continuum of hard and soft measures of health also connects medicine and sociology (135).

Occupational cohort studies are commonly concerned with only one stage of disease (ie, death). However, different stages of disease form one dimension, and the effect of exposure can often be manifested as milder stages of disease (36, 43, 92, 100). Health selection tends to affect the stage at which a disease manifests itself (24, 94, 136, 137). The manifestation of stages of disease are thus an issue comparable to that of competing causes of death.

Statistics on causes of death are used to indicate mortality, and registers on disability pensions are used as an indicator of disability. Milder stages of morbidity can be measured from different disease registers, by clinical examinations, or by questionnaires and interviews. It is often said that the harder the measure, the more reliable the information (36, 138-140). But harder measures also contain sources of error, for example, misclassifications, differences in diagnostic criteria (causes of death and disability), temporal changes in the use of diagnostic nomenclature (health status), diagnostic inaccuracy, and changes in the criteria for the benefits granted any specific disease (disability pensions, specially compensated medication for chronic diseases) (6, 42, 141-143). Standardization and well-controlled techniques can lead to high reliability of the data obtained by interviews and questionnaires (93, 126, 131, 144). In addition, not all disease groups appear in mortality statistics; examples are mental disorders and musculoskeletal diseases. Subjective symptoms and dissatisfaction can be measured only by interviews and questionnaires.

II. OBJECTIVES OF THE STUDY

The main objective of the study was to explore disturbance effects of selective turnover on mortality and morbidity rates in various types of work (heavy, medium, light). Mortality and morbidity rates were mainly studied in the most selective disease groups (musculoskeletal, respiratory and cardiovascular diseases).

Another objective of the study was to determine which age and exposure categories are the most prone to health selection.

The third objective was to seek the "points of inflection" in age and exposure categories, where the measures of different stages of disease turn from

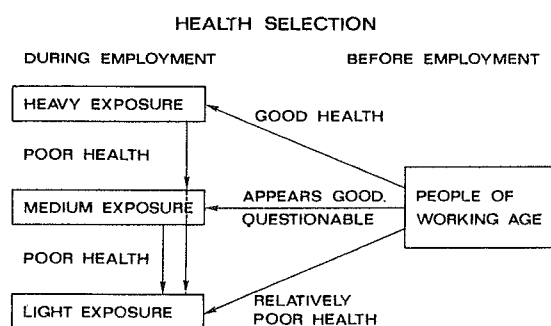


Figure 2. A scheme of health selection before and during employment.

mainly hard measures into mainly soft ones.

Special attention was paid to the correctness of occupational classifications as recorded at workplaces in comparison with the data on complete occupational histories collected by a questionnaire.

III. HYPOTHESES

Because health selection occurs at the beginning of and during employment, decreased mortality or morbidity among the workers in one occupation may be reflected as increased mortality or morbidity among the workers in another occupation.

The following hypotheses were formed (figure 2):

(i) If the levels of exposure are defined as heavy, medium, and light according to the physical demands of the work and other exposures (eg, dust and chemicals) connected with it, the strongest health selection and, consequently, the lowest mortality rates occur at the heavy level.

(ii) The medium level has the highest degree of mortality for three reasons. First, it includes workers primarily unfit for heavy work; second, it comprises workers who could not continue at the heavy level; third, the work itself may involve considerable amounts of exposure, thereby promoting the manifestation of disease.

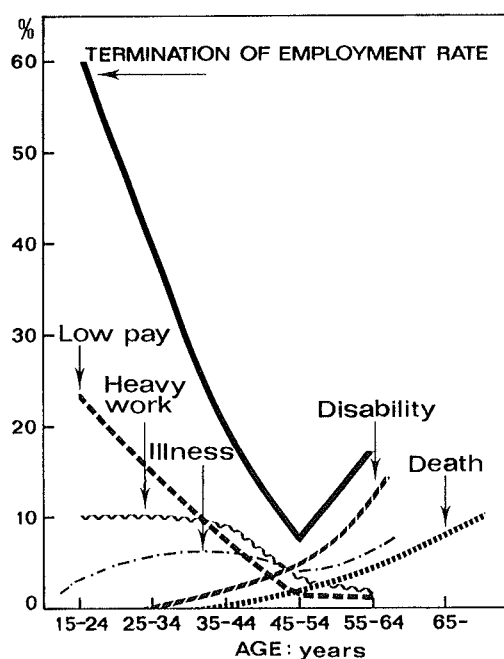
(iii) Strong occupational and negative health preselection occurs at the light level. Selection during the period of employment is low.

(iv) The mechanisms of selection result in different turnover rates at the three levels.

(v) Because different stages of disease form only one dimension (dissatisfaction - death), high mortality and morbidity rates are not necessarily concentrated at the same level(s). The following findings can be expected:

Level of exposure	Subjects	Expected findings
Heavy	Current workers	Symptoms
	Former workers	Morbidity, turnover
Medium	Current workers	Symptoms, morbidity
	Former workers	Morbidity, disability, mortality
Light	Current workers	Symptoms, morbidity
	Former workers	Morbidity, disability

On the basis of earlier findings (145), soft and hard measures can be expected to follow each other as explanations of the termination-of-employment rate (figure 3).



¹The reasons for termination reflect different stages of disease as follows:

Reason	Stage of disease	(Type of measure)
Death	Death	(medical)
Disability pension	Disability	(medical)
Illness	Disease	(medical)
Heavy work	Discomfort	(sociological)
Low pay	Dissatisfaction	(sociological)

Figure 3. Termination of employment and reasons for termination¹ versus age in the cohort of cotton mill workers (adapted from reference 145).

(vi) The prevalence rates of the diseases under study depend on the termination of employment via selection in the same way that low mortality rates in some occupations are compensated for by higher rates in others. If there is little opportunity for turnover, the prevalence of findings rises almost linearly with age in a group of current workers (as in the total population) (144, 146). But if there are good opportunities for turnover, the prevalence rate begins to decline at a certain age (92, 94, 147). This decline is compensated for by a corresponding increase in the group of former workers of the same age. It is presumed that the point of infection differs for age in the three exposure levels.

IV MATERIAL

1. Study design and criteria for the definition of the study population

The study design was that of a retrospective cohort study. The diseases known to affect selection (cardiovascular, respiratory and musculoskeletal diseases) were the main topics of interest. Some other diseases (tumors, violent deaths, and mental disorders) also had to be considered.

The following criteria were used to define the study population:

(i) Three exposure levels were formed: heavy, medium, and light. The primary criteria used to define the exposure levels were physical job demands. Other work-related exposures (especially those that can cause respiratory and cardiovascular diseases) constituted the secondary criteria. The exposure levels had to be the same according to the primary and the secondary definition criteria.

(ii) The three exposure cohorts were formed within one main industrial category.

(iii) The workplaces were restricted to a certain geographic area. Thus workers had similar opportunities to change jobs, and geographic differences could not affect mortality or morbidity.

(iv) The same period of follow-up was required for all the workplaces included (at least 20 years), and they must have existed before the first year of follow-up.

(v) The study subjects were male workers first hired during the follow-up period by the firms under study.

(vi) To obtain a moderate number of cases for the analyses of mortality and disability, the size of the cohort from each exposure level was set at 4000-6000 workers. To make a questionnaire study feasible, the minimum number of current workers at every level was 400.

2. Empirical study population

The population for this study was obtained from the metal industry. Iron foundries were chosen to represent the heavy exposure level, the manufacture of metal products (fabricated metal products, machinery and equipment) represented the medium exposure level, and the production of electrical devices (electrical machinery, apparatus, appliances, and supplies) stood for the light exposure level (148). The names and addresses of the firms in the three branches of industry were collected from the register of enterprises maintained by Statistics Finland (149, 150). The lists were checked with the registers of employer organizations.

The study was restricted geographically to the three southwest provinces of Finland (Häme, Uusimaa, and Turku-Pori), where most of the metal industry is situated.

Only workplaces that had been founded before 1950 and were still in existence in December 1976 were included in the study base. Thus the study base comprised 22 iron foundries, 147 metal product manufacturers, and 58 producers of electrical devices.

An inquiry to determine the number of employees in different occupations, the type of products, the pro-

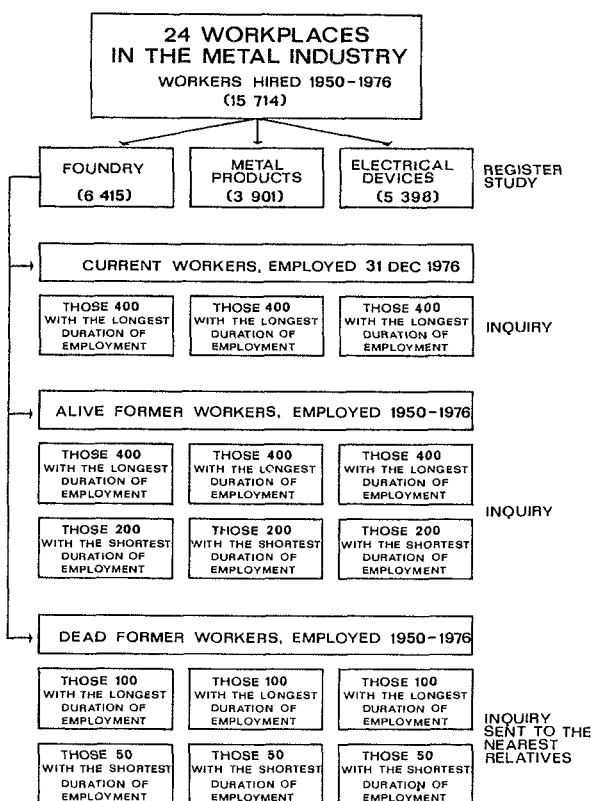


Figure 4. Flow-chart of the study.

duction process, and the availability of personnel registers was sent to all these firms. In all 91% of the iron foundries, 82% of the metal product manufacturers, and 88% of the electrical device producers responded. An industrial hygienist selected the 15 most typical workplaces in each industrial branch on the basis of the employers' replies. The workplaces were then ranked according to the number of workers employed. The list was divided into five categories, each with an equal proportion (20%) of the total number of current workers. The aim of this procedure was to get 100 workers from each interval per branch, making the total sample size 500, so that there would be at least 400 current workers (left after recent turnover) per branch for the questionnaire study. In all, the samples comprised eight iron foundries, ten metal product manufacturers, and six electrical device producers.

The population under study comprised 15 714 men hired for the first time between 1 January 1950 and 31 December 1976. There were 6415 foundry workers, 3901 metal product workers, and 5398 electrical workers. The distribution of the annual entry into the cohorts showed that the cohort of workers manufacturing electrical devices proved to be somewhat younger than the two other cohorts. The median difference from the foundry workers was 3.3 years.

Employees who had been hired earlier and were still working in 1950 (the first follow-up year) were included to form another methodological (cross-sectional) cohort. This additional cohort comprised 1292 men and was used in this study only for comparisons.

The flow-chart of the study is given in figure 4. The study was performed in three stages. The first stage was a register-based study of mortality, disability, and chronic diseases among all 15 714 workers who had been hired by the 24 workplaces in the sample. The second stage was a postal questionnaire. A questionnaire was sent to 400 current workers per branch who were employed on 31 December 1976. (Because the original sample contained more than 400 current workers, those with the longest duration of employment were sent the questionnaire). In each branch, the questionnaire was also sent to the 400 alive former workers with the longest duration of employment and to the 200 with the shortest duration of employment. The third stage was a questionnaire sent to the closest relatives of 150 deceased workers from each branch, 100 of them with the longest and 50 with the shortest duration of employment. The questionnaire studies were carried out in December 1980 and in January 1981.

To obtain the necessary 150 deceased workers per branch (450 in all) with at least one close relative still alive, 20 extra men were chosen for the three samples

of workers (a total of 300) with the longest duration of employment and ten extra for those (150 workers in all) with the shortest duration of employment. The sample of the deceased foundry workers with the longest duration of employment included 13 persons who had been in an earlier study of lung cancer mortality among iron foundry workers (37, 151, 152), and their earlier responses were also used (11 had been received). The actual sizes of the samples of deceased workers are presented in table 4 in the method section.

To ensure the detection of possible effects, the samples of alive and deceased former workers were formed from the extremes on the continuum of the duration of employment periods.

V. METHODS

1. Source of information

The basic information on the subjects (name, date and place of birth, and work history at the firms) was collected from the employers' personnel records. The subjects were then traced through the Population Information System of Finland maintained by the Population Register Centre. Persons who could not be identified from the register (which includes the entire Finnish population from 1967 on) were traced from church registry offices or census officials on the basis of the last place of residence or the native parish. In all 98.7% of the total cohort (96.6% of the foundry workers, 99.9% of the metal product workers, and 99.8 % of the electrical workers) could be traced. The loss of 1.3% cannot have had any fundamental effect on the figures for mortality and disability. The missing persons were excluded from the calculation of the results.

The causes of death were ascertained from death certificates according to the eighth revision of the International Classification of Diseases (ICD) (143). All deaths occurring before 31 December 1978 were included.

The causes of disability, similarly coded according to ICD codes, were obtained from the Social Insurance Register of the Social Insurance Institution. Because the uniform system of recording disability pensions starts from 1969, the follow-up period for disability was restricted to the period between 1 January 1969 and 31 December 1978.

Data on diseases receiving special compensation for medication in 1964-1978 according to the National Sickness Insurance Law were obtained from the Social Insurance Institution.

Table 1. Objects and types of questions used in the questionnaires sent to the current and former workers of the three branches in the metal industry.

Study subjects	Object of question	Type of question
Current and former workers (alive)	History and description of the subject's work under study; all other occupations and their duration	Open-ended
	The subject's own assessment of his present work capacity in comparison with that at his best work age (on a scale of 0 to 10, 10 being the best)	Classified
	The subject's own assessment of his present health (fully healthy, satisfactory, no complaints, could be better, ill)	Classified
	Previously diagnosed diseases of the circulatory, respiratory, or musculoskeletal system	Classified
	Angina pectoris (153)	Classified
	Chronic bronchitis (154) (including smoking habits)	Classified
	Symptoms of musculoskeletal diseases	Classified
Former workers (alive)	Reasons for the termination of employment under study	Classified (order of importance open-ended)
	Occupation taken up after leaving the work under study	Open-ended
	The subject's own assessment of his work capacity at the time he left the work under study in comparison with that at his best work age (on a scale of 0 to 10, 10 being the best)	Classified
Deceased workers (inquiry sent to the closest relatives)	History and description of the subject's work under study; all other occupations and their duration	Open-ended
	Smoking habits	Classified

Data about softer measures of disease or health (morbidity, health status, work capacity), the complete occupational history, reasons for turnover, and smoking were collected by questionnaire. In each branch the questionnaire was sent to 400 current workers, 400 alive former workers with the longest duration of employment, and 200 former workers with the shortest duration of employment. A questionnaire about the complete occupational history and smoking habits was sent to the closest relatives of the deceased workers (a sample of 100 workers with the longest duration of employment and 50 workers with the shortest duration of employment for each branch). Table 1 shows the objects and types of questions in the questionnaires.

The response rates are shown in table 2. The percentage of response for current and alive former workers with the longest duration of exposure was good, but it was lower for alive former workers with the shortest duration of employment. The reasons for

not responding are presented in table 3. The category "reason unknown" was probably due to low motivation resulting from the very short duration of employment in the branch under study. The rate of nonresponse was fairly evenly distributed in every group of subjects according to age. Only in the group of former metal product workers with the shortest duration of employment were the nonrespondents somewhat older than the respondents. The distribution of the length of time that had elapsed since leaving the job under study was about the same for all the groups of respondents and nonrespondents.

The rate of response to the questionnaire sent to the closest relatives of the deceased workers was satisfactory for all the groups except the foundry workers with the shortest duration of employment (only 56%). Experience has shown that the response rates to questionnaires about deceased persons (37, 152) remain low. For this reason close relatives also had the chance to answer by phone. In all, 30% of the

Table 2. Cumulative response (in percent) to the questionnaires sent to the current and former workers or to the next-of kin of deceased workers. (_l = the longest duration of employment, _s = the shortest duration of employment)

Study subjects	Questionnaire	First reminder	Second reminder
Foundry			
Current workers	57	74	81
Former workers _l	55	78	82
Former workers _s	36	64	67
Deceased workers _l	55	79	85
Deceased workers _s	40	53	56
Metal product			
Current workers	65	83	87
Former workers _l	58	76	79
Former workers _s	38	61	67
Deceased workers _l	59	79	83
Deceased workers _s	45	75	76
Electrical devices			
Current workers	59	76	81
Former workers _l	50	69	76
Former workers _s	35	54	60
Deceased workers _l	48	71	75
Deceased workers _s	45	73	82

respondents used this form of responding. The reasons for nonresponse among the closest relatives are presented in table 4. Kinship, the age of the closest

relative, and the subject's cause of death had no demonstrable effect on the probability of responding.

2. Exposure

This study involved no hygienic measurements of exposure. Exact and reliable measures of exposure are rarely available when a retrospective study design is used, and cross-sectional measurements during the study do not provide data about the past. Therefore, a coarse classification into heavy, medium, and light exposure levels was used. The classification was based on occupational labels and their further classification into different categories according to, for example, the duration and level of exposure (heaviness of the work).

Definition of occupation. Occupation was defined according to three criteria: (i) occupational history in the branch under study as recorded by the employer, (ii) occupational history in the branch under study as reported on the questionnaire, and (iii) the complete occupational history throughout the worker's lifetime. Also considered was the occupational history in all of the metal industry, which was mentioned in the questionnaire. The detailed definitions and coded information are given in table 5. The occupational labels for occupations in the metal industry were coded according to the classification of occupations used by the Finnish Metal Workers' Union (155). The complete occupational history during the worker's lifetime was coded according to the classification used for censustaking (156).

Table 3. Current and alive former workers who responded and did not respond to the questionnaire (in percent) and the reasons for not responding. (_l = the longest duration of employment, _s = the shortest duration of employment)

	Foundry workers			Metal product workers			Electrical workers		
	Current (N=400)	Former _l (N=400)	Former _s (N=200)	Current (N=400)	Former _l (N=400)	Former _s (N=200)	Current (N=400)	Former _l (N=400)	Former _s (N=200)
Replied	80.8	82.0	68.5	86.8	79.3	66.5	81.3	75.8	60.0
Did not reply	19.2	18.0	31.5	13.2	20.7	33.5	18.7	24.2	40.0
Dead	0.5	1.8	0.5	0.3	2.0	1.0	0.3	0.5	0.5
Unable to reply	0.0	0.5	1.5	0.5	0.5	1.5	0.0	0.8	0.5
Address unknown	1.0	0.3	4.0	0.0	0.0	2.0	0.3	1.0	2.0
Abroad	0.0	0.5	0.5	0.3	0.3	1.0	0.0	0.3	1.0
Refused to reply	0.5	2.3	1.0	0.0	1.5	1.0	0.8	2.8	4.5
Reason unknown	17.3	12.8	24.0	12.3	16.5	27.0	17.5	19.0	31.5
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4. Actual sample sizes used for the questionnaire sent to the nearest relatives of the deceased workers, responses (in percent) and the reasons for not responding (in percent, marked with the italics). (*l* = the longest duration of employment, *s* = the shortest duration of employment)

	Foundry workers		Metal product workers		Electrical workers	
	Deceased _l	Deceased _s	Deceased _l	Deceased _s	Deceased _l	Deceased _s
Total sample size (N)	108	53	107	54	105	53
No relatives (N)	8	8	12	3	9	4
Actual sample size (N)	100	45	95	51	96	49
Replied (%)	85.1	55.6	83.2	76.5	75.0	81.6
Did not reply	14.9	44.4	16.8	23.5	25.0	18.4
Dead	3.4	0.0	0.0	0.0	1.0	0.0
Unable to reply	1.1	20.0	2.1	3.9	7.3	0.0
Refused to reply	1.1	4.4	2.1	5.9	2.1	4.1
Reason unknown	9.2	20.0	12.6	13.7	14.6	14.3
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0

Table 5. Different definitions of occupation according to the source of information. (^aThe main occupation was defined to be the one at which the worker had been employed for the longest period of time.)

Source of information	Coverage of the occupational history	Definition of the occupation	Coded information
Employers' records	Branch under study	(1) First occupation (2) Main occupation ^a (3) Last occupation	Occupational label, exposure level, date began and terminated
Questionnaire	Branch under study	(1) First occupation (2) Main occupation ^a (3) Last occupation	Occupational label, exposure level, date began and terminated
Questionnaire	Entire metal industry	(1) First occupation (2) Main occupation ^a	Occupational label, exposure level, date began and terminated
Questionnaire	Complete occupational history during the lifetime	(1) Main occupation ^a (2) Last occupation	Occupational label, exposure level, date began and terminated
		(3) Occupation before entering the branch under study (4) Occupation after leaving the branch under study	Occupational label, exposure level
		(5) Changes in heaviness (exposure level)	Change from one exposure level to another, time of the change

Occupational history. When the total cohorts were analyzed, only the occupations and periods of employment shown in the employers' records were taken into account. The breakdown of the subjects in the cohorts according to their main occupation is shown in table 1 in the appendix. For the analyses of mortality, occupations similar in character were grouped into larger categories. See the appendix, table 2. Groups of typical and atypical occupations were also formed in each branch, and laborers were grouped separately. See the appendix, table 3.

The search for mechanisms of selection prevented any minimum duration of exposure from being set. Thus most of the employment periods lasted for only a short time (table 6). In addition employers' records usually mention only the length of employment at a specific workplace and thus underestimate the duration of exposure. Therefore classification of the duration of exposure proved useful only for some occupation-specific and cause-specific calculations and was divided into three categories (<1 year, 1.0-4.9 years, $\geq$ 5 years).

Because of inaccuracies in the occupational history data recorded at workplaces, the complete occupational histories acquired via the questionnaire were used to define the occupations and their levels of heaviness in the branch under study for the analysis of soft measures of health (state of health, work capacity, symptoms, diagnosed diseases).

One of the objectives of this study was to evaluate the errors in the occupational history as recorded at the workplace with respect to the actual occupational history in the branch during the worker's lifetime. For this reason the questionnaire requested data on the complete occupational history of current, former, and deceased workers.

The coverage of the duration of exposure as registered on employers' records in comparison with the information reported by the workers (percentage of the former to the latter) was the most accurate for the

current workers and former workers with the longest duration of exposure and the least accurate for the former workers with the shortest duration of exposure (5). Dead former workers had somewhat lower coverage percentages than the corresponding groups of alive workers. The coverage also decreased as the duration of exposure were less than two years (68% to 90% for different groups of current workers and 37% to 85% for different groups of former workers). The largest discrepancies were found among the metal product workers, whose periods of employment were generally longer than those of foundry workers and electrical workers.

The data on the complete occupational history acquired via the questionnaire were divided into five categories of quality (excellent, good, satisfactory, rather poor, poor) on the basis of the thoroughness with which the period of working age was covered.

Most of the occupational histories reported by the alive workers were excellent, good, or satisfactory. The proportion of rather poor or poor answers varied from 13% to 15% among the foundry workers, from 6% to 9% among the metal product workers, and from 5% to 9% among the electrical workers. Of the occupational histories reported by the closest relatives of the deceased workers, 25% were classified as rather poor or poor (the proportion varying for different groups from 18% to 40%).

Complete occupational histories were available only for the samples. The effect of the lack of complete histories on the mortality results was estimated by calculating person-years both from the years of entry registered on the employers' records and those reported by the workers until the end of the follow-up. The errors in person-years were clearly smaller than the errors in the durations of exposure. The greatest loss of person-years was found for the deceased metal product workers. On the basis of the questionnaire data and regardless of the quality of the response, the proportion of workers who had entered the branch under study before the first year of follow-up (1950) was the highest for the deceased workers and the alive former workers with the longest duration of exposure (5).

The quality did not depend on whether the response was received after the questionnaire, the first reminder, or the second reminder was sent. The groups of former foundry workers and metal product workers with the shortest duration of employment were exceptions; the quality of their responses was poorer after two reminders. The quality of responses among all the worker groups deteriorated with age regardless of how promptly the responses were returned. The quality of the responses provided by the

Table 6. Employees hired between 1950 and 1976 according to the duration of employment (duration of exposure) recorded by the employers.

Duration of employment (years)	Foundry workers	Metal product workers	Electrical workers
	(N)	(N)	(N)
<1.0	4 755	1 723	3 385
1.0-4.9	1 088	1 246	1 612
$\geq$ 5.0	572	932	401
Total	6 415	3 901	5 398

closest relatives were also independent of promptness. But the data on occupational histories were clearly more complete when the answers were received by phone than by mail because more precise answers could be requested during conversations. Although the methods of response were different, the quality of the answers received by phone was more like the quality of the answers received from the subjects still alive than like the answers received by mail from the closest relatives of the deceased workers.

Exposure levels. The main criterion used to form the cohorts was the exposure level. The three levels were classified primarily according to the physical demands of the jobs (the heaviness of the work) as heavy, medium, and light. The classification of the three industrial branches, done by an industrial hygienist, was based on an estimation of the average energy consumption at work per shift (157): (i) <1000 kcal per shift for light exposure, (ii) 1000–1500 kcal per shift for medium exposure, and (iii) >1500 kcal per shift for heavy exposure.

The secondary criterion was other exposures connected with the work, especially exposures able to cause respiratory or cardiovascular diseases. Dust or chemical exposure was considered a risk factor for respiratory diseases; exposure to certain chemicals or heat and the physical demands of the work were considered risk factors for cardiovascular diseases. An industrial hygienist also performed these assessments on the basis of knowledge of the hygienic conditions in the three industrial branches. The results of earlier research projects (157–159) and data from previous industrial hygienic measurements (160) were used in the assessments.

Because there was some variation within the levels, each occupation was classified in the same way into three exposure levels. The classification is shown in table 4 in the appendix. The distribution of the workers according to the three exposure levels, with laborers indicated separately, is presented in table 7. When the complete occupational history was considered, the occupation codes of the census were also grouped into three exposure categories according to the heaviness of the work. See the appendix, table 8.

Furthermore, changes in the heaviness of the work and the time of such changes were coded throughout the complete occupational histories.

When the main occupations (according to the census code) during the lifetime were considered, the industrial branch was the same among 71% to 93% of the current workers, 52% to 84% of the alive former workers with the longest duration of employment, and only 10% to 42 % of those with the shortest duration of employment. Among the dead former workers the corresponding percentages were 38% to 78% for the workers with the longest duration of employment and 8% to 56% for the workers with the shortest duration of employment.

The correctness of the levels of heaviness was controlled by comparing the classifications of the occupations recorded at the workplaces with those reported by the workers, with several time periods used for the classification (eg, heaviness of the main occupation in the branch under study or during the lifetime). The heaviness of the main occupation in the branch under study proved to be the same among 69% to 95% of the alive workers and among 78% to 100% of the deceased workers, depending on whether the classification was based on the occupations recorded at the workplaces or the occupations reported via the questionnaire. The comparison of the average point of heaviness during the lifetime with the heaviness of the main occupation in the branch under study gave similar results. Little variation in the levels of heaviness according to calendar times (see figure 16) was detected for the groups of foundry workers and metal product workers, whereas older electrical workers had transferred from work on heavier exposure levels.

3. Confounders and modifiers

A confounder (ie, a factor that causes comparison bias) is a causal risk factor of the outcome and is statistically associated with the exposure under study. Epidemiologic studies may involve several potential

Table 7. Distribution of the employees (numbers) according to main occupation (in the employer's records) on the three exposure levels in the industrial branches.

Industrial branch	Exposure level				
	Heavy	Medium	Light	Laborers	Total
Foundry (heavy)	1 887	1 218	25	3 285	6 415
Metal products (medium)	1	3 002	286	612	3 901
Electrical devices (light)	—	1 550	2 634	1 214	5 398

Table 8. Age structure of the cohorts. The person-years were calculated for the period of follow-up from 1950 to 1978.

Age (years)	Foundry workers		Metal product workers		Electrical workers	
	Person- years	%	Person- years	%	Person- years	%
15-24	10 937	11.7	11 570	21.5	21 021	30.7
25-34	31 600	33.8	18 719	34.9	25 156	36.7
35-44	28 533	30.5	12 068	22.5	13 503	19.7
45-54	15 779	16.9	6 787	12.6	5 847	8.5
55-64	5 470	5.9	3 335	6.2	2 307	3.4
65-74	1 164	1.2	1 082	2.0	603	0.9
≥75	73	0.1	142	0.3	111	0.2
Total	93 556	100.0	53 703	100.0	68 548	100.0

confounding factors, the effects of which can be diminished by their association with other factors already controlled (161).

The design of this study excluded such potentially confounding factors as gender (the cohorts contained only men) and region (the workplaces were in a restricted area), and the three cohorts had similar criteria of admission and follow-up.

Age was an obvious confounder in this study. The distributions of person-years in the cohorts according to age are shown in table 8. Differences in age structure were eliminated by calculating age-specific figures in the analysis of mortality and disability. The age distributions of the samples in the questionnaire study differed significantly for the three industrial branches (see table 9). The current metal workers were older than the current foundry workers and the electrical workers, who were the youngest. Among the alive former workers, the foundry workers were the oldest and the electrical workers the youngest. The electrical workers were the youngest of the deceased former workers with the longest duration of exposure, but the samples of those with the shortest duration of exposure did not deviate essentially from each other in age structure (age at death).

Morbidity and mortality vary according to socioeconomic factors, the lower social classes having higher rates (69, 70, 75, 78, 94). Socioeconomic factors were a problem in this study, as social factors are intermingled with the definition of exposure levels. The heaviness of exposure correlates with socioeconomic status; the work of people in lower social classes is generally heavier than the work of people whose social status is higher (75, 78). Thus men of working age are selected into different exposure levels not only on the basis of health but also on the

basis of social factors. Consequently, social selection confounds the study of health selection.

Social factors were not examined on the individual level or within the industrial branches because health selection was analyzed only between the three exposure levels.

Foundry workers were selected to represent the heavy level of exposure, and it was also assumed that they were socially less selected than the other two exposure cohorts. Skilled workers accounted for only 45% of the foundry workers; the corresponding figures were 83% for the metal workers and 76% for the electrical workers. For this reason the results were calculated separately for laborers.

The average earnings of the metal product workers and the electrical workers were higher than those of the foundry workers (according to the metal employers' payroll statistics). The questionnaire data revealed that the cohort of electrical workers had the most occupational training and the foundry workers the least (table 10). The number of children was highest among the foundry workers, and families with three or more children were more frequent than among the other groups. Calculation of the average number of children per worker (with the different age structure taken into consideration) yielded a similar result.

There were also other factors that could be used as indicators of social selection. Such factors include the facility with which the persons in the cohorts could be traced, the duration of employment, high turnover rates, and variations in the number of employees according to economic fluctuations. Some diseases are associated with low social selection (69, 70). In this study excessive mortality from violent deaths (especially suicides), mortality from deaths in which

alcohol was a contributing factor, and disability due to mental disorders were interpreted to suggest social unselectiveness.

Smoking is one of the most discussed potential confounders in epidemiologic studies (68, 162-165). If occupational factors themselves produce a strong effect, the control of smoking becomes less important. But when the rate ratio is low, smoking should be controlled (36). In this study the duration of exposure varied, and there was no minimum exposure period. Both of these factors are prone to produce low rate ratios. Thus smoking habits were controlled in the questionnaire studies. Stratification according to smoking habits was used when angina pectoris and chronic bronchitis were analyzed. The smoking habits of the deceased persons were also controlled by the questionnaire sent to the closest relatives, and data on

smoking habits were used to assess the etiology of cancer mortality in the three cohorts. The distribution of smokers, ex-smokers, and nonsmokers in the samples of the questionnaire study is shown in table 11.

Some methodological factors also modify the results of a cohort study, eg, the definition of the cohort, the length of follow-up, and the minimum duration of exposure (7, 29, 42, 45). These methodological factors were controlled in two ways: (i) in the study design, by the construction of longitudinal and cross-sectional cohorts from each industrial branch and (ii) stratification of the results according to the different criteria used to define the cohorts, the length of follow-up, and the minimum duration of exposure. The effect of methodological factors has been analyzed and discussed in a separate paper (3).

Table 9. Age distribution of current and former workers according to the questionnaire. ($_l$ = the longest duration of employment, $_s$ = the shortest duration of employment)

Age (years)	Alive workers						Dead workers					
	Current		Former $_l$		Former $_s$		Former $_l$		Former $_s$			
	N	%	N	%	N	%	N	%	N	%	N	%
<i>Foundry workers</i>												
15-24	14	4.4	0	0.0	3	2.2	0	0.0	0	0.0		
25-34	84	26.3	41	12.7	32	23.7	6	7.1	7	28.0		
35-44	88	27.6	86	26.5	41	30.4	16	19.0	6	24.0		
45-54	75	23.5	103	31.8	42	31.1	25	29.8	6	24.0		
55-64	53	16.6	53	16.4	14	10.4	21	25.0	4	16.0		
≥65	5	1.6	41	12.7	3	2.2	16	19.0	2	8.0		
Total	319	100.0	324	100.0	135	100.0	84	100.0	25	100.0		
<i>Metal product workers</i>												
15-24	0	0.0	1	0.3	0	0.0	1	1.3	3	7.9		
25-34	81	23.4	46	14.6	69	53.5	5	6.3	5	13.2		
35-44	122	35.3	115	36.5	28	21.7	12	15.0	9	23.7		
45-54	78	22.5	74	23.5	21	16.3	21	26.3	8	21.1		
55-64	56	16.2	39	12.4	8	6.2	18	22.5	10	26.3		
≥65	9	2.6	40	12.7	3	2.3	23	28.8	3	7.9		
Total	346	100.0	315	100.0	129	100.0	80	100.0	38	100.0		
<i>Electrical workers</i>												
15-24	36	11.2	2	0.7	14	11.9	10	13.9	7	17.5		
25-34	176	54.7	97	31.6	53	44.9	8	11.1	5	12.5		
35-44	53	16.5	124	40.4	36	30.5	13	18.1	7	17.5		
45-54	37	11.5	53	17.3	9	7.6	14	19.4	6	15.0		
55-64	18	5.6	18	5.9	4	3.4	15	20.8	7	17.5		
≥65	2	0.6	13	4.2	2	1.7	12	16.7	8	20.0		
Total	322	100.0	307	100.0	118	100.0	72	100.0	40	100.0		

4. Comparison groups

Mortality. Four bases for comparison were used in the analysis of mortality: (i) internal comparison between different subcategories in each industrial cohort, (ii) intercomparison of the three cohorts, (iii) comparison of the longitudinal and cross-sectional cohorts, and (iv) comparison between the cohorts and the general male population of Finland.

Internal comparison was used to compare occupational groups, classes of exposure time, and the exposure levels within one branch. Because the main objective of the study was the detection of selection mechanisms, most of the comparisons were done between the three cohorts. Some subcategories were also compared, such as the typical exposure levels (ie, heavy work on the heavy level was compared with medium-level work on the medium level or light-level work on the light level).

The cohorts under study (longitudinal cohorts that comprised men hired between 1950 and 1976) were compared with cross-sectional cohorts from the same industrial branches (that comprised employees who had been hired earlier and were still working in 1950). Cross-sectional cohorts are usually highly selected groups, and so their use for comparisons can show health selection during employment.

The general male population of Finland was also used as a base for comparison in the analysis of mortality (166, 167). The purpose was twofold: (i) to reveal health-based selection in the cohorts; and (ii) to provide a baseline for the comparisons between the cohorts.

Disability. The bases of comparison for the analysis of disability were principally the same as for the analysis of mortality: (i) comparison of the exposure levels within an industrial branch, (ii) intercomparison of the three cohorts, (iii) comparison between longitudinal and cross-sectional cohorts, and (iv) comparison between the cohorts and the active male population of Finland.

The reasons for the selection and use of the first three comparison groups were similar to those in the analysis of mortality. The fourth base for comparison was the active male population instead of the general male population. Three different incidence statistics on disability pensions were compared with each other before the decision to use this base was made: (i) the total male population (168, 169), (ii) the male population of working capacity (169), and (iii) the active male population (170). Disability statistics (on both incidences and prevalences) for the total male population are not a good base for comparison because the statistics include men who have never been fit to work. The statistics thus yield excessively high expected numbers, especially for young age classes but also to some extent for the oldest age class, for which the denominator is reduced by disabled and deceased persons. The expected numbers calculated with the male population of working capacity as the base were similar to those calculated with the (economically) active male population as the base. However, the active male population seemed to be a better comparison group because its use also excludes persons who have never been active (eg, students and young unemployed persons) from the denominator.

Table 10. Distribution of occupational training in the study groups. (_l = the longest duration of employment, _s = the shortest duration of employment)

Study subjects	Practical training		Periodic courses		Vocational school		Secondary school		Total
	N	%	N	%	N	%	N	%	
Foundry workers									
Current	237	80	23	8	31	10	5	2	296
Former _l	220	75	29	10	36	12	9	3	294
Former _s	84	72	17	15	3	3	13	11	117
Metal product workers									
Current	145	44	45	14	133	41	4	1	327
Former _l	139	48	33	11	102	35	18	6	292
Former _s	50	43	22	19	29	25	15	13	116
Electrical workers									
Current	114	36	196	61	1	0	11	3	322
Former _l	52	17	212	69	6	2	37	12	307
Former _s	52	55	12	13	22	23	8	9	94

Table 11. Distribution of smokers, ex-smokers, and nonsmokers in the samples of the questionnaire study. (I₁ = the longest duration of employment, S₁ = the shortest duration of employment)

Study subjects	Smokers		Ex-smokers		Nonsmokers		Total
	N	%	N	%	N	%	N
Foundry workers							
Current	158	50	99	31	60	19	317
Alive former _I	154	47	124	38	49	15	327
Alive former _S	82	61	25	19	27	20	134
Dead former _I	61	87	..	..	9	13	70
Dead former _S	19	90	..	..	2	10	21
Metal product workers							
Current	124	36	114	33	105	31	343
Alive former _I	113	36	124	40	75	24	312
Alive former _S	67	53	32	25	28	22	127
Dead former _I	62	85	..	..	11	15	73
Dead former _S	30	83	..	..	6	17	36
Electrical workers							
Current	137	43	85	26	100	31	322
Alive former _I	123	40	94	31	87	29	304
Alive former _S	58	50	34	29	25	21	117
Dead former _I	56	80	..	..	14	20	70
Dead former _S	30	81	..	..	7	19	37

Soft measures of morbidity. No external population was used for comparison when the soft measures acquired by the questionnaires were analyzed. The results for the samples of current and former workers were compared with each other within and between the industrial branches. Comparisons were also done between the exposure levels.

5. Methods of analysis

Mortality. The life-table technique was used for the comparisons of mortality between the three cohorts (171). The annual probability of mortality at age *a* was estimated graphically from incidences in five-year age categories. The radix of the table was fixed at the age of 30 years, at which point the number of survivors was defined as 100 000. The number of deaths at age *a* was distributed into different causes of death according to the proportion at that age. The proportional numbers were added to the corresponding cause-specific numbers cumulated from the previous age classes.

When the cohorts and the subcohorts were compared with the general male population, the SMR was computed for the cause of death. Because there were no essential differences in the age structure of the cohorts and the subcohorts, the SMR method yielded results analogous to the comparison of incidences

between the cohorts. The official statistics on causes of death in 1970 were selected for comparison with the general male population in the analysis of the longitudinal cohorts (hired between 1950 and 1976), and the official statistics for 1965 were used in the analysis of the cross-sectional cohorts (still at work in 1950 but hired earlier) (166, 167). These years were chosen on the basis of the median year of deaths in the cohorts. The use of the median year was based on separate calculations for the median year of the deaths and five-year calendar-specific mortality rates (3). The effects of cohort formation, the period of entry, and the period of follow-up on the results for mortality are also reported in a separate paper (3).

Incidence density, cumulative incidence, and proportional mortality figures were used to compare the causes of death in the occupational subgroups. To obtain the proportional mortality figures, the observed occupational distribution among the workers who died from a certain cause of death was compared with an expected distribution calculated on the basis of the occupational distribution of each cohort (ie, proportions of person-years in different occupational groups according to age).

Disability. The incidence densities and the cumulative incidences were calculated to compare the occurrence of disability in the cohorts and the subcohorts between 1969 and 1978. The comparison between the cohorts and the active male population was

done with proportional disability figures. The age-specific expected numbers were calculated for cause of disability, with the active male population as the base. The age-specific and cause-specific proportions were used as weights. The statistics on disability pensions granted to the active male population in 1979 were selected for comparison (172).

The duration of follow-up on the incidences of disability was short, only ten years. Therefore, to ensure the correctness of the results, age-standardized prevalences were also computed for the whole cohorts (1950-1976) at the end of the follow-up as of 31 December 1978. The age distribution of the Finnish male population, 16-64 years, as of 31 December 1978, was used as the standard (136).

Decrement through disability or death. The decrement of the cohorts through disability or death was computed by the life-table technique. The period of follow-up was 1 January 1969 - 31 December 1978, as the incidences of disability pensions were available only for this period. Besides the total decrement through disability or death, the decrement was also calculated separately for disability and death according to which one occurred first. The method of calculation was the same as that for the analysis of mortality.

Turnover. The termination of employment in the three cohorts was calculated as percentages in relation to the number of continuing employments per age category. The reasons for turnover were calculated as percentages according to age in the samples of the questionnaire study.

Diseases and health. The incidence densities per 1000 person-years were calculated for diseases granted specially compensated medication by national sickness insurance law between 1964 and 1978. The age-standardized incidence rates were also calculated. The total age distribution of person-years in the three cohorts was used as the standard.

The prevalences of diagnosed diseases and symptoms and the assessments of the present health state, as reported on the questionnaire, were calculated according to age. Age-standardized prevalences were also calculated. The age distribution of the Finnish male population of 15-74 years as of 31 December 1979, with the accuracy of a ten-year age class, was used as the standard.

Work capacity. The results for the assessment of work capacity were analyzed by means of linear regression. Two regressions were computed for each sample of alive workers. The first one expresses changes in work capacity between the beginning and the end of employment and was calculated as a function of age at the beginning of employment and the duration of employment. The coefficient of the dura-

tion of employment shows the speed of change in work capacity in a year. The second regression expresses changes in work capacity after the cessation of the work and was formed as a function of age at the end of employment, the duration of employment, and the length of time between age at the cessation of the work, and age in 1980.

6. Significance testing

The Poisson-distribution model was used to test the significance of the cause-specific and exposure-specific observed number of deaths against the expected number based on national figures (SMR) and internal occupational distributions (proportional mortality) (173). Incidence densities between the cohorts and between different subcohorts were tested by the Mantel-Haenszel chi-square test for incidence density data (174). The same chi-square test was used for the survival curves and the cause-specific mortality curves produced by the life-table technique.

The observed number of disability pensions was tested against the expected number by the Poisson-distribution model (173), and the incidence densities were tested by the chi-square test (174). The decrement model was tested in the same way as the survival curves.

The incidence densities of specially compensated medicines were tested between the cohorts and between different subgroups by the chi-square test (175).

The differences between the prevalences of the samples in the questionnaire study were tested by the Mantel-Haenszel (175) chi-square test. The comparisons were done with stratification into ten-year age classes to eliminate the influence of the differences in the age distributions.

The normal approximation test (173) was used to test for differences between the regression coefficients, which show changes in the work capacity of the employees in the questionnaire samples.

VI. OCCUPATIONAL MORTALITY AND MORBIDITY

1. Mortality

Total mortality. When the mortality of the three exposure-level cohorts were compared with the mortality of the general male population of Finland, the

SMR values were 124 for the foundry workers, 92 for the metal product workers, and 107 for the electrical workers even though the SMR values of working populations usually remain below 100. The most probable reason for the high ratios was that, for methodological reasons, there were no criteria for the duration of employment. The age-specific observed and expected numbers of deaths are shown in tables 12-14 (on pages 27-29). The foundry workers had a significantly higher overall rate of mortality than the expected rate based on the general male population.

The survival curves of the three cohorts implied that the heavy-level cohort had the highest mortality and the medium level the lowest (figure 5). Comparison of these extreme mortality patterns gave a P-value of less than 0.001 (Mantel-Haenszel chi-square test for incidence density data). The survival curve for the light level was similar to the medium one until the workers aged; then the curve nearly attained that of the heavy-exposure cohort and significantly differed from that of the medium-exposure cohort (>55 years of age $P<0.05$). The difference between the heavy-level cohort and the light-level cohort was also statistically significant ($P<0.05$). Among the general male population, the number of survivors at 65 years of age from the radix of 100 000 persons aged 30 years was 64 600; the corresponding figures were 57 800 among the foundry workers, 67 400 among the metal product workers, and 60 000 among the electrical workers.

Although SMR values are not mutually comparable, in this case, they yielded a mortality pattern similar to that obtained with the direct comparison method of the survival curves. The resemblance of these patterns was due to the similarity in the shape of the age distributions between the cohorts and the reference population.

Because social and health factors are intermingled, variations in the numbers of unskilled workers could have caused different mortality patterns among the three exposure-level cohorts. Laborers had a tendency towards the higher mortality than skilled workers, especially among foundry workers ($P<0.05$). But the order of the survival curves between the industries remained unchanged even when the laborers were excluded from each level.

The cohorts were subdivided into three exposure levels according to the level of the main occupation, and the corresponding levels were then combined. Again the order of the survival curves between the exposure levels remained unchanged in comparison with the order of the original cohorts. The laborers from all exposure levels, who were considered one additional group, had the highest mortality pattern. The difference in the incidence densities between the laborers and the medium exposure level was the

greatest and was highly significant ($P<0.001$); the difference from the light level was also statistically significant ($P<0.05$). The heavy-level workers had nearly the same incidences as the laborers.

Cause-specific mortality. The most important causes of death are presented in tables 12-14. Violent deaths were more frequent among the foundry and electrical workers than expected on the basis of the general male population data. The excess was due to suicides, in the group of foundry workers also to motor vehicle accidents and other accidental deaths. Occupational accidents were not responsible for the frequency of accidental deaths among the foundry workers. Most of the accidents occurred during leisure time and could be explained by social factors.

Mortality from respiratory diseases exceeded the expected mortality among the foundry workers ($P<0.05$). The observed numbers were excessive from the age of 35 years on. Mortality from respiratory diseases among the metal product workers and the electrical workers was slightly less than expected. There were somewhat more deaths from cardiovascular diseases among the foundry workers than was expected on the basis of national figures. The excess mainly originated from the age group of 45-54 years. There was no excessive mortality from cardiovascular diseases in the two other cohorts. Cardiovascular diseases were also analyzed for the subcategories of coronary heart disease (CHD) and cerebrovascular

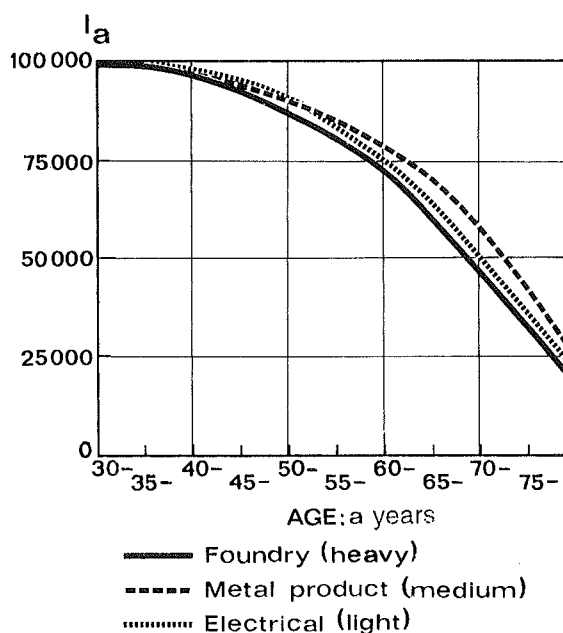


Figure 5. Survivors ≥ 30 years of age according to the three levels of exposure. [I_a = survivors at age a , I_{30} = 100 000 (radix)].

Table 12. Foundry workers' mortality from certain diseases in an age-specific comparison with the expected (E) number of deaths calculated on the basis of death rates for the Finnish male population. (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence limit)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15–24	10 937	15.2	19	11.4	15	2.5	8 **	4.6	4	2.8	2	0.3	—
25–34	31 600	62.9	79	40.4	55 *	13.1	23 *	10.6	13	10.4	12	1.2	2
35–44	28 533	130.5	180 ***	50.0	94 ***	15.9	27 *	8.2	17 **	18.5	38 ***	3.5	10 **
45–54	15 779	170.1	225 ***	32.3	59 ***	9.6	16	6.2	11	11.6	22 **	6.3	10
55–64	5 470	143.5	159	11.3	17	3.4	3	3.0	3	3.5	9 *	7.8	9
65–74	1 164	67.6	70	2.8	7 *	0.7	2	0.7	1	1.0	3	5.9	8
≥75	73	10.5	14	0.3	1	0.0	—	0.1	1	0.2	—	1.4	1
Total	93 556	600.3	746 ***	148.5	248 ***	45.2	79 ***	33.4	50 **	48.0	86 ***	26.4	40 *
SMR			124		167		175		150		179		152
95% CI			115 – 133		147 – 189		138 – 218		111 – 197		143 – 221		108 – 206

Age (years)	Person-years	Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15–24	10 937	0.5	3 *	0.0	—	0.2	2	1.2	—	0.0	—	0.0	—
25–34	31 600	9.0	9	3.1	3	3.9	3	5.1	9	0.0	1	0.7	—
35–44	28 533	44.7	44	29.5	30	9.0	9	14.8	11	3.2	2	2.9	2
45–54	15 779	84.6	105 *	63.6	72	10.5	16	30.9	35	10.0	14	6.8	10
55–64	5 470	79.1	74	56.6	56	11.3	7	34.5	47 *	16.0	20	7.3	15 *
65–74	1 164	38.1	36	23.0	21	7.7	8	15.1	12	5.9	9	4.0	1
≥75	73	6.2	9	2.6	7 *	1.7	2	1.6	2	1.9	1	0.6	—
Total	93 556	262.2	280	178.4	189	44.3	47	103.2	116	37.0	47	22.3	28
SMR			107		106		106		112		127		126
95% CI			95 – 120		91 – 122		78 – 141		93 – 135		93 – 169		83 – 181

*P<0.05, **P<0.01, ***P<0.001, Poisson distribution.

Table 13. Metal product workers' mortality from certain diseases in an age-specific comparison with the expected (E) number of deaths calculated on the basis death rates for the Finnish male population (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence limit)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 570	16.1	12	12.0	8	2.6	3	4.8	2	2.9	3	0.3	—
25-34	18 719	37.2	36	23.9	28	7.8	9	6.3	9	6.2	9	0.7	—
35-44	12 068	55.2	54	21.2	22	6.7	7	3.5	5	7.8	9	1.5	—
45-54	6 787	73.2	82	13.9	17	4.1	7	2.7	4	5.0	5	2.7	3
55-64	3 335	87.5	68 *	6.9	9	2.1	3	1.8	2	2.1	4	4.7	7
65-74	1 082	62.8	55	2.6	1	0.7	—	0.4	1	0.9	—	5.6	4
≥75	142	20.4	18	0.6	1	0.1	—	0.1	1	0.4	—	2.6	1
Total	53 703	352.4	325	81.1	86	24.1	29	19.6	24	25.3	30	18.1	15
SMR			92		106		120		122		119		83
95% CI			82 - 103		85 - 131		81 - 173		78 - 182		80 - 169		46 - 137

Age (years)	Person-years	Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 570	0.5	2	0.0	—	0.3	1	1.2	2	0.0	—	0.0	—
25-34	18 719	5.3	— **	1.8	—	2.3	—	3.0	1	0.0	—	0.4	—
35-44	12 068	18.9	21	12.5	13	3.8	5	6.2	5	1.4	2	1.2	1
45-54	6 787	36.4	36	27.3	21	4.5	5	13.3	19	4.3	5	2.9	5
55-64	3 335	48.2	40	34.5	24	6.9	12	21.0	10 *	9.8	6	4.4	4
65-74	1 082	35.4	36	21.3	24	7.1	3	14.1	10	5.5	2	3.8	6
≥75	142	12.0	12	5.1	5	3.4	2	3.1	4	0.7	1	1.1	2
Total	53 703	156.7	147	102.5	87	28.3	28	61.9	51	21.7	16	13.8	18
SMR			94		85		99		82		74		130
95% CI			79 - 110		68 - 105		66 - 143		61 - 108		42 - 120		77 - 206

*P<0.05, **P<0.01, Poisson distribution.

Table 14. Electrical workers' mortality from certain diseases in an age-specific comparison with the expected (E) number of deaths calculated on the basis of death rates for the Finnish male population. (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence limit)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	21 021	29.3	32	21.9	26	4.7	7	8.8	13	5.3	5	0.5	—
25-34	25 156	50.0	49	32.2	32	10.4	11	8.4	8	8.3	9	1.0	1
35-44	13 503	61.7	54	23.7	28	7.5	10	3.9	5	8.8	13	1.7	2
45-54	5 847	63.0	72	12.0	18	3.6	10	2.3	2	4.3	4	2.3	1
55-64	2 307	60.5	83	4.8	15	1.4	4	1.3	6	1.5	5	3.3	5
65-74	603	35.0	36	1.4	2	0.4	2	0.4	—	0.5	—	3.0	2
≥75	111	15.9	10	0.5	—	0.1	—	0.1	—	0.3	—	2.1	1
Total	68 548	315.4	336	96.5	121	28.1	44	25.2	34	29.0	36	13.9	12
SMR			107		125		157		135		124		86
95% CI			95 – 119		104 – 150		114 – 210		93 – 189		87 – 172		45 – 151

Age (years)	Person-years	Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	21 021	0.9	1	0.0	1	0.5	—	2.2	3	0.0	—	0.1	1
25-34	25 156	7.2	5	2.4	1	3.1	3	4.1	3	0.0	—	0.6	1
35-44	13 503	21.1	17	14.0	9	1.3	3	7.0	3	1.5	—	1.4	3
45-54	5 847	31.3	27	23.6	23	3.9	1	11.5	12	3.7	3	2.5	4
55-64	2 307	33.4	39	23.9	30	4.8	1	14.5	19	6.8	9	3.1	5
65-74	603	19.7	16	11.9	12	4.0	2	7.8	13	3.1	8	2.1	2
≥75	111	9.4	6	4.0	3	2.7	1	2.4	2	0.6	—	0.8	1
Total	68 548	123.0	111	79.8	79	20.3	11	49.5	55	15.7	20	10.6	17
SMR			90		99		54		111		127		160
95% CI			74 – 109		78 – 123		27 – 97		84 – 145		78 – 197		93 – 257

*P<0.05, **P<0.01, ***P<0.001, Poisson distribution.

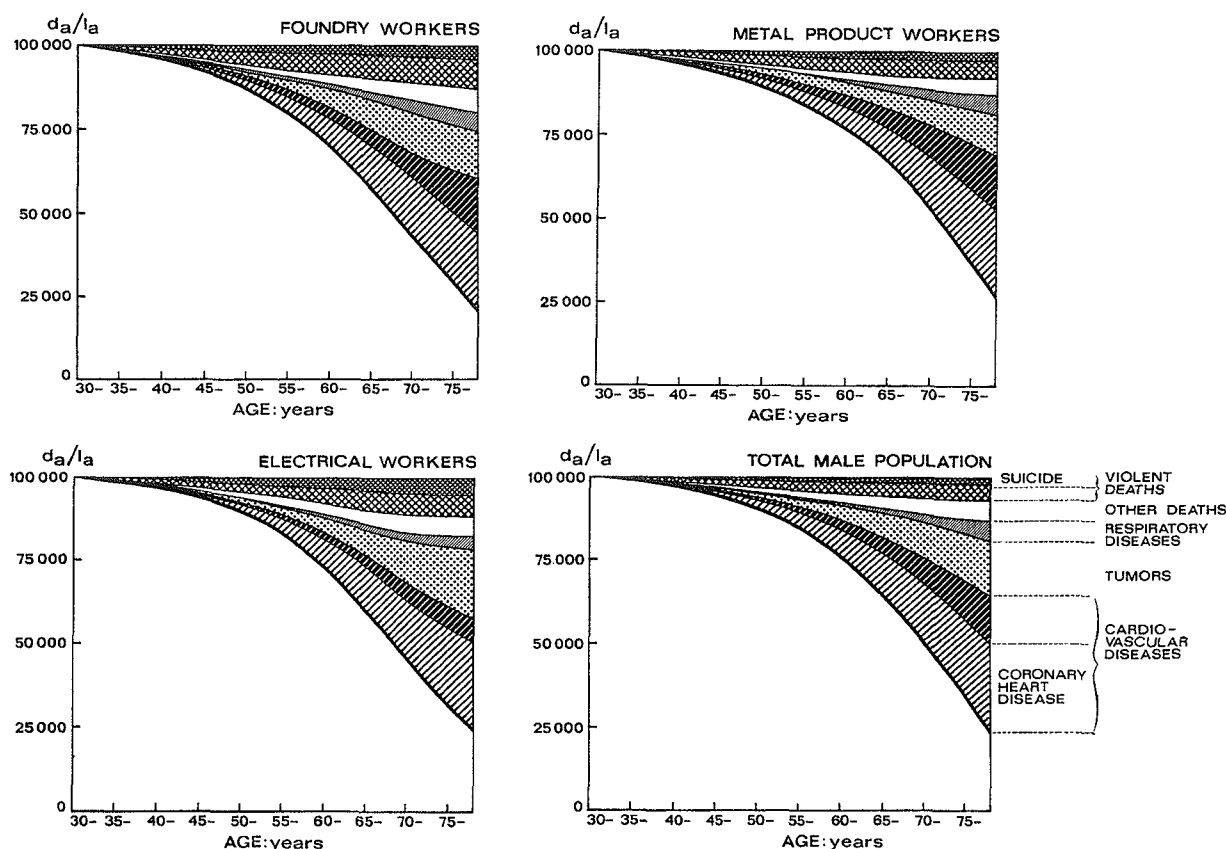


Figure 6. The survivors and the deceased ≥ 30 years of age by cause of death in the three cohorts and in the total male population of Finland. [l_a = survivors at age a , d_a = the deceased at age a , $1_{30} = 100\,000$ (radix)].

diseases, but there were no remarkable differences when the cohorts were considered as a whole.

The observed numbers of tumors exceeded the expected numbers in the middle-age classes (45-64 years) among the foundry workers ($P < 0.05$ at 55-64 years of age). The excess was apparently caused by cancer of the digestive organs and lung cancer in the corresponding age classes. The metal product workers had fewer tumors than expected, but they had slightly more cancer of the digestive organs. Mortality from tumors was somewhat higher among the electrical workers than expected in the older age classes and was due to lung cancer and cancer of digestive organs. The difference for all cancers, however, was not statistically significant.

In the cross-sectionally based cohorts the total SMR values were 87 for the foundry workers, 83 for the metal product workers, and 147 for the electrical workers. See table 6 in the appendix. The main differences between the observed and expected numbers originated from cardiovascular diseases. The observed

numbers were lower than was expected for the foundry workers and metal product workers, whereas the opposite was true for the electrical workers.

The comparison of cause-specific mortality between the three longitudinal exposure-level cohorts and between the cohorts and the general male population is seen in figure 6. The differences in incidence densities of cause-specific mortality were tested by the Mantel-Haenszel chi-square test for incidence density data (table 15). As stated earlier, the foundry workers had the highest mortality and the metal product workers the lowest. The same was true if violent deaths were excluded.

The comparison revealed some special features. The foundry workers' probability of violent death was 1.5 times that of the metal workers. Mortality from tumors was highest among the foundry workers and was pronounced in the middle-age classes. The electrical workers' cancer mortality was concentrated into the older age classes; the proportion of cardiovascular diseases other than coronary heart disease conse-

quently decreased at older ages. Mortality from cerebrovascular diseases was higher among the foundry and metal product workers than among the electrical workers. Of the three exposure cohorts, metal product workers (the medium-level cohort) had the mortality pattern closest to that of the general male population.

Occupation-specific mortality. Mortality was also analyzed for occupational categories even though the numbers of deaths and person-years were relatively small in each subcategory and the study design had no minimum criterion for the duration of exposure (a factor which hindered the detection of specific occupational risks). The overall mortality figures by occupation are shown in tables 16-18.

Foundry workers. Floor molders', fettlers', and laborers' mortality was the main cause of the foundry workers' excess mortality. Thirty-eight violent deaths had occurred among the floor molders although the expected number was 21.5 ($P < 0.01$, Poisson distribution). There were also more cardiovascular deaths than expected (27 observed versus 21.0 expected). The clearest increase was in the age class of 45 to 54 years (15 coronary deaths being observed against 8.6 expected). The floor molders had significantly more deaths from respiratory diseases (9 observed deaths) than expected (2.8, $P < 0.01$). When proportional mortality figures were investigated, deaths from tumors other than lung cancer and cancer of the digestive organs were more frequent than expected among the floor molders. The number of cases expected on the basis of the occupational distribution of the foundry workers' person-years was 5.2, but 11 cases were observed ($P < 0.05$, Poisson distribution). The excess was caused by leukemia and other neoplasms of the lymphatic and hematopoietic tissue, 5 observed and 1.3 expected, calculated from the death rates of the Finnish male population ($P < 0.05$, Poisson distribution).

There were 22 violent deaths among the fettlers with 13.2 expected ($P < 0.05$). A slight excess was also found for cardiovascular diseases (30 deaths observed, 25.5 expected). In the age class of 45-54 years, the observed deaths were 1.6 times those expected. The greatest excess of violent deaths was found among the laborers (147 observed versus 83.1 expected, $P < 0.001$). There were significantly more deaths from respiratory diseases than expected (25 observed versus 16.3 expected, $P < 0.05$). The laborers also had a tendency towards higher mortality from cardiovascular diseases than expected (182 observed versus 158.7 expected, the corresponding figures being 65 and 49.5 in the age class of 45 to 54 years, $P < 0.05$).

Mortality from tumors was the most prominent among the laborers in the foundry worker cohort, the total observed number being 81 and the expected

being 44.4 on the basis of age-specific figures ($P < 0.001$). The excess occurred mainly in the age class of 45 to 64 years ($P < 0.001$) and comprised sev-

Table 15. Significances of the differences in the incidence densities for cause-specific mortality in the three cohorts (vs = versus).

Comparison	Rate ratio	$\chi^2_{(1)}$	
All deaths			
Foundry vs metal product workers	1.3	16.74	***
Foundry vs electrical workers	1.1	3.95	*
Metal product vs electrical workers	0.9	3.86	*
Violent deaths			
Foundry vs metal product workers	1.5	11.08	***
Foundry vs electrical workers	1.2	3.55	
Metal product vs electrical workers	0.8	2.34	
All natural deaths			
Foundry vs metal product workers	1.3	7.31	*
Foundry vs electrical workers	1.1	1.31	
Metal product vs electrical workers	0.9	1.68	
Cardiovascular diseases			
Foundry vs metal product workers	1.2	1.80	
Foundry vs electrical workers	1.2	1.48	
Metal product vs electrical workers	1.0	0.03	
Coronary heart disease			
Foundry vs metal product workers	1.3	3.69	
Foundry vs electrical workers	1.1	0.33	
Metal product vs electrical workers	0.8	1.30	
Cerebrovascular diseases			
Foundry vs metal product workers	1.0	0.01	
Foundry vs electrical workers	2.1	5.56	*
Metal product vs electrical workers	2.2	4.89	*
Respiratory diseases			
Foundry vs metal product workers	1.7	2.81	
Foundry vs electrical workers	1.6	2.09	
Metal product vs electrical workers	1.0	0.01	
Tumors			
Foundry vs metal product workers	1.3	3.22	
Foundry vs electrical workers	1.0	0.00	
Metal product workers vs electrical workers	0.7	2.77	
Lung cancer			
Foundry vs metal product workers	1.8	3.96	*
Foundry vs electrical workers	1.0	0.01	
Metal product vs electrical workers	0.6	3.06	
Cancer of digestive organs			
Foundry vs metal product workers	0.9	0.04	
Foundry vs electrical workers	0.8	0.79	
Metal product vs electrical workers	0.9	0.23	

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 16. Foundry workers' mortality according to occupational group in comparison with the expected (E) number of deaths calculated on the basis of age-specific death rates for the Finnish male population. (O = observed, SMR = standardized mortality ratio)

Occupational group	Person-years	All deaths		SMR	95% CI
		E	O		
Floor molders	13 775	74.3	103 **	139	113 – 168
Machine molders	5 213	27.2	17	63	36 – 100
Coremakers	2 237	10.4	13	125	67 – 214
Casters and ingot casters	3 000	23.6	20	85	52 – 131
Fettlers	8 278	56.8	70	123	96 – 156
Knock-out men	2 302	9.6	8	83	36 – 164
Furnacemen	3 006	21.8	16	73	42 – 119
Laborers	51 634	356.0	469 ***	132	120 – 144
Others	4 097	21.8	30	138	93 – 196

P<0.01, *P<0.001, Poisson distribution.

eral subgroups of diseases. The observed number of lung cancer cases was 34 (21.8 expected, $P<0.05$). The corresponding number for cancer of the digestive organs was 24 (13.7 expected, $P<0.05$). There were 13 cases of malignant neoplasms of the stomach, five cases of malignant neoplasms of the pancreas, and six others. There were also slightly more neoplasms of the lymphatic and hematopoietic tissue (6 observed) among the laborers than was expected (3.2 expected). In the total group of foundry workers there were 7 malignant neoplasms of the bones, connective tissue, and skin with 3.0 expected. Malignant melanoma of the skin had caused 6 deaths (2.4 expected); 4 of these deaths occurred among the laborers (1.4 expected).

Metal product workers. The cohort of metal product workers, as stated earlier, had the lowest mortality figures. Consequently, only a few excesses were detected for this cohort in the occupation-specific analysis. In the group of metal plate workers, sheet metal workers and plumbers, the observed number for all tumors was 18 (11.4 expected); for the age class of 45–54 years, the respective number was 8 (2.3 expected, $P<0.01$). Six of the 18 observed tumors were cancer of the digestive organs, and 5 were cancer of the stomach (1.7 expected). The occurrence of lung cancer did not exceed that of the general male population (5 observed versus 4.4 expected), but when proportional mortality was calculated on the basis of the occupational distribution of the metal product workers, this occupational group had a tendency towards higher rates than expected. The total number of deaths due to lung cancer among the cross-sectional and longitudinal cohorts of metal plate workers, sheet metal workers and plumbers was 9 (4.9 expected).

Ten deaths due to cardiovascular diseases occurred among the truck and crane drivers (4.7 expected on the basis of the general male population of Finland, $P<0.05$). The proportional mortality analysis confirmed this result.

Electrical workers. In the cohort of electrical workers, coronary deaths were more frequent than expected among the truck and crane drivers (8 observed versus 4.5 expected). The excess was especially visible in the age class of 55–64 years (7 observed versus 1.6 expected, $P<0.01$). There had been 17 cancers of the digestive organs among all the electrical workers (10.6 expected). Cancer of the stomach was responsible for 6 (6.6 expected). The remaining 11 cases were excessive in comparison with the expected value of 3.9 ($P<0.01$). The excess was found among the warehouse workers and packers (6 observed versus 1.6 expected, $P<0.05$). When cancer of the stomach was excluded, the corresponding number was 4 (0.5 expected, $P<0.01$).

As mentioned earlier, the electrical workers had a tendency towards higher lung cancer mortality in the older age classes than expected. But, with the exception of the laborers, there was no clear concentration in any specific occupational group. For the laborers, the observed number in the age class of 55–64 years was 5 (1.3 expected, $P<0.05$).

There was slightly more mortality from other, unspecified cancers (ICD 190-199) among the machine fitters, assemblers and electrical and electronic equipment assemblers. In this occupational group the observed number was 3 (0.7 expected); all three cases had occurred in the age class of 55–64 years (0.2 expected, $P<0.01$).

Seven deaths due to cancer of the urogenital or-

Table 17. Metal product workers' mortality according to occupational group in comparison with the expected (E) number of deaths calculated on the basis of age-specific death rates for the Finnish male population. (O = observed; SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Occupational group	Person-years	All deaths		SMR	95% CI
		E	O		
Tool makers	1 439	10.1	4	40	11 – 101
Tool setters, turners, machine workers, metal grinders, shotblasters and machine operators	9 085	57.2	39 *	68	48 – 93
Inspectors and testers	1 437	7.7	3	39	8 – 114
Machine fitters, electrical and electronic equipment assemblers	11 557	70.3	62	88	68 – 113
Metal plate workers, sheet metal workers and plumbers	5 798	59.3	62	105	80 – 134
Welders and flame cutters	5 031	25.2	28	111	74 – 161
Painters, metal platers and coaters	2 340	20.7	17	82	48 – 131
Warehouse workers and packers	2 715	22.8	21	92	57 – 141
Electricians, woodworkers and maintenance workers	1 435	10.6	4	38	10 – 97
Truck drivers and crane drivers	1 700	10.8	19	176	106 – 275
Apprentices and students	956	1.9	2	105	13 – 380
Laborers	8 852	57.1	64	112	86 – 143
Others	1 382	7.9	– ***	–	0 – 47

*P<0.05, ***P<0.001, Poisson distribution.

Table 18. Electrical workers' mortality according to occupational group in comparison with the expected (E) number of deaths calculated on the basis of age-specific death rates for the Finnish male population. (O = observed; SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Occupational group	Person-years	All deaths		SMR	95% CI
		E	O		
Tool makers	2 122	15.0	13	87	46 – 148
Tool setters, turners, machine workers, metal grinders and shotblasters	3 826	26.3	28	106	71 – 154
Inspectors and testers	3 091	10.4	8	77	33 – 152
Machine fitters, assemblers and electrical and electronic equipment assemblers	19 867	67.7	67	99	77 – 126
Electricians	5 910	25.9	25	97	62 – 142
Metal plate workers, sheet metal workers and plumbers	436	4.2	6	143	52 – 311
Welders and flame cutters	1 019	3.3	2	61	7 – 219
Painters, metal platers and coaters	1 289	10.1	14	139	76 – 233
Warehouse workers and packers	8 513	44.2	58	131	100 – 170
Maintenance workers	1 529	10.1	7	69	28 – 143
Truck drivers and crane drivers	2 267	15.5	21	135	84 – 207
Apprentices and students	394	0.7	–	–	–
Laborers	16 234	70.1	74	106	83 – 133
Others	2 024	7.6	13	171	91 – 293

gans occurred among all the electrical workers (4.3 expected). Four of the deaths occurred in the age class of 45–54 years with an expected value of 1.0 (P<0.05).

2. Disability

Total disability. During the follow-up period of 1969 to 1978, there were 739 new cases of disability among the foundry workers (who had accumulated 47 435 person-years), 326 cases among the metal product

workers (29 548 person-years), and 292 cases among the electrical workers (40 100 person-years). Compared with the active male population of Finland (35), the standardized disability ratios were 121 for the foundry workers, 108 for the metal product workers, and 97 for the electrical workers.

Comparison of the incidence densities of disability pensions between the three cohorts indicated that the foundry workers had the highest rates and the electrical workers the lowest. The difference between the foundry workers and electrical workers was highly significant ($P < 0.001$, Mantel-Haenszel chi-square test for incidence density data). Metal product workers had slightly higher rates than the electrical workers, but the difference was not statistically significant. In the younger age classes the foundry workers had higher incidences than the metal product workers, but the reverse was true in the older classes, the level of significance being 0.05.

When the typical exposure levels of the three branches of industry were compared (see appendix), the pattern of disability was similar to that between the whole industrial group. The laborers working in foundries had remarkably higher incidences of disability than foundry workers on the typical exposure level ($P < 0.05$). Laborers manufacturing metal products also had higher incidences of disability than metal product workers on the typical exposure level ($P < 0.01$). However, laborers producing electrical devices did not have incidences significantly higher than electrical workers on the typical exposure level. Correspondingly, when the three groups of laborers were compared, the highest incidences were found in the manufacture of metal products. The difference from the laborers in foundries was not significant, but the difference from the laborers in the production of electrical devices was highly significant ($P < 0.001$). The laborers in foundries also had significantly higher incidences than the laborers in the production of electrical devices ($P < 0.001$).

Subdividing the cohorts into three exposure levels (laborers being considered separately) according to the main occupation and combining the corresponding levels of the three branches of industry produced the highest disability rates for the laborers and the second highest rates for the heavy exposure level, with the exception of the oldest age class for the medium level (figure 7). The difference in the incidence densities was not significant between the laborers and the heavy level, but was significant between the laborers and the medium ($P < 0.05$) and light ($P < 0.001$) levels. The light level had the lowest incidences of disability (heavy versus light level, $P < 0.01$; medium versus light level, $P < 0.01$). The heavy level and the medium level did not differ sig-

nificantly from each other because of higher incidences in the younger age classes on the heavy level and higher incidences in the oldest age class on the medium level.

The results indicated that the workers on the heavy level had the highest rates of disability, and these high rates occurred particularly in the younger age classes, whereas workers on the medium level had the highest rates in the older age classes. The workers on the light exposure level had the lowest disability rates. The total disability results can be compared briefly with an index defined so that the observed number equals 100 for each age category (figure 8). The expected numbers were based on disability figures of the active male population of Finland.

The age-standardized prevalence rates of disability as of 31 December 1978 showed that there was no great difference between the foundry workers (11.4%), metal product workers (12.3%), and electrical workers (10.0%).

Cause-specific disability. Disability pensions due to mental disorders were more frequent among the foundry workers than expected on the basis of the active male population of Finland ($P < 0.001$, Poisson-distribution) (table 19). The excess was found for all age classes but was especially clear in the youngest age class, in which mental disorders accounted for about two-thirds of all the disability pensions. The observed numbers of all cardiovascular diseases, and of coronary heart disease separately, were significantly lower ($P < 0.01$ and $P < 0.05$) for the foundry workers than for the active Finnish male population. Disability due to respiratory diseases was slightly higher than expected, especially for the oldest age class of 55–64 years (29 observed versus 19.0 expected, $P < 0.05$). Respiratory diseases also proved to be a cause of excess disability in the cross-sectional cohort (20 observed versus 10.4 expected, $P < 0.05$). The longitudinal cohort also had an excess of respiratory diseases, especially in the oldest age class. The observed number of musculoskeletal diseases was equal to the expected number, but somewhat more musculoskeletal diseases than expected were detected in the older age classes of the cross-sectional cohort.

As stated earlier, the observed numbers of disability among metal product workers were higher than expected in the older age classes (figure 8). The primary causes of the excess were respiratory diseases and mental disorders (in both the longitudinal and the cross-sectional cohorts), but no specific cause reached statistical significance.

The electrical workers had disability rates below the expected values. The youngest age class was an exception, as this class had an excess of disability

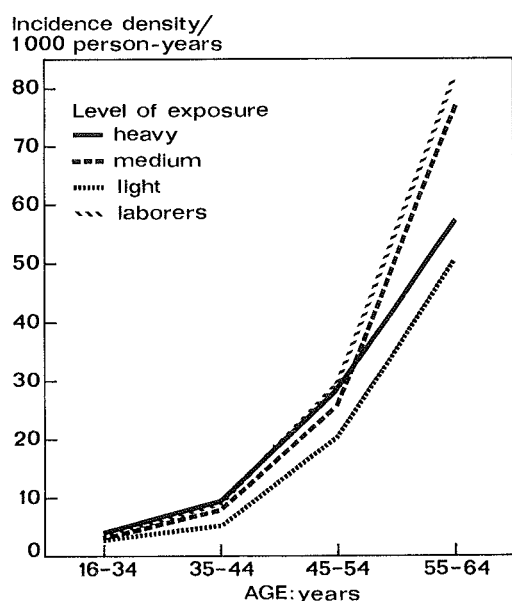


Figure 7. Incidence densities of disability pensions according to exposure level. The similar levels were combined through the three industrial branches.

($P < 0.001$) caused by mental disorders. When compared with the age-specific expected numbers, the highest excess of mental disorders occurred among the age class of 45–64 years. Disability due to cardiovascular diseases was significantly lower than expected ($P < 0.05$), as was disability due to musculoskeletal diseases.

The three cohorts were compared according to the causes of disability by means of age-specific incidence densities. (See table 8 in the appendix.) The differences were tested by the Mantel-Haenszel chi-square test for incidence density data (table 20).

Mental disorders were more frequent among the foundry workers than among the metal product workers or electrical workers. Disability due to mental disorders was significantly more common among the laborers in foundries and in the manufacture of metal products than among workers on the typical exposure levels in foundries and the manufacture of metal products ($P < 0.05$). Similar differences were not found for the electrical workers.

The incidence densities for cardiovascular diseases were slightly higher among the metal product workers than among the foundry workers. The electrical workers had the lowest rates. Disability due to cardiovascular diseases also tended to be higher among the laborers than among the workers on the typical exposure level, especially in the group of foundry workers ($P < 0.05$). Both the foundry workers and the metal product workers had higher disability rates due to respiratory diseases than the electrical workers did. The differences were derived mainly from the oldest age classes.

Musculoskeletal diseases were clarified as a cause of disability for foundry and metal product workers in comparison with electrical workers. When laborers and occupations on the typical exposure level were compared, the incidence densities were similar among the foundry workers, whereas the laborers in

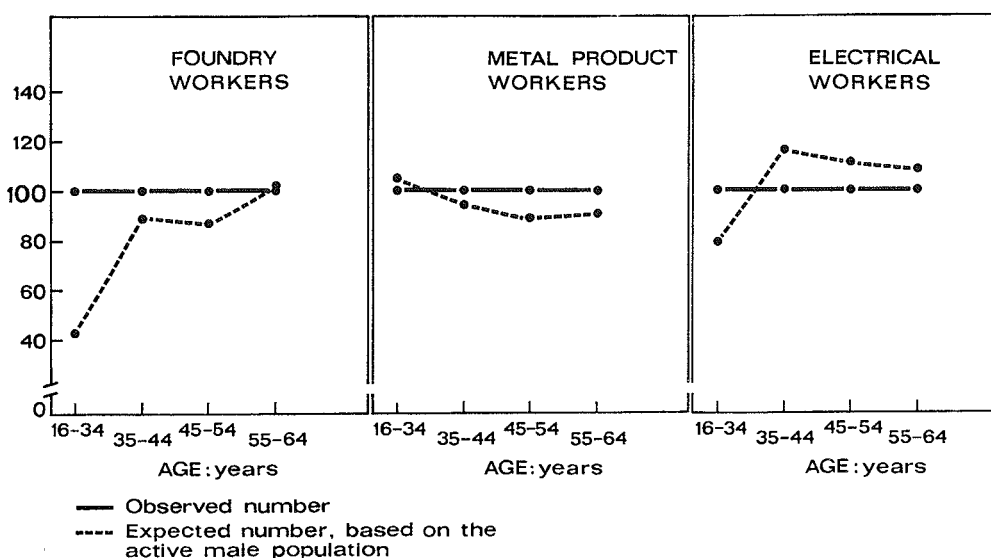


Figure 8. Observed and expected numbers of new disability pensions during the period 1969–1978. The numbers are expressed as an index; observed numbers = 100.

Table 19. Cause-specific observed (O) and expected (E) numbers of disability pensions according to age among workers hired between 1950 and 1976. The expected values are based on the proportional disability figures for the active Finnish male population. The follow-up period was 1969-1978. (SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Age (years)	Mental disorders		Cardiovascular diseases		Coronary heart disease		Respiratory diseases		Musculoskeletal diseases		Others					
	E	O	E	O	E	O	E	O	E	O	E	O				
Foundry workers																
16-34	39.6	63	***	5.2	3		1.0	-	1.9	-	13.4	13	34.9	16	***	
35-44	36.7	50	*	27.9	13	**	14.8	6	*	5.3	5	40.3	32	46.6	57	
45-54	25.4	38	*	95.3	74	*	57.3	48	16.7	16	75.3	78	60.3	67		
55-64	8.1	10		88.8	82		47.1	42	19.0	29	56.7	64	41.3	29		
Total	109.8	161	***	217.2	172	**	120.2	96	*	42.9	50	185.7	187	183.1	169	
SMR	147		***	79			80			117			101			92
95% CI	112 - 189			68 - 92			65 - 98			87 - 154			87 - 116			79 - 107
Metal product workers																
16-34	14.6	19		1.9	2		0.4	-	0.7	-	4.9	5	12.8	9		
35-44	13.3	15		10.1	10		5.4	4	1.9	1	14.6	10	16.9	21		
45-54	10.0	18	*	37.7	35		22.7	20	6.6	8	29.8	26	23.9	21		
55-64	4.8	2		52.3	48		27.7	22	11.2	18	33.4	39	24.3	19		
Total	42.7	54		102.0	95		56.2	46	20.4	27	82.7	80	77.9	70		
SMR	126			93			82			132			97			90
95% CI	95 - 165			75 - 114			60 - 109			87 - 193			77 - 120			70 - 114
Electrical workers																
16-34	30.0	39		4.0	1		0.8	-	1.4	-	10.2	5	26.4	27		
35-44	13.3	19		10.1	8		5.4	3	1.9	1	14.6	13	16.9	16		
45-54	7.8	15	*	29.3	26		17.6	15	5.1	3	23.2	14	18.6	26		
55-64	3.0	10	**	32.8	24		17.4	16	7.0	6	20.9	17	15.2	21		
Total	54.1	83	***	76.2	59	*	41.2	34	15.4	10	68.9	49	*	77.1	90	
SMR	153		***	77			83			65			71			117
95% CI	104 - 217			59 - 100			57 - 115			31 - 119			53 - 94			94 - 143

*P<0.05, **P<0.01, ***P<0.001, Poisson distribution.

the group of metal product workers had higher rates than the workers on the typical exposure level (P<0.05 in the age classes of 35-44 and 45-54 years). Among all the electrical workers, the laborers had slightly lower rates than the workers on the typical exposure level.

3. Morbidity

Subjective health status and work capacity. Comparison of the current and former workers' own assessments of their health status and work capacity provides a general picture of the smooth measures.

Differences in health status appeared mainly in the older age classes (figure 9). More former workers aged 45 years or older felt themselves to be in poor health than current workers of the same age. Significantly more current foundry workers aged 45 years or older felt themselves to be in poor health than the corresponding group of electrical workers. There was little difference between the current foundry workers and current metal product workers. Of the three industrial groups, however, the former metal product workers with the longest duration of exposure had the largest proportion of workers with poor subjective health.

Table 20. Significances of differences in incidence densities for cause-specific disability pensions in the three cohorts. (vs = versus)

Comparison	Rate ratio	$\chi^2_{(1)}$
All causes		
Foundry vs metal product workers	1.1	3.84 *
Foundry vs electrical workers	1.4	19.80 ***
Metal product vs electrical workers	1.1	2.24
Mental disorders		
Foundry vs metal product workers	1.8	13.26 ***
Foundry vs electrical workers	1.5	8.67 **
Metal product vs electrical workers	0.8	1.67
Cardiovascular diseases		
Foundry vs metal product workers	0.9	1.42
Foundry vs electrical workers	1.2	1.75
Metal product vs electrical workers	1.4	4.87 *
Coronary heart disease		
Foundry vs metal product workers	1.0	0.04
Foundry vs electrical workers	1.1	0.41
Metal product vs electrical workers	1.2	0.35
Respiratory diseases		
Foundry vs metal product workers	0.9	0.22
Foundry vs electrical workers	2.1	4.48 *
Metal product vs electrical workers	0.4	5.05 *
Musculoskeletal diseases		
Foundry vs metal product workers	1.1	0.28
Foundry vs electrical workers	1.7	9.88 **
Metal product vs electrical workers	1.5	5.19 *

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

The workers used a 10-point scale to compare their present work capacity with that at their best working age (ie, 10 points). They also assessed their work capacity at the time they left the work under study in comparison with that at their best working age. These assessments showed that foundry workers had at least the same work capacity as metal product workers and electrical workers when they entered the industry (figure 10). Foundry workers' average duration of employment was shorter than that of the other workers, but their work capacity decreased even during rather short periods of employment. For example, former foundry workers with the longest duration of employment had an estimated average work capacity of 9.4 points when they entered the industry at the age of 26 years (the average entry age), but their work capacity had dropped to an average of 6.8 points by the time they reached 37 years of age (the average quitting age). Their average work capacity also dropped with age after they quit foundry work.

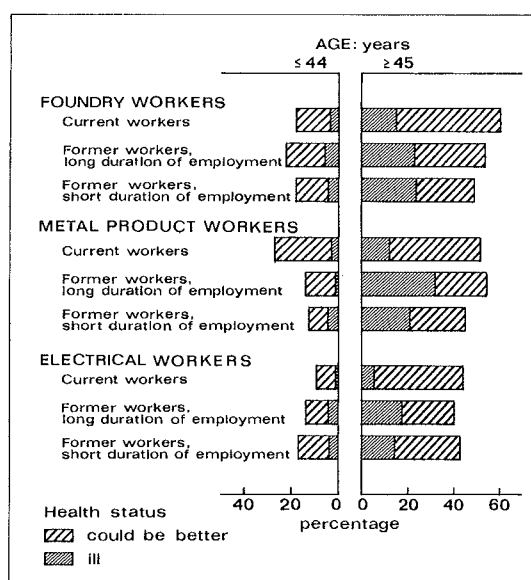


Figure 9. Percentages of current and former workers who felt themselves to be in poor health.

The mean current work capacity was 6.1 at the age of 48 years (the average current age).

The metal product workers' age of entry was about 21 years, and their work capacity averaged 9.8 points. Their average duration of employment was the longest of the three groups of industrial workers. Their work capacity clearly weakened while they were manufacturing metal products. But scattering the decreased work capacity according to age showed that the metal product workers had a higher concentration of decreased work capacity at the older ages than the foundry workers.

The electrical workers entered the industry at the age of 20–22 years, when their average work capacity was 9.8 points. The former electrical workers with the longest duration of employment had an average quitting age of 32 years, and their mean work capacity then was 8.4 points.

When the three industrial groups were compared and the time after termination was taken into consideration, it was found that the electrical workers best maintained their work capacity as they aged. This conclusion was confirmed by regression analyses on changes in work capacity during employment and after its termination (table 21). Among the current workers, the electrical workers' work capacity showed the slowest change. The former electrical workers with the longest duration of employment had the slowest speed of change in work capacity during employment, but after its termination their work capacity declined the fastest of the three groups of

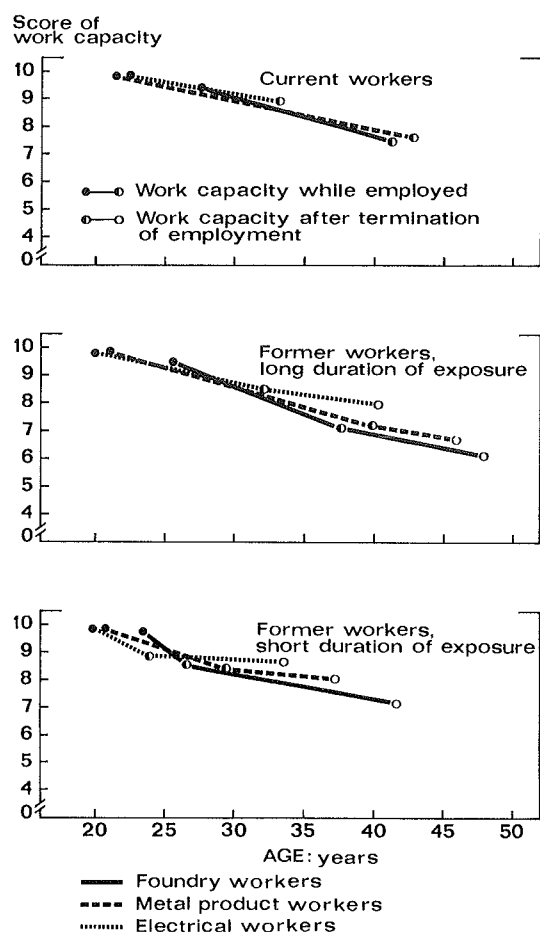


Figure 10. Average current work capacity as compared with a person's best working age and work capacity at the time of entry and termination of employment as assessed by current and former workers (0 to 4 points on a 10-point scale).

industrial workers. This result for former electrical workers differed with the speed of change in work capacity in the corresponding groups of metal product workers.

The difference in the speed of change in work capacity between the electrical workers and metal product workers with the longest duration of employment was statistically significant ($P < 0.05$, normal approximation test) after the termination of the work. The corresponding difference during employment was statistically weaker ($P < 0.10$). The foundry workers again experienced a rather fast speed of change in work capacity, both while they were working at foundries and after the work was terminated.

Symptoms and diagnosed diseases. Differences in health status and work capacity were also reflected in the prevalences of certain diseases and symptoms. Primary attention was paid to musculoskeletal, respiratory, and cardiovascular diseases.

Musculoskeletal diseases. Ache or pain in musculoskeletal organs within the last 12 months had been prevalent among 57% of the current foundry workers, 62% of the former foundry workers with the longest duration of employment, and 58% of the former foundry workers with the shortest duration of employment. The corresponding rates were 58%, 58%, and 41% for the metal product workers and 36%, 43%, and 35% for the electrical workers.

Sciatica and/or low-back pain was more frequent among the current foundry workers than among the current electrical workers ($P < 0.05$) (table 22). The difference between the former foundry workers with a long duration of exposure and the same group of electrical workers was statistically significant ($P < 0.001$), as was that of metal product workers un-

Table 21. Changes per year in work capacity during employment and after its termination as estimated by the linear regression coefficient with standard error in parentheses. The scale for subjective work capacity was 0 to 10. ($_l$ = the longest duration of employment, $_s$ = the shortest duration of employment)

Subjects	Foundry workers		Metal product workers		Electrical workers	
	During employment	After termination of employment	During employment	After termination of employment	During employment	After termination of employment
Current	- 0.11 (0.01)		- 0.14 (0.01)		- 0.08 (0.01)	
Former $_l$	- 0.08 (0.01)	- 0.08 (0.02)	- 0.09 (0.01)	- 0.03 (0.02)	- 0.06 (0.01)	- 0.10 (0.01)
Former $_s$	- 0.08 (0.02)	- 0.09 (0.02)	- 0.06 (0.02)	- 0.05 (0.02)	- 0.04 (0.02)	- 0.06 (0.02)

der 45 years of age ($P < 0.001$). The metal product workers also had higher rates than the electrical workers of the same age ($P < 0.05$). Among former workers with the short duration of exposure the differences were smaller (foundry workers versus metal product workers $P < 0.05$, foundry workers versus electrical workers under 45 years $P < 0.05$, metal product workers versus electrical workers not significant).

The prevalence of pain in the neck and shoulder region and/or the upper limbs was also higher among the current foundry workers and metal product workers than among current electrical workers ($p < 0.01$). Among the former workers with the long duration of exposure the difference was more pronounced in the older age classes; the foundry workers had higher rates than the electrical workers ($P < 0.01$), and the foundry workers of 44 years or more of age had higher rates than the metal product workers of the same age ($P < 0.01$). Similarly, the metal product workers 44 years or more of age had higher rates than the electrical workers ($P < 0.01$). Among the workers with the short duration of employment the differences were smaller; only the foundry workers had clearly higher rates than the electrical workers ($P < 0.05$).

The frequency of diagnosed musculoskeletal diseases which had caused incapacity to work for at least one month was significantly higher among the current and former foundry workers than among the electrical workers (table 22). The differences in the occurrences were smaller between the foundry and metal product workers. In the younger age classes the foundry workers had higher occurrences than the metal product workers, but in the older age classes the opposite was true. The former foundry workers with the longest duration of employment had more diagnosed musculoskeletal diseases than the current foundry workers (table 23). The trend towards an excess surfaced in all the age classes. Furthermore, the occurrences among the current and former metal product workers with the longest duration of employment did not deviate from each other.

Musculoskeletal diseases were not only analyzed according to present age, but also according to age upon diagnosis. The groups of current and former workers were combined for each industrial branch. The age-standardized rates were 7.1% for the foundry workers, 4.8% for the metal product workers, and 3.5% for the electrical workers. The higher occurrences among foundry workers appeared in the younger age classes and continued, whereas the metal product workers had low occurrences in the younger age classes and higher ones in the older age classes.

Musculoskeletal disorders and diagnosed diseases were also analyzed according to the heaviness of the work. The occurrences of any previously diagnosed musculoskeletal diseases which had prevented work for at least one month did not significantly differ on the three levels of exposure within a branch and within the groups of current or former workers. But when the three branches were combined and the occurrences were determined according to the level of heaviness for current workers, for former workers with the longest duration of employment, and for former workers with the shortest duration of employment, the occurrences were significantly higher for both the current and former workers on the heavy exposure level than for those on the light exposure level ($P < 0.05$ for current workers and former workers with the shortest duration of employment, $P < 0.001$ for former workers with the longest duration of employment, Mantel-Haenszel's chi-square test). The occurrences were higher on the heavy exposure level than on the medium level, but the difference was statistically significant only for the former workers with the longest duration of exposure ($P < 0.01$).

When both the three branches of industry and the groups of current and former workers were combined, the differences between the three exposure levels became more distinct (table 24). The heavy level had significantly higher occurrences than the medium level ($P < 0.01$) or the light level ($P < 0.001$), and the medium level had higher occurrences than the light level ($P < 0.01$).

The occurrences of sciatica or low-back pain were analyzed separately from the other musculoskeletal complaints. Statistical significance was detected between the heavy and medium exposure levels ($P < 0.05$), the heavy and light levels ($P < 0.001$), and the medium and light levels ($P < 0.001$).

Typical exposure levels were also used to determine the occurrences of previously diagnosed musculoskeletal diseases according to the level of exposure. When the industrial branches and the groups of current and former workers were combined, the age-standardized occurrences were 41.1% for the heavy exposure level, 33.2% for the medium level, and 25.9% for the light level. These values were similar to those calculated when all the levels of heaviness in each industrial branch were used to form the combined exposure levels for the three industries. Both calculations were based on the heaviness of the main occupation (according to the questionnaire) in the industrial branch under study.

Table 22. Ache or pain in musculoskeletal organs within the last 12 months and previously diagnosed musculoskeletal diseases (incapacity for at least one month). The occurrences are presented as percentages according to age. (_l = the longest duration of employment, _s = the shortest duration of employment)

Disease	Ache or pain within 12 months					Earlier diagnosed musculoskeletal disease (one month's incapacity)				
	Age (years)					Age (years)				
	≤ 24	25-34	35-44	45-54	≥ 55	≤ 24	25-34	35-44	45-54	≥ 55
<i>Sciatica or low-back pain</i>										
Foundry workers										
Current	29	29	39	52	48	14	11	24	39	31
Former _l	.	34	36	50	43	—	22	36	35	41
Former _s	.	25	44	33	53	33	19	27	36	65
Metal product workers										
Current	.	30	38	41	42	—	10	17	31	37
Former _l	—	15	30	46	52	0	6	15	35	52
Former _s	.	17	39	29	45	—	6	21	19	45
Electrical workers										
Current	14	15	28	51	45	6	5	13	30	30
Former _l	.	16	25	32	39	0	7	12	19	32
Former _s	14	19	28	44	50	14	13	6	44	50
<i>Pain in the neck and shoulder region or other pain in the upper limbs</i>										
Foundry workers										
Current	7	15	33	48	43	—	6	13	21	26
Former _l	.	22	31	44	44	.	10	20	21	29
Former _s	33	22	32	38	53	67	16	15	17	53
Metal product workers										
Current	.	22	28	49	46	.	4	11	24	31
Former _l	—	17	24	45	46	—	4	6	24	33
Former _s	.	14	32	35	45	.	6	11	14	55
Electrical workers										
Current	14	13	23	30	40	8	2	6	9	15
Former _l	—	15	25	32	26	.	2	7	15	23
Former _s	14	13	17	44	33	.	4	6	22	33
<i>Any musculoskeletal disease</i>										
Foundry workers										
Current	29	43	56	71	69	14	20	33	52	47
Former _l	.	46	55	69	68	.	29	47	46	59
Former _s	67	50	59	57	71	.	31	34	43	82
Metal product workers										
Current	.	40	55	67	74	.	16	29	45	60
Former _l	.	37	50	70	71	—	17	22	49	66
Former _s	.	29	54	48	73	.	16	21	29	64
Electrical workers										
Current	28	27	37	65	74	16	9	13	38	40
Former _l	.	30	44	51	61	.	13	20	32	67
Former _s	29	30	36	56	67	14	26	11	56	67

Table 23. Significances of the differences in the occurrences of earlier diagnosed musculoskeletal diseases which had caused incapacity to work for at least one month. (_l = the longest duration of employment, _s = the shortest duration of employment)

Subjects	Sciatica and/or low back pain		Ache or pain in the neck and shoulder region or the upper limbs		Any musculoskeletal disease	
	Rate ratio	$\chi^2_{(1)}$	Rate ratio	$\chi^2_{(1)}$	Rate ratio	$\chi^2_{(1)}$
Foundry versus metal product workers						
Current	1.2	0.71	0.9	0.01	1.1	0.11
Former _l	1.3	2.38	1.2	0.80	1.3	3.47
Former _s	2.1	4.78 *	1.5	0.87	2.1	5.73 *
Foundry versus electrical workers						
Current	1.7	4.37 *	2.7	7.76 **	2.1	11.92 ***
Former _l	2.7	22.78 ***	2.1	8.10 **	2.1	15.50 ***
Former _s	1.9	3.09	2.7	5.56 *	1.9	4.23 *
Metal products versus electrical workers						
Current	1.4	1.12	2.7	7.73 **	2.0	9.10 **
Former _l	1.6	5.05 *	1.5	1.51	1.3	1.24
Former _s	0.8	0.15	1.5	0.34	0.7	2.09

*P<0.05, **P<0.01, ***P<0.001

Respiratory diseases. Chronic bronchitis was used to indicate the prevalence of respiratory symptoms. The criteria used to define chronic bronchitis were the same as in an earlier study of Finnish foundry workers (176), in which data on respiratory symptoms were collected with the Medical Research Council's Short Questionnaire on Respiratory Symptoms (154, 177–179). According to this questionnaire, cough (or the production of phlegm) was classified into the following four categories: (i) no cough (phlegm); (ii) cough (phlegm) on getting up in the morning; (iii) cough (phlegm) during the day or night; and (iv) cough (phlegm) on most days for as much as three months a year. Chronic bronchitis was defined as cough and the production of phlegm for at least three months a year. Because the occurrences rose nearly systematically in the different study groups with age, age-standardized prevalences were used to compare the industrial branches and subgroups.

The age-standardized prevalence of chronic bronchitis was higher for the former foundry workers than for the current workers (table 25), but the differences were not statistically significant. The prevalences were similar in the groups of metal product workers. The current electrical workers had a lower prevalence than both the former workers with the longest duration of employment and those with the shortest duration

of employment ($P<0.05$, Mantel-Haenszel's chi-square test).

When the three industrial branches were compared, the current foundry workers had significantly higher prevalences of chronic bronchitis than the electrical workers ($P<0.01$) and slightly higher prevalences than the metal product workers. Among the former workers with the longest duration of employment, the foundry workers also had the highest

Table 24. Previously diagnosed musculoskeletal diseases which had prevented working for at least one month according to exposure level. The three industries and the groups of current and former workers were combined for each level.

Age (years)	Exposure level					
	Heavy		Medium		Light	
	N	%	N	%	N	%
15–24	3	33.3	4	16.7	5	13.5
25–34	20	26.0	62	18.4	31	11.9
35–44	37	36.3	109	27.4	39	20.2
45–54	63	55.8	118	41.5	36	37.9
55–64	43	61.4	98	62.8	18	48.6
≥65	11	45.8	41	54.7	9	47.4
Total	177	44.8	432	33.9	138	21.5

Table 25. Age-standardized prevalences of chronic bronchitis according to smoking in different study groups (the prevalences for the smoking categories are marked with the italics). (*l* = the longest duration of employment, *s* = the shortest duration of employment)

Study subjects	Foundry workers		Metal product workers		Electrical workers	
	N	%	N	%	N	%
Current	48	14.7	35	10.7	14	5.8
Nonsmokers	5	7.3	5	4.7	1	2.0
Ex-smokers	9	9.0	5	3.7	4	4.7
Smokers	34	22.3	25	19.9	9	9.0
Former _l	52	16.9	33	11.9	25	7.3
Nonsmokers	2	3.6	5	8.5	3	3.3
Exsmokers	9	7.2	10	10.3	3	2.6
Smokers	41	28.1	18	18.6	19	21.2
Former _s	25	24.8	9	10.6	15	17.3
Nonsmokers	—	0.0	—	0.0	1	2.7
Exsmokers	3	9.7	—	0.0	—	0.0
Smokers	22	36.2	9	22.5	14	32.7

prevalences and the electrical workers the lowest, but the differences were not statistically significant. The former foundry workers with the shortest duration of employment had a higher prevalence than the corresponding group of metal product workers ($P < 0.05$), but the electrical workers had nearly the same prevalence as foundry workers.

Because smoking promotes chronic bronchitis, the occurrence of this disorder was calculated for different exposure groups according to the workers' smoking habits (table 25). Among the current and former foundry workers, chronic bronchitis occurred clearly more often among the smokers than among nonsmokers. Similar differences were found between the smokers and nonsmokers among the metal product workers and the electrical workers.

Although smoking was the main causal factor of chronic bronchitis, the effect of exposure was not only reflected as different occurrences among the current and former workers, but also as differences between the three industrial branches (the three exposure levels). Regardless of smoking habits, the current and former foundry workers had chronic bronchitis more often than the metal product workers and the electrical workers. Even though there were some differences in the distributions of smokers, ex-smokers and nonsmokers between the three industrial branches, the age-standardized prevalences of chronic bronchitis depended on the exposure level. This dependency was especially clear for the current work-

ers whose exposure was still continuing.

Current foundry workers (the heavy exposure level) had almost twice as much chronic bronchitis as the electrical workers (the light exposure level) regardless of their smoking habits.

Acute respiratory diseases were so frequent in the younger age classes that the analysis of the occurrences of all previously diagnosed lung diseases revealed no great differences between the worker groups (table 26). The effect of exposure was reflected in the older age classes as higher prevalences of emphysema among the foundry workers and metal product workers and as a higher prevalence of bronchial asthma among the former metal product workers with the longest duration of employment.

Previously diagnosed lung diseases were analyzed separately according to age upon diagnosis. The groups of current and former workers were combined for each industrial branch. The age-standardized occurrences were 4.7% for the foundry workers, 3.3% for the metal product workers, and 4.3% for the electrical workers. The occurrences among the foundry and metal product workers were fairly evenly distributed throughout the age range, whereas those among the electrical workers were the highest in the youngest age class.

The occurrences of previously diagnosed lung diseases were also determined according to the exposure level. This analysis was based on the total occupational history reported in the questionnaire (the simi-

Table 26. Occurrences (in percentage) of previously diagnosed lung diseases according to age. (_l = the longest duration of employment, _s = the shortest duration of employment)

Disease	Age (years)				
	≤ 24	25-34	35-44	45-54	≥ 55
<i>Emphysema and/or bronchitis and/or asthma</i>					
Foundry workers					
Current	28	14	27	25	25
Former _l	—	20	15	23	29
Former _s	—	13	22	26	41
Metal product workers					
Current	—	13	20	23	15
Former _l	—	15	12	18	36
Former _s	—	22	7	19	36
Electrical workers					
Current	17	18	19	22	20
Former _l	50	26	24	29	16
Former _s	14	29	14	33	—
<i>Any lung disease</i>					
Foundry					
Current	43	20	40	45	45
Former _l	—	32	27	53	52
Former _s	—	34	37	48	59
Metal products					
Current	—	25	32	40	48
Former _l	—	28	27	30	46
Former _s	—	32	29	33	55
Electrical devices					
Current	17	25	36	38	35
Former _l	50	34	32	45	48
Former _s	36	30	33	33	67

lar levels were combined for the three industries and for the groups of current and former workers). When the total occupational history in the branch under study was used, the prevalences of all diagnosed lung diseases were the highest for the heavy exposure level (42%), the second highest for the medium level (36%), and the lowest for the light level (32%) (table 27). The patterns for the prevalences of emphysema or bronchitis were similar (23% for the heavy exposure level, 19% for the medium level, and 17% for the light level). Similar results were also found when the corresponding exposure levels were combined through the total occupational history for the entire work life (prevalence of any diagnosed lung disease

41% for the heavy exposure level, 37% for the medium level, and 32% for the light level).

Cardiovascular diseases. The occurrence of mild or severe angina pectoris was used to indicate cardiovascular symptoms. Angina pectoris was interpreted as prevalent if the subject, on the standardized questionnaire (153), reported (i) that chest pain occurred when he walked uphill at an increased pace on level ground or at a normal pace on level ground, (ii) that chest pain caused him to stop or slow down, (iii) that the pain disappeared within 10 min of rest, and (iv) that the pain was localized substernally or simultaneously on the left side of the thorax and in the left arm. Angina pectoris was classified as mild if the pain appeared only when the respondent was hurrying or walking uphill and as severe if the pain began when the respondent was walking at a normal pace on level ground.

The age-standardized prevalences of angina pectoris were greater for the former than the current foundry workers (table 28). The same was also true for the metal product workers. But the current electrical workers' prevalences were higher than those of former workers. These differences, though logical, did not reach statistical significance.

When the three industrial branches were compared, the current foundry workers' prevalences of angina pectoris were nearly statistically significantly higher than the current metal product and electrical workers' prevalences. Correspondingly, the former foundry workers had higher prevalences than the former electrical workers ($P < 0.01$ for former workers with the longest duration of exposure and $P < 0.05$ for former workers with the shortest duration of exposure).

Table 27. Previously diagnosed lung diseases according to the exposure level. The three industries and the groups of current and former workers were combined for each level.

Age (years)	Exposure level					
	Heavy		Medium		Light	
	N	%	N	%	N	%
15-23	2	22.2	10	43.5	6	16.2
25-34	18	23.4	95	28.2	76	28.7
35-44	40	39.2	122	30.7	60	31.3
45-54	57	50.4	114	40.1	39	41.1
55-64	38	54.3	77	49.4	21	56.8
≥ 65	12	50	34	45.3	4	21.1
Total	167	42.3	452	35.5	206	31.9

Table 28. Age-standardized prevalences of mild or severe angina pectoris according to smoking habits in the different study groups. (_l = the longest duration of employment _s = the shortest duration of employment)

Study subjects	Foundry workers		Metal product workers		Electrical workers	
	N	%	N	%	N	%
Current	26	7.8	17	4.3	7	6.4
Nonsmokers	1	1.4	1	0.9	—	0.0
Ex-smokers	8	4.7	11	7.1	2	3.7
Smokers	17	8.8	5	4.3	5	10.8
Former _l	38	8.9	24	6.2	5	1.6
Nonsmokers	2	2.9	2	1.1	—	0.0
Ex-smokers	17	10.3	17	11.1	1	2.1
Smokers	19	14.4	5	3.9	4	3.2
Former _s	9	8.5	5	7.0	1	1.7
Nonsmokers	1	2.2	1	7.4	—	0.0
Ex-smokers	3	6.8	1	2.8	—	0.0
Smokers	5	5.1	3	7.5	1	3.9

Because smoking habits confound the occurrences of angina pectoris, as well as the occurrences of chronic bronchitis, the results were analyzed according to smoking habits. The nonsmokers generally had lower prevalences of angina pectoris than the ex-smokers and smokers. However, the order of the exposure levels did not essentially change when the nonsmokers and those who had smoked (ex-smokers and smokers) were considered separately.

There were no great differences in the occurrences of previously diagnosed heart diseases between the groups of current and former workers (although the former workers tended to have slightly higher rates) and between the three industrial branches (table 29). Somewhat higher prevalences were found for the foundry workers in the younger age classes and the metal product workers in the older age classes. The metal product workers' higher rates were especially clear in the age class of 55 years or more, in which the prevalence for former metal product workers was nearly twice that of the foundry workers ($P < 0.01$ for former workers with the longest duration of employment).

The prevalences of angina pectoris or myocardial infarction were correspondingly higher among the former than the current foundry and metal product workers. The metal product workers in the oldest age class had higher prevalences than the workers in the oldest age classes employed in the other industrial branches.

Previously diagnosed hypertension was slightly more frequent in the younger age classes among the foundry workers than among the metal product or electrical workers, but in the oldest age classes the metal product workers again had the highest prevalences (table 30). This finding corresponded with that for previously diagnosed heart diseases.

In addition to analysis according to present age, previously diagnosed cardiovascular diseases were also determined according to age upon diagnosis. The groups of current and former workers were combined for each industrial branch. The occurrences were rather low: 1.3% for the foundry workers, 1.3% for the metal product workers, and 0.7% for the electrical workers.

Previously diagnosed heart diseases were also studied according to the exposure level; the similar levels were combined for the three industrial branches and for both the current and former workers (table 31). This calculation did not reveal great differences between the exposure levels, the medium level having the highest prevalence (16%), the heavy level having the second highest prevalence (14%), and the light level having the lowest prevalence (10%). Workers 45 years or older on the medium exposure level had significantly more previously diagnosed heart diseases than workers of the same age on the light level. The analysis of previously diagnosed hypertension according to the level of exposure gave a similar pattern, the prevalences being the highest among the

Table 29. Occurrences (in percentage) of previously diagnosed heart diseases according to age. (_l = the longest duration of employment, _s = the shortest duration of employment)

Disease	Age (years)				
	≤ 24	25-34	35-44	45-54	≥ 55
<i>Angina pectoris or myocardial infarction</i>					
Foundry workers					
Current	—	—	2	9	14
Former _l	.	—	3	9	17
Former _s	—	—	—	2	12
Metal product workers					
Current	.	1	1	6	15
Former _l	—	—	—	8	20
Former _s	.	—	—	10	27
Electrical workers					
Current	—	—	—	8	5
Former _l	—	—	2	2	16
Former _s	—	—	—	—	—
<i>Any heart disease</i>					
Foundry workers					
Current	—	6	9	24	31
Former _l	.	10	12	18	24
Former _s	33	3	12	14	18
Metal product workers					
Current	.	4	8	24	29
Former _l	—	2	4	20	47
Former _s	.	7	11	29	36
Electrical workers					
Current	8	5	4	19	25
Former _l	—	9	9	17	29
Former _s	7	9	8	—	—

older age classes on the medium level (in the age class of ≥55 years, $P < 0.05$ for the medium level versus the light level). The analysis according to total occupational history within the industrial branch under study gave results similar to the ones for the total occupational history during the worklife.

Chronic diseases. A more serious stage of morbidity was measured by the occurrences of two types of diseases: (i) those treated by medication specially compensated by the national sickness insurance law and (ii) those that indicated, by the questionnaire response, to have decreased overall work capacity (any chronic disease or injury). Neither of these disease patterns required inactivity.

Table 30. Previously diagnosed hypertension (in percentage) according to age. (_l = the longest duration of employment, _s = the shortest duration of employment)

Study group	Age (years)				
	≤ 24	25-34	35-44	45-54	≥ 55
Foundry workers					
Current	7	12	25	16	26
Former _l	.	2	23	16	21
Former _s	—	13	17	33	18
Metal product workers					
Current	.	6	14	19	37
Former _l	—	4	10	20	27
Former _s	.	7	7	29	27
Electrical workers					
Current	.	7	11	27	30
Former _l	.	5	15	23	23
Former _s	7	8	19	22	—

Table 31. Previously diagnosed heart diseases according to the exposure level. The three industrial branches and the groups of current and former workers were combined for each level.

Age (years)	Exposure level					
	Heavy		Medium		Light	
	N	%	N	%	N	%
15-23	0	0.0	4	16.7	1	2.7
25-34	5	6.5	19	5.6	17	6.4
35-44	13	12.7	27	6.8	17	8.8
45-54	18	15.9	67	23.6	14	16.5
55-64	16	22.9	54	34.6	10	27.0
≥65	5	20.8	29	38.7	5	26.3
Total	57	14.4	200	15.7	64	10.1

The incidence densities per 1000 person-years for diseases granted specially compensated medication by the national sickness insurance law between 1964 and 1978 are presented in figure 11. The age-standardized incidences were 11.5 for the foundry workers, 11.3 for the metal product workers, and 11.5 for the electrical workers. In the younger age classes the foundry workers had the highest incidences and the metal product workers the lowest, but from the age class of 45-54 years on, the metal product workers' incidences were the highest. The incidences were also calculated separately for typical occupations and for laborers. This analysis yielded similar results for both groups.

Comparison of the cross-sectional cohorts

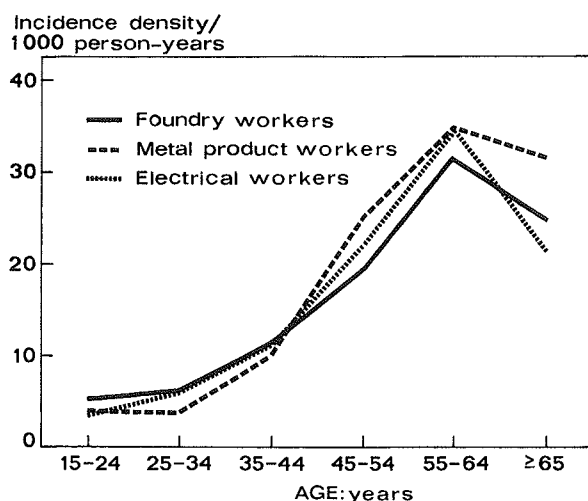


Figure 11. Incidence densities of diseases granted specially compensated medication by national sickness insurance from 1964-1978.

(workers who were occupationally active in 1950 but who had been hired earlier) showed no great differences between the branches. When the cross-sectional cohorts were compared with the longitudinal ones by industrial branch, the age-standardized incidences were higher for the cross-sectional cohorts, which was mainly due to the higher incidence rates for hypertension and myocardial insufficiency.

The granting of compensation for medication for the groups of diseases of particular interest in this study (musculoskeletal, respiratory, and cardiovascular diseases and mental disorders) was considered separately for each group of diseases. The age-standardized incidence of specially compensated medication for bronchial asthma was 0.7 for the foundry workers, 0.8 for the metal product workers, and 0.9 for the electrical workers. No essential differences in the incidences were found between the laborers and workers in typical occupations or in the comparison of the incidences for the longitudinal and cross-sectional cohorts.

The incidences of rheumatic arthritis were also very low for all groups: 0.5 for the foundry workers, 0.7 for the metal product workers and 0.5 for the electrical workers. The differences between the occupational subgroups were small.

The age-standardized incidence of compensated medication for myocardial insufficiency was 2.2 for the foundry workers, 2.3 for the metal product workers, and 2.3 for the electrical workers. Among the foundry workers, the laborers had higher incidences

than the workers in typical occupations. Among the metal product workers and electrical workers, the differences in the incidences were not as great between the laborers and workers in typical occupations. The age-standardized incidences were higher for the cross-sectional cohorts than for the longitudinal cohorts, being 10.2 for the foundry workers, 8.1 for the metal product workers, and 9.8 for the electrical workers.

Hypertension was the most common disease for which special compensation was granted for medication. The age-standardized incidence was 4.9 for the foundry workers, 5.5 for the metal product workers, and 5.8 for the electrical workers. The metal product workers in typical occupations had the highest incidences (typical occupations versus laborers $P < 0.05$) and the electrical workers the lowest. The differences between the industrial branches were small, but the foundry workers had somewhat lower incidences in the older age groups (≥ 55 years) than the workers in the two other industrial branches. The cross-sectional cohorts had higher incidences than the longitudinal cohorts in all the industrial branches. The higher incidences of the cross-sectional cohorts were statistically significant for the foundry and electrical workers ($P < 0.05$).

The age-standardized incidence of compensated medication for mental disorders was 2.3 for the foundry workers, 1.8 for the metal product workers, and 1.7 for the electrical workers. The highest incidences were found for the foundry workers in the young age classes. Among the metal product workers, the laborers had higher incidences than the workers in typical occupations ($P < 0.05$), but the opposite was true of the electrical workers. Among the foundry workers, there were no great differences in the incidences for the laborers and workers in typical occupations. The incidences were very low for the cross-sectional cohorts.

The questionnaire inquired into diseases that decreased overall work capacity (chronic disease or injury). The foundry workers had the highest age-standardized occurrences (42-45%), followed by the electrical workers (35-45%) and by the metal product workers (32-39%).

Chronic musculoskeletal diseases were reported by 13% of the current foundry workers, 21% of the former foundry workers with the longest duration of employment, and 17% of the former foundry workers with the shortest duration of employment. The rates for the same worker groups were 12%, 16%, and 11% among the metal product workers and 7%, 10%, and 9% among the electrical workers.

Chronic respiratory diseases troubled 5% of the current foundry workers, 6% of the former foundry

workers with the longest duration of exposure, and 4% of the former foundry workers with the shortest duration of employment. The corresponding figures were 3%, 4%, and 1% for the metal product workers and 2%, 4%, and 3% for the electrical workers

Chronic cardiovascular diseases were reported more often by the current (9%) and former foundry workers (11% of those with the longest and 6% of those with the shortest duration of employment) than the metal product workers (the respective rates being 7% for the current and 8% and 3% for the former workers). The electrical workers reported the lowest rates: 4% for the current workers, 6% for those with the longest duration of employment, and 3% for those with the shortest duration of employment.

Mental disorders were fairly seldom reported to be chronic (from 0.3% to 4% of the workers), perhaps because of their delicate nature.

The age-specific results on chronic diseases showed that the metal product workers tended to have higher occurrences in the older age classes (≥ 45 years) especially for cardiovascular and musculoskeletal diseases.

Thus both of the indicators used to measure more severe morbidity revealed higher morbidity rates for the younger age classes of foundry workers and for the older age classes of metal product workers.

4. Combined results for mortality, disability, and morbidity

Since mortality and disability reduced the cohorts in different ways, the total decrease through mortality and disability was calculated by the life-table technique. The period of follow-up ranged from 1969 to 1978 because the data on disability were available from the year 1969 on.

The total decrement through disability or death (inactives in figure 12) was significantly higher for the foundry workers (heavy level) than the metal product workers (medium level; $P < 0.01$, Mantel-Haenszel chi-square test for incidence density data) or the electrical workers (high level; $P < 0.001$). The difference between the metal product workers and the electrical workers was not significant.

Decrement of the cohorts through mortality and disability showed that the number of workers still active between 30 and 65 years of age was the highest on the light exposure level, second highest on the medium level, and the lowest on the heavy level. The greatest decrement through mortality was found in the cohort of workers on the heavy exposure level, and the greatest decrement through disability was

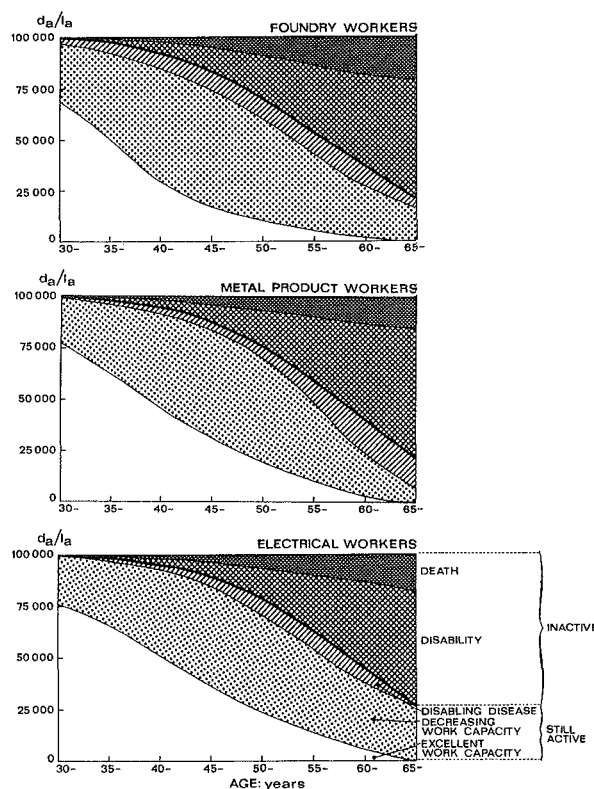


Figure 12. Decrement of the cohorts ≥ 30 years of age through death, disability, disabling disease, or decreasing work capacity [l_a = still active at age a , d_a the deceased or disabled at age a ($l_{30} = 100\,000$ = radix), still active with disabling disease or decreasing work capacity, and still active with excellent work capacity].

detected among the older workers on the medium exposure level.

The effect of softer measures on the three exposure-level cohorts was analyzed by calculating the decrement through disability, disease, and decreasing work capacity for the still active workers included in the life tables (figure 12). For this purpose disabling disease was defined as a subjectively assessed current work capacity of 0 to 4 points on a 10-point scale and a reported chronic disease that decreased the overall work capacity. Decreasing work capacity was defined as a subjectively assessed current work capacity of 5-8 points on a 10-point scale. Excellent work capacity was correspondingly defined to be a rating of 9-10 points. The age-specific figures for the current workers were used to represent the figures of still active workers when the decrements were estimated.

The decrement through disabling diseases was somewhat larger in the younger age classes of the heavy-level cohort than in the two other cohorts, but

it did not increase with age. On the contrary, the proportion of workers with disabling diseases was the highest in the older age groups on the medium exposure level. This result was consistent with the increased decrement through disability in the older age classes on the medium level. The lowest decrement through disabling diseases was found for light exposure.

On the heavy exposure level, the proportion of workers with excellent work capacity decreased the most rapidly with age. The workers on the light exposure level maintained their excellent work capacity until older ages than the workers on the heavy or medium exposure level.

Thus the combined results for mortality, disability, and morbidity indicated that different stages of disease decreased the cohorts of heavy, medium, and light exposure in different ways. The cohort of workers on the heavy level decreased through lessening work capacity, disability, and death. The cohort of workers on the medium level decreased mainly through disabling diseases and disability in the older age classes. Workers on the light level had the smallest decrement through different stages of disease; however, they had an increased decrement through death in the older age classes.

5. Turnover

A comparison of the turnover of employees in the three industrial branches showed that foundry workers had the highest termination-of-employment rate until the age class of 40–44 years, whereafter the rate was the highest among the electrical workers. In all the age classes the metal product workers had considerably lower rates than the other two groups. The termination-of-employment rates were the highest for the young workers regardless of the level of heaviness (figure 13).

Table 32 presents former workers' reasons for changing jobs. Low pay was reported to be the most important reason by the former metal product workers and the electrical workers with the longest duration of employment more often than by the former foundry workers with the longest duration of employment ($P < 0.001$, Mantel-Haenszel's chi-square test). But the foundry workers gave physically demanding (heavy) work as the reason more often than the metal product workers ($P < 0.01$) and the electrical workers ($P < 0.001$). The same was true for poor work conditions (foundry workers versus metal product workers, $P < 0.001$, foundry workers versus electrical workers, $P < 0.001$, metal product workers versus electrical

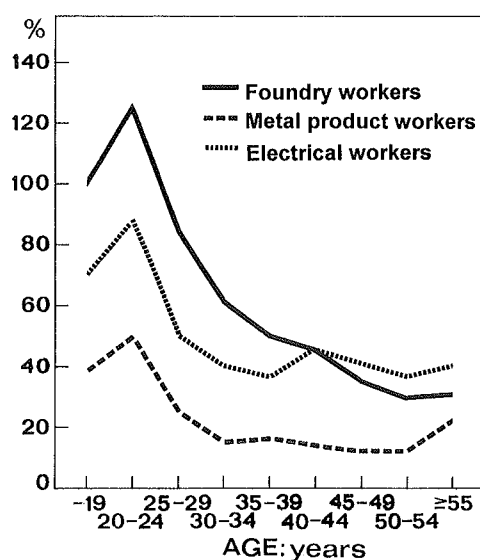


Figure 13. Termination of employment in the three industries (terminations as percentages of continuing employment per age category).

workers, not significant). The foundry workers reported illness as the most important reason for changing jobs more often than the electrical workers ($P < 0.01$). The difference between the foundry workers and metal product workers was not significant.

The most important reasons for changing jobs were similarly distributed in the groups of former workers with the shortest duration of employment. A statistically significant difference was found between the foundry and metal product workers concerning the physical demands of the work ($P < 0.05$).

The reasons for turnover were also examined according to age when changing jobs. Low pay, heavy work, and illness were mentioned as the three most important reasons. For all the groups low pay was a prominent reason for changing jobs among the younger age classes, whereas heavy work and illness were prominent among the older age classes. However, there were differences between the study groups. Among the groups of former workers with the longest duration of employment, the foundry workers reported low pay the most often in the youngest age class (15–24 years), heavy work the most often in the next age class, and illness the most often in the following age class. The order of the reasons was the same among the metal product workers, but the first peak (low pay) appeared one age class later (25–34 years) than among the foundry workers. The electrical workers reported low pay the most commonly in the youngest age class (15–24 years) and both heavy work and illness in the age class of

Table 32. Workers' reasons for changing jobs. The respondents were asked to indicate the three most important reasons for the change. (_l = the longest duration of employment, _s = the shortest duration of employment)

Reason for changing jobs	Foundry workers		Metal product workers		Electrical workers	
	Former _l (%)	Former _s (%)	Former _l (%)	Former _s (%)	Former _l (%)	Former _s (%)
Low pay	26	31	35	38	51	35
Physically demanding work	29	28	8	8	5	9
Illness	20	8	7	6	6	2
Uninteresting work, poor prospects	29	52	20	44	62	50
Training	2	12	8	12	13	13
Poor work conditions	37	52	21	23	17	14
Family, housing	14	20	15	22	14	15
Lack of work	17	10	14	16	20	20
Friction at work	7	5	7	7	5	6
Other	12	9	9	9	14	10

45–54 years. The order of the three reasons varied among the workers with the shortest duration of employment. Among the foundry workers heavy work preceded low pay as the reason for turnover. Among the metal product workers the peaks for all these three reasons were located in the same age class (25–34 years). Low pay was the most prominent reason among the electrical workers, whereas illness had little importance.

In connection with the questions on musculoskeletal diseases, the workers were also asked to report whether they had ever had to change jobs in the industrial branch under study because of the heaviness of the work or illness. Both heavy work and illness were mentioned by the current foundry workers more often than by the current metal product workers (table 33). Illness was reported as the reason for change by the current foundry workers more often than by the current electrical workers. More former foundry workers with the longest duration of employment also reported that they had changed jobs because of heavy work and illness than the corresponding group of electrical workers. Similarly the former metal product workers mentioned heavy work more frequently than the electrical workers. Of the former workers with the shortest duration of employment, the foundry workers changed jobs because of heavy work more often than the electrical workers. None of the electrical workers had changed jobs in the manufacture of electrical devices because of illness.

Turnover was also analyzed on the basis of the data on complete occupational histories collected by questionnaire. The occupations of each worker throughout his lifetime were classified according to three exposure levels (heaviness of the work) as

heavy, medium, or light. The groups of former workers were combined because the distributions of occupations from which the workers had entered the branch under study and those to which they transferred after changing branches were similar.

Most of the foundry workers had entered either from heavy level occupations such as agriculture and forestry work (55%) and construction work (40%) or from medium-level occupations (every third from the manufacture of metal products). Although 26% of the foundrymen transferred to heavy work after leaving foundries, most of the workers sought lighter work (mostly in the metal industry). One of every three foundry workers whose new job involved heavy work transferred to another foundry.

The metal product workers either began their worklives within the metal product industry (44%) or they transferred to it from work on either the same or the heavy exposure level. When the metal product workers quit a job, they generally transferred to medium-level occupations. They continued doing the same task (60% of the ones who transferred on the medium exposure level), or they chose a lighter form of work in the metal industry. Every third metal product worker left the work because of disability, old age, or death.

The electrical workers had seldom transferred from the same level. They generally switched from medium-level work, 45% of them from work within the metal industry. Of the electrical workers 42% had begun their worklives within the electrical industry. They sought medium-level or light-level work in the metal industry after they left the production of electrical devices.

Table 33. Significances of the differences in the occurrences of heavy work and illness as reasons for changing jobs within the same branch of industry. (_l = the longest duration of employment, _s = the shortest duration of employment)

Study subjects	Heavy work		Illness	
	Rate ratio	$\chi^2_{(1)}$	Rate ratio	$\chi^2_{(1)}$
Current				
Foundry versus metal product workers	2.20	10.03 **	1.89	6.03 *
Foundry versus electrical workers	1.54	1.80	2.25	4.58 *
Metal product versus electrical workers	1.34	0.45	0.80	0.28
Former_l				
Foundry versus metal product workers	1.35	1.28	1.33	1.12
Foundry versus electrical workers	4.21	11.26 ***	2.31	5.12 *
Metal product versus electrical workers	3.75	6.40 *	1.51	1.02
Former_s				
Foundry versus metal product workers	2.56	2.78	0.72	0.12
Foundry versus electrical workers	4.97	4.69 *	.	.
Metal product versus electrical workers			.	.

*P<0.05, **P<0.01, ***P<0.001

VII. SELECTION

1. Social selection

Selection of the work force occurs both via employees' self-selection and employers' selection. Different industries set various requirements and recruit workers with different characteristics. The definition of the three exposure levels to some extent describes the workers' social selection. Skilled workers comprised 45% of the workers on the heavy level (foundry), 83% on the medium level (metal products), and 76% on the light level (electrical devices). Most of the foundry workers' periods of employment were short (74% less than one year and only 9% over five years), whereas the duration of metal product workers' periods of employment were longer (44 less than one year and 24% over five years). Sixty-three percent of the electrical workers had periods of employment that lasted for less than one year, and 7% had periods of employment longer than five years.

Loss (ie, persons who could not be traced from population registers) accounted for 3.4% of the foundry workers, 0.1% of the metal product workers, and 0.2% of the electrical workers.

Foundry workers, on the average, had more children than metal product workers or electrical work-

ers. Families with three or more children were more common among the foundry workers than among the two other groups.

There were variations in the way economic fluctuations affected the entry of new workers into the three industrial branches (94, 180–183). The number of new foundry workers was the most clearly associated with the economic situation. The number of new metal product workers showed the least variation (figure 14).

In the mortality study of the three exposure-level cohorts, laborers and other unskilled workers had a tendency towards higher mortality than the skilled workers did. However, the order of the survival curves remained unchanged between the industrial branches when the unskilled workers were excluded from each level.

It was supposed that employees who enter a particular industrial branch during economic recessions are socially selected and vice versa. The survival of foundry workers before the age of 65 years was better for those who started foundry work during economic recessions than for those who started during periods of economic growth (figure 15). The reversed mortality pattern at older ages originated in typical foundry occupations. In addition to social selection, the result also reflects health selection among skilled foundry workers. The growth and recession curves of the metal product workers were the opposite of the survival curves of the foundry workers, and they crossed at the age of 65 years. The higher mortality in

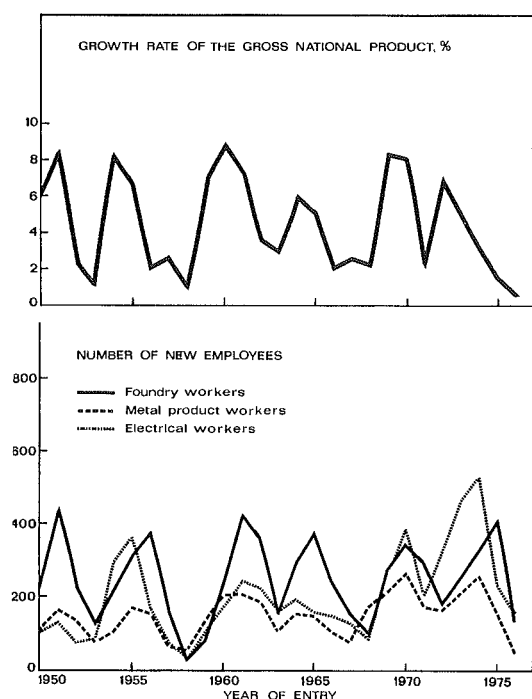


Figure 14. Number of new employees versus growth rate of the gross national product.

the older age classes of workers who had entered a specific type of work during periods of economic growth was caused by the higher mortality of laborers and nontypical metal product workers. However, the laborers in the metal product industry had lower mortality rates than the laborers in foundries. The metal product workers appeared to be a socially and, to some extent, also a health selected group. The electrical workers who had entered the industry during recessions had a slightly but systematically lower mortality than those who had entered during a period of growth. The result may be due to negative health selection.

Some cause-specific mortality results supported social and health selection. The probability of violent death was the highest for the foundry workers (about 1.5 times that of the metal product workers). The foundry workers also had the highest incidence of deaths with alcohol as a contributing factor (ICD codes 291, 303, 571, 979, and E 980). The metal product workers had the lowest incidence (foundry versus metal products $P < 0.001$). The highest incidences of deaths with alcohol as a contributing factor were found for the older age classes of electrical workers (electrical devices versus metal products $P < 0.001$). This finding may reflect negative social and health selection.

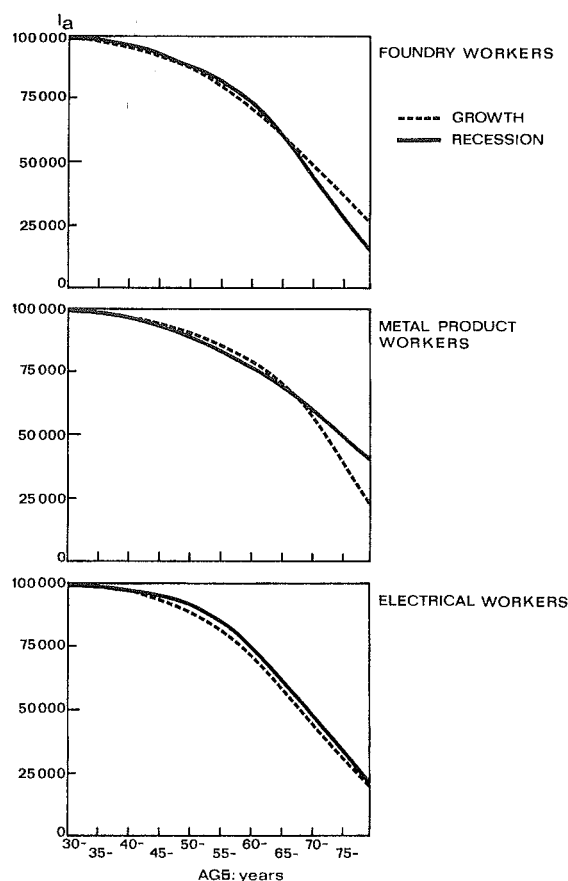


Figure 15. Survivors ≥ 30 years of age according to economic fluctuation. [l_a = survivors at age a , $l_{30} = 100\,000$ (radix)].

According to disability pensions and specially compensated medication for mental disorders, the foundry workers had mental disorders more frequently than the metal product workers or electrical workers. The excess was especially clear in the younger age classes and among the laborers, a finding which refers to low social and health preselection.

Smoking is also a factor that indirectly causes selection out of jobs, as smoking promotes, for example, lung diseases and cardiovascular diseases. Consequently the occurrences of chronic bronchitis and angina pectoris were higher among the former workers than among the current workers and were pronounced at the heavy exposure level (synergistic effect).

2. Health selection

Mortality. The survival curves showed no great differences between the three exposure levels. However, the heavy level had the highest degree of mortality

and the medium level the lowest. The unskilled workers had higher mortality rates than the skilled workers.

The foundry workers' higher rates of violent deaths and deaths with alcohol as a contributing factor suggest less social and health preselection than in the other cohorts.

Health selection during employment was indicated by the results for mortality from all cardiovascular diseases combined and coronary heart disease separately (figure 16). The cumulative incidences were compared with those for the cross-sectional cohorts which included workers who were occupationally active in 1950 but who had been hired earlier (highly selected groups). The younger cohort of foundry workers had a higher mortality from cardiovascular diseases than the older cohort. The difference occurred mainly in the mortality from coronary heart disease. A similar difference was found for the cohorts of the metal product workers, but coronary heart disease did not explain the difference. The electrical workers again had an opposite model. The older cohort of electrical workers had higher mortality than the younger one. This result suggests that health selection during employment was low.

The low total mortality rate and cause-specific results suggest that the metal product workers were both socially selected and health selected.

The mortality rates for the electrical workers in the older age classes were almost as high as for the foundry workers, which may be a sign of negative health selection. The total mortality rates and some cause-specific results (deaths with alcohol as a contributing factor, certain tumors) suggest that the older electrical workers probably had an occupational history which differed from that of the younger electrical workers. When the annual cohort entries were compared between the three branches of the metal industry, the cohort comprised of workers who manufactured electrical devices was younger than the other two cohorts. Evidently, the older electrical workers had different occupations in their histories, and these occupations were closer to the heavy than to the medium level. This conclusion was supported when the complete occupational histories of the current and former workers were analyzed in five-year time periods according to the average level of heaviness of the main occupation during the lifetime and birth area (rural or urban) (figure 17).

The score of heaviness was formed by giving 3.0 points to the heavy exposure level, 2.0 points to the medium level, and 1.0 points to the light level. The average points during different calendar periods were classified again into the three levels of heaviness: light (1.0 to 1.6), medium (1.7 to 2.3) and heavy (2.4

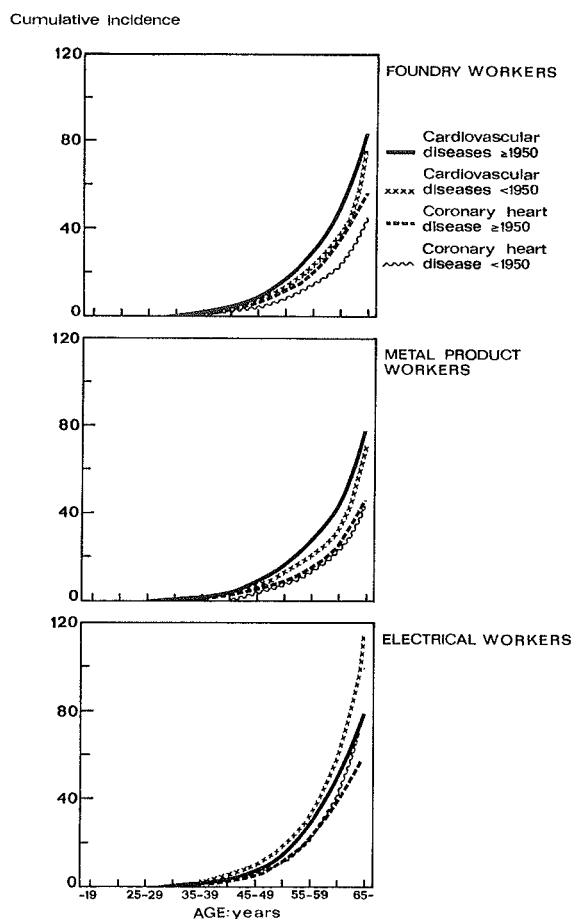


Figure 16. Mortality from all cardiovascular diseases and coronary heart disease. Comparison of the workers who entered the industries in 1950-1976 and those who entered earlier but were still at work in 1950.

to 3.0). Although the jobs generally became lighter as the work force in agriculture and forestry became smaller, the change of heaviness has been the greatest among electrical workers who came from the countryside. This finding was especially evident for alive and dead former workers with the longest duration of employment, but the trend was the same for the current workers and for the alive and dead former workers with the shortest duration of employment.

Disability. In a comparison with the active male population of Finland, the standardized disability ratio was 121 for the foundry workers, 108 for the metal product workers, and 97 for the electrical workers. The effect of selection could be seen when different comparison groups were tested. Preselection was the most evident when the observed disability numbers were compared with the expected numbers calculated from the total male population (figure 18). Selection during employment was the clearest when the observed numbers were compared with the ex-

pected numbers calculated from the active male population. See also figure 8.

The high disability rates among the young foundry workers were mainly due to mental disorders, and they indicated low social and health preselection. The number of all cardiovascular diseases and the number of coronary heart disease cases alone were significantly lower for the foundry workers than for the active male population. This finding can be explained both by health selection into and out of heavy-level exposure and by the mortality rates for the older age groups. Health selection during employment was also suggested by the rates of respiratory diseases. Respiratory diseases were more frequent than expected in both the cross-sectional and the longitudinal cohorts, but the excess was greater in the cross-sectional one. Musculoskeletal diseases also caused selection out of heavy-level work. The cross-sectional cohort had a greater excess of disability due to musculoskeletal diseases than the longitudinal cohort did.

The expected disability rates were exceeded in the older age classes of the metal product workers, who were obviously the most strongly affected by social and health selection when they entered the occupation. The metal product workers also had lower numbers of cardiovascular diseases than expected, a finding which again refers to health selection. But the difference between the expected and observed numbers was smaller than for the foundry workers.

The electrical workers' disability rates were below the expected values in all but the youngest age class, for which mental disorders caused an excess. The electrical workers had less social and health selection than metal product workers did. There were significantly higher disability rates of mental disorders in the older age classes than expected. Disability from cardiovascular diseases was below the expected values in both the cross-sectional and the longitudinal cohorts. This result may indicate negative health selection: Workers who transfer from heavier exposure levels can continue working at the light level and are thus spared from disability but die from cardiovascular diseases (as stated in the comparison of cardiovascular deaths between the cross-sectional and longitudinal cohorts).

Morbidity. Morbidity was investigated in samples of currently employed workers and former workers. The inquiry concentrated on musculoskeletal, respiratory, and cardiovascular diseases. The inquiry included questions on both symptoms and earlier diagnosed diseases. Health selection was studied by comparing the findings between the three exposure levels and between the current and former workers within the same levels.

Ache or pain in the musculoskeletal system within

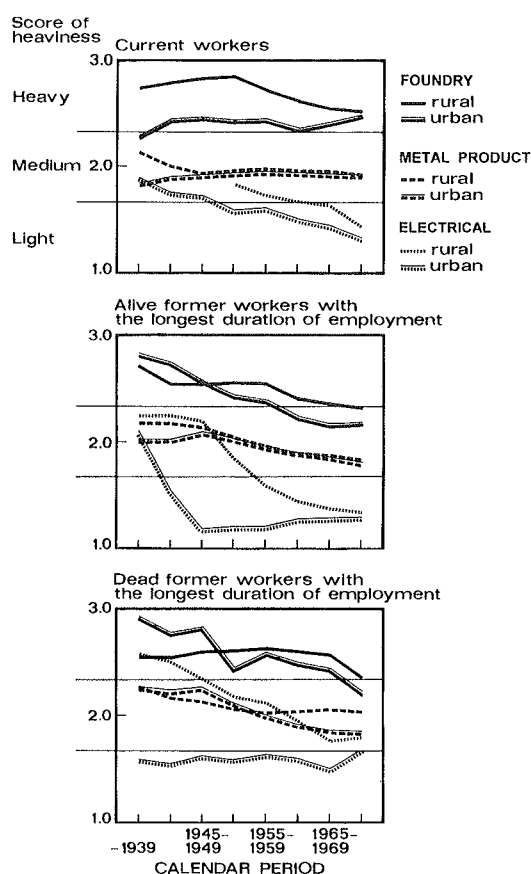


Figure 17. Average level of heaviness of the workers' main occupation according to birth area (rural or urban) during different calendar periods.

the last 12 months was more frequent among the foundry and metal product workers than among the electrical workers. Both currently employed and former foundry workers had significantly more earlier diagnosed musculoskeletal diseases than the electrical workers did. The younger age classes of foundry workers (<45 years) had a higher occurrence of musculoskeletal diseases than the metal product workers; in older age classes the opposite was true.

The former foundry workers had more diagnosed musculoskeletal diseases than the current workers; there was no such difference among the metal product workers. The results mean that musculoskeletal diseases clearly lead to selection away from heavy-level work. The effect of selection was especially evident in the disease groups of sciatica and low-back pain.

Both the current and the former foundry workers had higher rates of chronic bronchitis (in different categories for smoking habits) than the corresponding groups of metal product and electrical workers. Se-

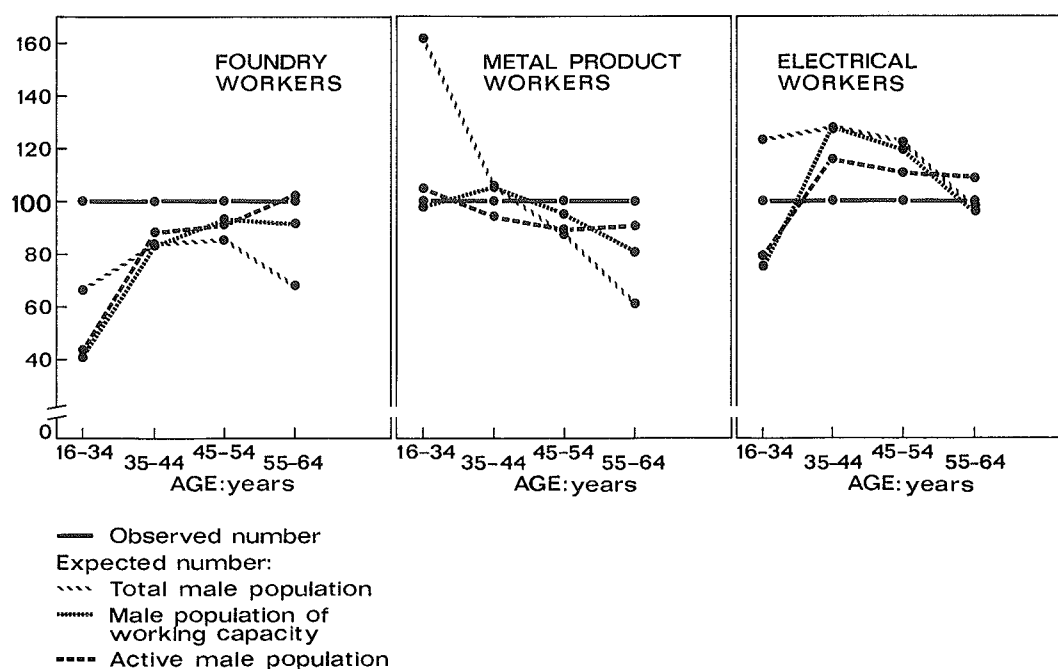


Figure 18. Observed and expected numbers of new disability pensions between 1969 and 1978. The expected numbers were calculated on the basis of different comparison populations. The numbers are expressed as an index; observed numbers = 100.

lection away from heavy-level exposure was indicated by higher occurrences of chronic bronchitis among the former than the current foundry workers from the age class of 45–54 years on. A similar trend was found for the metal product workers, but the rates were lower. Diagnosed lung diseases were also more frequent at the heavy exposure level than at the medium or light level. Negative health selection was shown as higher occurrences of diagnosed emphysema and bronchitis in the youngest age class of electrical workers.

Angina pectoris (irrespective of smoking habits) was more prevalent among both the current and former foundry workers than among the electrical workers, whereas the difference between the foundry workers and metal product workers was not significant. The former foundry workers had somewhat higher occurrences than the current workers. The same was true among the metal product workers. The current electrical workers had higher occurrences than the former electrical workers. This result may reflect negative health selection to the light exposure level from the heavy and medium levels.

Previously diagnosed heart diseases were more frequent among the former than the current workers. The former foundry workers with the longest duration

of employment had higher prevalences in the younger age classes and the metal product workers with the longest duration of employment in the older age classes (especially in the age class of ≥ 55 years). Angina pectoris or myocardial infarction was the highest among the former metal product workers with the shortest and the longest duration of exposure. The foundry workers had higher occurrences of previously diagnosed hypertension in the younger age classes than the metal product workers or the electrical workers, whereas in the oldest age classes the metal product workers had the highest prevalences. Analysis according to the complete occupational history showed that the workers at the heavy level had more diagnosed cardiovascular diseases in the younger age classes and the workers at the medium level in the older age classes, a finding which can be interpreted as the result of selection.

Cardiovascular diseases may also be manifested as different stages of disease, and each stage may cause health selection. The manifestation of different stages of cardiovascular diseases can be seen in figure 19. The incidences are calculated for the combined groups of current and former workers.

Complete occupational histories were used to place the occurrences of diseases on the correct levels

of exposure. In order to reduce the effect of health selection, similar exposure levels through the workers' lifetimes were combined. This procedure yielded clearer differences in the occurrences of musculoskeletal, respiratory, and cardiovascular diseases between the three exposure levels (figure 20).

The heavy exposure level then had significantly higher occurrences of any previously diagnosed musculoskeletal disease which had prevented working for at least one month (45%) than the medium (34%) or the light level (22%), and the medium exposure level had higher occurrences than the light level.

The prevalences of all diagnosed lung diseases were the highest at the heavy exposure level (42%), the second highest at the medium level (36%), and the lowest at the light level (32%). The differences between the branches were not statistically significant.

Previously diagnosed heart diseases were also studied according to the main exposure level during the workers' lifetimes. This analysis did not reveal great differences between the three levels. The medium level had the highest prevalence (16%), the heavy level the second highest (14%), and the light level the lowest (10%). However, workers 45 years or older at the medium exposure level had significantly

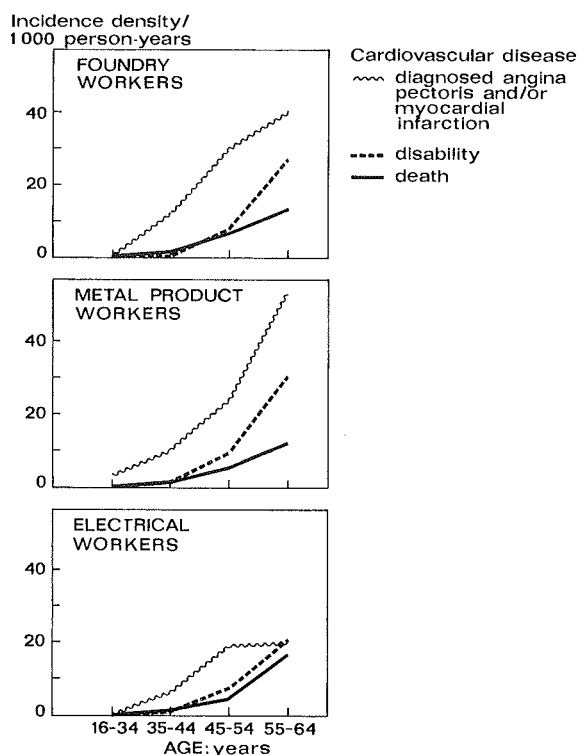


Figure 19. Incidence densities of cardiovascular diseases for the three cohorts.

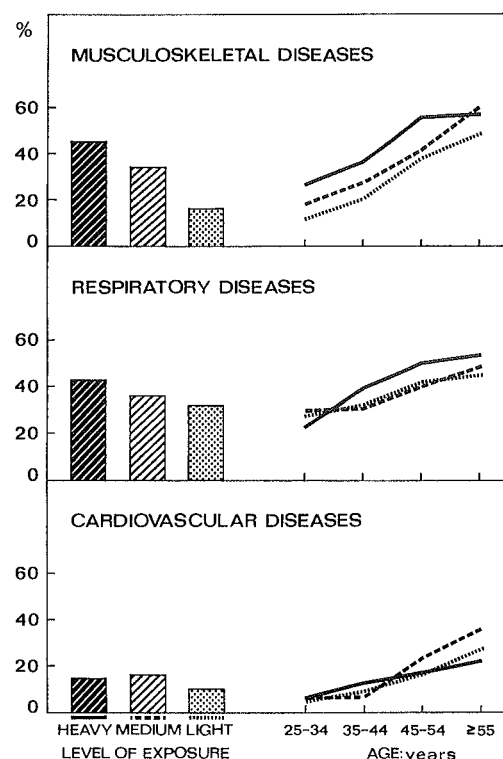


Figure 20. Occurrences of diagnosed diseases (%) according to the main exposure level during the workers' lifetimes.

more previously diagnosed heart diseases than workers of the same age at the light level.

3. Chain of selection and life cycle

Changes in heaviness of the work. The results for mortality and morbidity indicated different social and health selection into and out of the heavy, medium, and light exposure levels. Therefore selection into and out of the industries was analyzed on the basis of the complete occupational histories collected with the questionnaire. The occupational histories of current and former workers (as classified when the original cohorts were formed in 1976) were compared for changes in heaviness throughout their complete occupational histories. The occupations were again classified into three exposure levels on the basis of physical demands (heavy, medium, and light). Transitions from one level to another were grouped into transitions to either heavier or lighter exposure levels. The changes are expressed as percentage differences (percentages were calculated in five-year age classes for each exposure level, the total percentage being

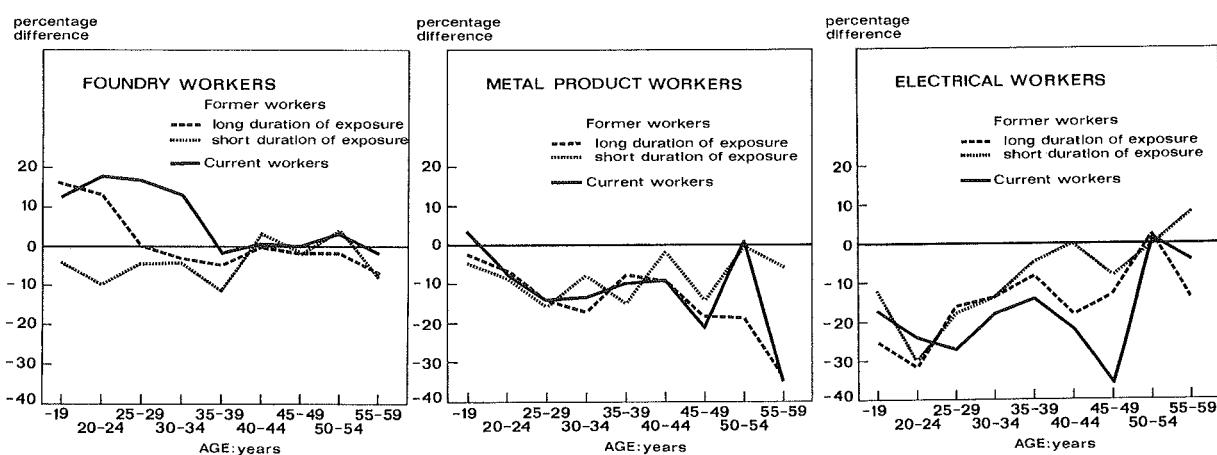


Figure 21. Changes in the heaviness of the work throughout the complete occupational histories of the foundry, metal product, and electrical workers, expressed as percentage differences.

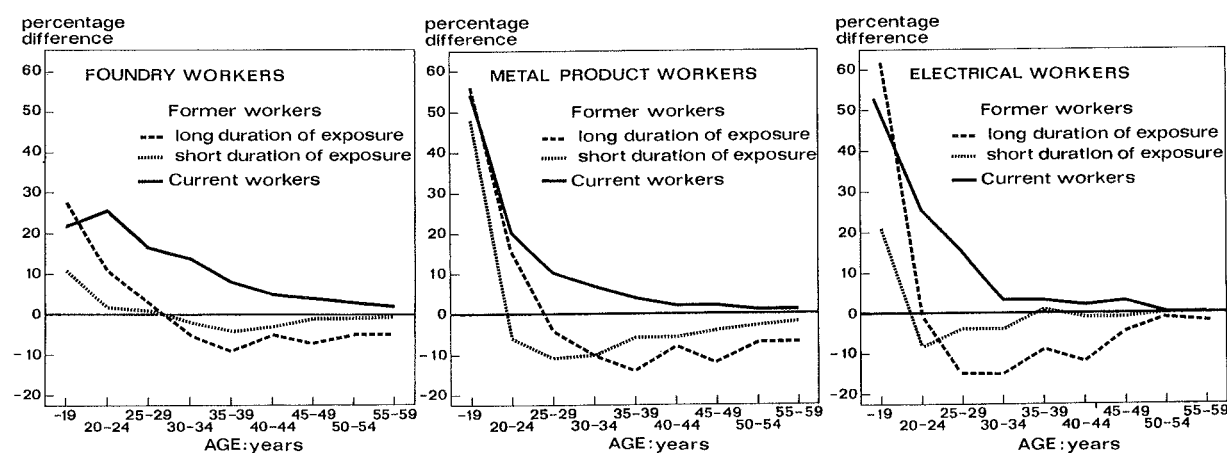


Figure 22. Beginning and termination of work according to age, expressed as percentage differences. The timing of the foundry, metal product, and electrical work was based on the complete occupational histories.

300; the percentages of transitions to lighter exposure levels were subtracted from those to heavier levels and divided by three, the total percentage in each age group being 100) in relation to the total number of workers in the age class.

The timing of the work under study within the workers' complete occupational histories was examined in the same way as percentage differences. The results were expressed as the percentages of workers who entered the industry minus those who left it.

Among the foundry workers, the current workers had transferred mainly to heavier work until the age of 35 years. Former workers with a long duration of exposure had moved to heavier work until the age of 25 years, whereafter they switched to lighter work. Former workers with a short duration of exposure had

sought lighter work from the very beginning (figure 21). Changes in the heaviness of the work were clearly associated with the occupational histories within foundries (figure 22).

Among metal product workers, workers who had changed the level of heaviness during their lifetime tended to choose a lighter exposure level. The trend was quite even until the age of 45 years, whereafter most of the changes were to lighter exposure levels. The metal product workers' changes were also associated with the complete occupational histories, but not as clearly as among the foundry workers.

The electrical workers who had changed the level of heaviness during their lifetime transferred mainly to lighter levels. However, the two downward peaks (at the ages of 20-24 and 45-49 yrs) indicate bimo-

dality in the age distribution at the time of entry (and also negative health selection).

Thus the three exposure levels had different patterns of changes in the heaviness of the work according to age throughout the workers' complete occupational histories. Selection into and out of jobs within and between different exposure levels thus formed a continuous process, a chain of selection. This phenomenon was ascertained when the complete occupational histories were analyzed according to the levels of heaviness (heavy, medium and light) of the occupations which the workers left and to which they transferred (figure 23). The groups of current and former workers were combined because of the similarity of occupational distributions before the workers entered and after they left the industrial branches.

The foundry workers entered the industrial branch from either heavy-level or medium-level occupations, and most of them sought lighter work in medium-level occupations. The metal product workers either began their worklives within the metal product branch of industry, or they transferred to it from work of the same level of heaviness. After leaving a job they generally moved to medium-level (the same level) or light-level occupations. The electrical workers switched from medium-level work, or they began their worklives within that industrial branch. When they left a job, they chose medium-level or light-level work in the metal industry.

Effect of changes in heaviness of the work on the occurrences of diseases. The changes in the heaviness of the work during the workers' lifetimes distort the occurrences of work-related diseases and underestimate or overestimate the differences in these occurrences between the originally defined exposure levels. Therefore two approaches were used to clarify

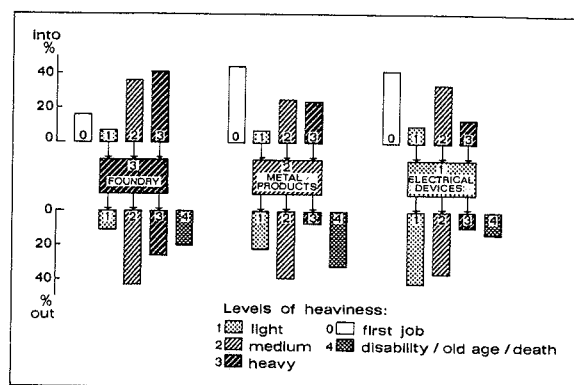


Figure 23. Selection of the workers into and out of jobs according to the heaviness of the work during their lifetimes.

	Heavy level	Medium level	Light level	
Current	35	33	21	Personnel records
Former ₁	42	34	28	
Current	36	32	23	Questionnaire
Former ₁	46	35	27	

Figure 24. Age-standardized occurrences of musculoskeletal diseases (%) and exposure level as defined in the employers' personnel records and in the questionnaire data. (₁ = the longest duration of employment)

the underestimates and overestimates. One approach was to compare the current and former workers, and the other was to calculate the occurrences according to the main exposure level as defined in the employers' personnel records and on the questionnaire.

When the occurrences of diagnosed diseases were compared between the three exposure levels, no great differences among the current workers were found in the total prevalence rates of diagnosed musculoskeletal, lung, or heart diseases. The differences were small, especially between the heavy and the medium levels. But the differences in occurrences became evident when the groups of former workers were included. For example, the age-standardized prevalences of musculoskeletal diseases among the current workers were 35% for the heavy exposure level, 33% for the medium level, and 21% for the light level (figure 29). The corresponding rates among the former workers with the longest duration of employment were 42%, 34%, and 28%. This series of prevalence rates not only shows differences between current and former workers, but also a process of health selection from one exposure level to another (marked with the arrows in figure 24).

However, the presented rates are still overestimates or underestimates, because they were calculated for the original exposure levels defined on the basis of the main occupation registered on the employers' records. When the complete occupational histories acquired by questionnaire were used, with the main occupations classified according to the three exposure levels, the occurrences could be placed on the correct levels (arrows in figure 24), and the transfers due to misclassification became clearer.

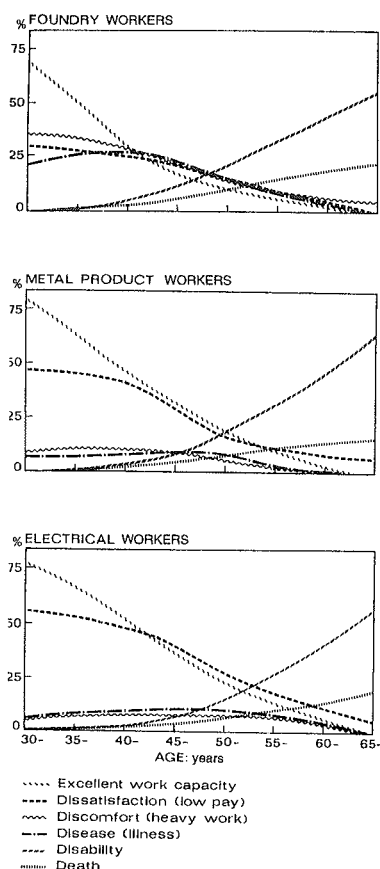


Figure 25. Occurrences of different stages of disease and excellent work capacity according to age.

Health changes during the life cycle. A chain of selection during the workers' lifetimes was formed not only by changes in the heaviness of the work, but also by health changes during the life cycle. Hard and soft measures comprise one dimension (dissatisfaction - death, see figure 1), and they were expected to follow each other as explanations of the termination of employment. See figure 3. The points of inflection in age, where the measures of different stages of disease turn from soft measures into hard ones, varied according to the exposure level (figure 25). The life-table technique was used to show the turning points of the measures.

The occurrences of excellent work capacity and soft measures (dissatisfaction, discomfort, disease) were calculated for the workers still active (see the life table in figure 12), whereas hard measures (disability, death) were considered complementary. The number of persons with excellent work capacity in the cohorts was estimated with the corresponding age-specific figures of the current workers. Excellent current work capacity was defined as a subjective

assessment of 9 to 10 points on a 10-point scale. Similarly, the three most important reasons for changing jobs reported by the former workers with the longest duration of employment were used to represent soft measures of disease: low pay was chosen to represent dissatisfaction, heavy work to represent discomfort, and illness to represent the term disease. See Elinson's classification, page 12.

The proportion of foundry workers with excellent work capacity decreased the most rapidly with age when compared with the workers of the other two branches. The highest point of dissatisfaction (low pay) was found before the age of 30 years (not shown in the figure), and it turned to discomfort (heavy work) between 30 and 34 years of age. Discomfort again changed to disease at about the age of 40 years. Different symptoms occurred, and their occurrences were clearly higher than in the other two branches of industry. Since heavy work and different symptoms led to selection out of heavy-level jobs, disease did not change to disability until near the age of 50 years. Thereafter hard measures were the most prominent.

Throughout the age classes, low pay was more important to the metal product workers than to the foundry workers. Correspondingly, the proportion of metal product workers who experienced the work as heavy was clearly smaller than that of foundry workers and disease appeared later (at about the age of 44 years). Nevertheless, disease changed to disability early in the next age class (45-49 years).

The electrical workers retained their excellent work capacity until older ages than the foundry workers and the metal product workers. The electrical workers also had the highest occurrences of low pay (dissatisfaction) throughout all the age classes. The proportions of heavy work and illness were low. Because light-level work is not physically demanding and because there was negative health selection, disease had slightly higher occurrences than discomfort. Discomfort and disease turned to disability in the age class of 50-54 years.

VIII. DISCUSSION

1. Validity of the study

This study was faced with many validity questions, as several measures of exposure and outcome and various methods for data collection were used. Most of these questions are common to all retrospective epidemiologic studies and have been discussed thoroughly earlier (11, 27, 29, 40, 42). Such questions

include the correctness of the diagnoses given on disability and death certificates, changes in diagnostic accuracy during the period of follow-up, and temporal variations in mortality from different causes of death (20, 26, 184). Errors in retrospective reporting on questionnaire studies have also been discussed (64, 129, 131). The questions of validity which will be addressed here have either received little attention or they are of specific methodological interest.

Formation of cohort and period of follow-up. Mortality comparisons of different occupational cohorts have not paid enough attention to differences in cohort formation, for example, the type of cohort (entry or cross-sectionally based cohort), the period of entry, and the period of follow-up. Different combinations can yield different results. Cohort formation has been considered only when a study has been unable to reveal occupationally dependent differences in mortality, especially differences in cancer mortality. The importance of methodological factors has also surfaced when the same cohorts have been followed up several times (3, 46).

Because the main topic of interest was to investigate selection into and out of jobs, the cohorts in this study were formed as entry (longitudinal) cohorts, and no minimum length of exposure was required. The cross-sectionally based cohorts gathered from the same workplaces were formed for comparison purposes (as highly selected cohorts).

In this study the cross-sectional and longitudinal cohorts had different mortality patterns. The cross-sectional cohorts generally had lower standardized mortality ratios than the longitudinal ones, but cause-specific results revealed different selection mechanisms. Furthermore, a detailed analysis of mortality according to period of entry and period of follow-up [published in a separate paper (3)] ascertained that discrepancies between different mortality studies in the same occupational groups may be caused by different criteria for cohort formation and by variations in the follow-up.

Determination of the type of cohort that best reveals potential excess mortality from a certain disease (ie, the optimum composition of the cohort) requires data on the age distribution of person-years in different periods of follow-up and the percentage of different periods of follow-up in a certain age class, as well as data on age-specific occurrences of the disease (3). The optimum composition of the cohort varies according to exposure and latency period. It is also affected by various confounding factors in different occupational cohorts and by turnover rates.

Stratified analysis is a tool that reveals the informativeness of the cohort study at a certain time. Earlier cohort studies have shown that excess mortal-

ity cannot be detected if the periods of follow-up are too short. However, failure to reveal excess mortality may also be due to selection of a point in time that is too late.

Completeness of occupational history. Lack of complete occupational histories causes underestimates or overestimates of occupational mortality and morbidity. In this study special attention was paid to the correctness of the occupational classifications recorded at workplaces, which were compared with the data collected by questionnaire on complete occupational histories.

The original study groups (samples for the questionnaire) were formed on the basis of the duration of exposure. For this reason some of the workers with the shortest duration of employment should have been included in study groups that comprised workers with the longest duration of employment. Misclassification therefore to some extent weakened the health effects for the groups of workers with the shortest duration of employment. However, the resultant smaller differences between groups of workers with long exposure and those with short exposure in the end even strengthened the results on occupational mortality and morbidity.

No division into categories with different durations of exposure was used in the analysis of mortality because the results had to be calculated on the basis of the occupational histories recorded at the workplaces.

Complete occupational histories were available only for the samples. The errors in person-years were clearly smaller than the errors in the durations of exposure (5). The greatest loss of person-years was found for the deceased metal product workers. On the basis of the questionnaire data and regardless of the quality of the response, the proportion of workers who had entered the industrial branch under study before the first year of follow-up (1950) was the highest for the deceased workers and alive former workers with the longest duration of exposure. This finding emphasizes the importance of complete occupational histories when mortality results must be calculated according to a period of latency. For instance, misclassification can cause cancer cases to be located in classes with too short a period of latency or even entirely exclude them from the study group (if criteria are set for the minimum period of exposure or latency).

When the main occupations (according to the census code) during the workers' lifetimes were considered, the industrial branch was the same among 71% to 93% of the current workers, 52% to 84% of the alive former workers with the longest duration of employment, and only among 10% to 42% of those with the shortest duration of employment. Among the

dead former workers the corresponding percentages were 38% to 78% for the workers with the longest duration of employment and 8% to 56% for the workers with the shortest duration of employment.

The correctness of the levels of heaviness was controlled by comparing the classifications of the occupations recorded at the workplaces with those reported by the workers, with several time periods used for the classification (eg, heaviness of the main occupation in the industrial branch under study or during the workers' lifetime). The heaviness of the main occupation in the industrial branch under study proved to be the same among 69% to 95% of the alive workers and among 78% to 100% of the deceased workers, depending on whether the classification was based on the occupations recorded at the workplaces or the occupations reported via the questionnaire. Comparison of the average point of heaviness during the workers' lifetimes with the heaviness of the main occupation in the branch under study gave similar results. Little variation in the levels of heaviness according to calendar time (see figure 17) was detected for the groups of foundry workers and metal product workers, whereas the older electrical workers had transferred from work on heavier exposure levels.

Measures of outcome. Mortality and disability. The causes of death were coded according to the eighth revision of the International Classification of Diseases. Because the period of follow-up included the span of years from 1950 to 1978, the sixth and seventh revised codes had to be changed to the codes of the eighth revision. To minimize errors in code transformation, the deaths in each main category were put into chronological order and then coded, working backwards from the present to the first year of follow-up.

The causes of disability were already coded with the eighth revision because the period of follow-up comprised only the ten last years, from 1969 to 1978. In cases of disability pension the period of follow-up was restricted, as the recording system had been different earlier. To reveal work-related disability, a 10-year period of follow-up is short. Therefore, in addition to the incidence rates, the prevalence rates were calculated for the total cohorts at the end of the follow-up (1978).

The results on the foundry workers' excess mortality from violent deaths, respiratory diseases, and lung cancer are consistent with the findings of earlier reports (37, 63, 152, 185–187). Excess mortality from cancer of the digestive organs has also been reported in connection with lung cancer mortality in dusty occupations (37, 188, 189). Excess cardiovascular mortality was more clearly seen in this study than in an earlier study on Finnish foundry workers (37).

Excess mortality from leukemia and other neoplasms of lymphatic and hematopoietic tissue was found for floor molders and laborers as was a slight excess mortality from skin melanoma for laborers. These results are only descriptive in nature because of the small numbers of cases. Therefore further studies are needed to determine the potential causality between chemical exposures and the excess cancer mortality (147, 190–192).

Among the metal product workers the groups of metal plate workers, sheetmetal workers, and plumbers had an excess mortality from tumors (cancer of the digestive organs and lung cancer). An elevated risk of cancer mortality, especially for welders and metal refinery workers, has been reported in several studies on the metal industry (193–198). The present study could not confirm these occupation-specific findings. But the occupational groups in the present study were small, and their exposures were different. The present study also found an excess mortality from cardiovascular diseases among truck drivers and crane drivers working in the metal industry.

The truck drivers and crane drivers at work in the electrical industry also had an excess mortality from cardiovascular diseases. The electrical workers' mortality from tumors (cancer of the digestive organs, lung cancer, cancer of the urogenital organs, and unspecified cancers) was higher than expected, especially in the older age classes. A more detailed study would be needed to clarify the potential occupational dependence, because confounding exposure in other metal work may have had some causal effects (199, 200).

Morbidity. Most of the softer measures were the same as those used in many epidemiologic studies in connection with questionnaires on the symptoms of respiratory, cardiovascular, and musculoskeletal diseases (92, 93, 144, 145, 154, 176, 201) and thus had already been tested in practice. Because comparisons were made between the three industrial branches and between groups of current and former workers, no external comparison groups were used. However, some specific comparisons were made to ascertain the validity of the questionnaire study. The occurrences of musculoskeletal diseases in this study resembled the corresponding occurrences in other studies. Low-back pain that caused incapacity to work for at least one month had been diagnosed during the last five years among 4.7% of active Finnish men aged 35–64 years, the corresponding value for sciatica being 2.9% (202).

The occurrences of earlier diagnosed low-back pain or sciatica were similar in the three industrial groups studied, being 6.7% for the foundry workers, 5.6% for the metal product workers, and 4.1% for the

electrical workers. In a Swedish study on men aged 40–47 years, the prevalence of current low-back pain or sciatica was 31% (203). The occurrences of low-back pain and/or sciatica during the last 12 months for the three metal industries were somewhat higher, about 30–40% (compare table 22).

The prevalences of chronic bronchitis were compared with the prevalences found in a previous study of Finnish foundry workers, in which the same definition criteria had been used (177). Both of the Finnish studies showed similar occurrences for current and former workers in different smoking categories. The occurrences of earlier diagnosed diseases were also similar for the foundry workers. Of the earlier diagnosed respiratory diseases, the occurrence of emphysema was compared with that of the active Finnish male population aged 35–64 years (202). The occurrence was 1.8% for the male population and, correspondingly, 0.9% for the electrical workers and 2.6% for the metal product workers, whereas for the foundry workers (the heavy exposure level) the occurrence was 5.9%.

The prevalences of previously diagnosed angina pectoris or myocardial infarction for a sample of the active Finnish male population aged 35–64 years (202) were similar (6.4%) to the prevalences for the current foundry workers (7.2%) and current metal product workers (6.0%) of the same age, whereas the current electrical workers had a lower prevalence (3.6%). In addition the prevalences of present angina pectoris (see table 28) detected in this study were, on the average, of the same magnitude as in a sample study of the Finnish male population aged 30–59 years (144). In that study of the male population, the validity of self-reporting was examined by comparing the reported symptoms with diagnosed cardiovascular diseases. The comparison showed that 77% of the men who reported severe angina pectoris or chest pain also had diagnosed myocardial infarction or angina pectoris.

The prevalences of previously diagnosed hypertension (shown in table 30) were somewhat higher in the younger age classes of current foundry workers and in the older age classes of the metal product and electrical workers than among the active male population.

The questions on workers' subjective assessments of work capacity and present health have been tested in earlier Finnish epidemiologic studies (92–94, 145). It has also been shown that these measures are highly correlated with each other (93).

2. Concluding remarks

The conclusions of this study are based not only on the statistical significances of the findings, but also on whether the occurrences of different disease measures were logical.

Verification of the hypotheses. The hypotheses formed for this study were verified or contradicted by inference from the findings.

(i) The strongest health-based selection out of jobs was found at the heavy level. This part of the hypothesis was supported. Contrary to the hypothesis, mortality was the highest at the heavy exposure level. The two most probable explanations were low social preselection and the high exposure level (dust, chemicals, and physically heavy work).

(ii) Mortality was the lowest at the medium level. Thus the hypothesis was not confirmed. Although turnover was rapid at the heavy level and workers transferred to the medium exposure level, the medium-level workers with health problems transferred to the light exposure level. Low mortality at the medium level could be explained by high health preselection and high social preselection. Furthermore, the medium exposure level did not involve exposures that could have had considerable causal effect(s) on mortality.

(iii) Because workers who could not continue working at the heavy or medium exposure level changed to the light level and because of older workers' low social selection, mortality in the older age groups of workers at the light level was rather high (ie, negative health selection). The results from the softer measures supported negative health selection on the light exposure level, for example, the occurrences of different symptoms were higher among the current workers than among the former workers. Selection during employment proved to be low because the exposure was light and because workers with health problems could continue working. In addition the assumption of strong occupational preselection proved to be true: Workers at the light exposure level had the most occupational training, especially in younger age classes.

(iv) The three exposure levels had different turnover rates. Changes in the heaviness of work throughout the workers' lifetime and the reasons for turnover suggested that the chain of selection had affected the turnover rates at the three levels.

(v) The "high" overall mortality, disability, and morbidity rates tended to be concentrated at the same (heavy) exposure level. However different stages of disease formed one continuum, and age-specific occurrences revealed differences in excess findings:

Heavy exposure level

- The highest mortality rates
- The highest disability rates
- The fastest turnover
- The highest occurrences of diagnosed diseases and symptoms, the former workers having higher occurrences than the current workers

Medium exposure level

- The lowest mortality rates
- The highest disability rates at the older ages
- The slowest turnover
- Increased morbidity rates among older workers
- Not as great differences in the occurrences of diagnosed diseases and symptoms between the former and current workers as at the heavy level

Light exposure level

- The lowest mortality rates in the younger age groups and the second highest in the older age groups
- The lowest disability rates
- The second fastest turnover in the younger age groups and the fastest in the older age groups
- The lowest occurrences of diagnosed diseases and symptoms; the current workers tending to have more symptoms than the former workers.

In agreement with the hypothesis of the study, soft and hard measures followed each other as explanations for the termination-of-employment rate. (See figures 13 and 22.)

(vi) The prevalence rates of diseases depended on the termination of employment via selection. The current workers' lower rates were offset by the former workers' higher rates. Such compensation was the strongest at the heavy exposure level. The age point of inflection, at which the decline in the current workers' prevalences begins to be offset by correspondingly increased prevalences among former workers, was slightly different for the three exposure levels. (See tables 26, and 29 and figure 25.) Although workers on all three exposure levels had good opportunities for turnover, the study showed that turnover remained low if the disease was not selective or the exposure was not heavy. Consequently the prevalences of the findings among the current workers (eg, symptoms of musculoskeletal diseases among the metal product workers) rose with age.

Fulfillment of the objectives. The main objective of the study was to explore to the extent to which selective turnover affects mortality and morbidity in various types of work (heavy, medium, light).

The three exposure levels showed different patterns of changes in the heaviness of the work accord-

ing to age throughout the workers' complete occupational histories. Selection into and out of jobs within and between different exposure levels appeared to be a continuous process, a chain of selection. The chain of selection from one exposure level to another also meant that the mortality and morbidity rates for a certain exposure level may be underestimated or overestimated if complete occupational histories are not available.

The results for mortality, disability, and morbidity indicated that different stages of disease decreased the cohorts on the heavy, medium, and light exposure levels in different ways. The cohort of workers on the heavy exposure level decreased because of lessening work capacity, disability, and death. The cohort of workers on the medium level was reduced mainly through disabling diseases and disability in the older age classes. Workers on the light level had the smallest decrement attributable to different stages of disease; however, they had an increased decrement due to death in the older age classes, a finding which indicates negative health selection.

The effect of selective turnover on mortality was shown in the following way: mortality was the highest at the heavy exposure level because of low social preselection and the high exposure level. Although turnover was rapid and workers transferred to the medium exposure level, medium-level workers correspondingly transferred to the light exposure level. Thus mortality at the medium exposure level was the lowest; it was rather high in the older age groups of workers at the light exposure level.

When the occurrences of diagnosed diseases were compared between the three exposure levels, no great differences were found among current workers in the prevalences of diagnosed musculoskeletal, lung, or heart diseases. The differences were small especially between the heavy and the medium levels. But the differences in occurrences became evident when the groups of former workers were included, and also a process of health selection from one exposure level to another was shown.

When the complete occupational histories acquired by the questionnaire were used, with the main occupations classified according to the three exposure levels, the occurrences could be placed on the correct levels, and the transfers due to misclassification became clear.

Another objective of the study was to determine which age and exposure categories are the most prone to health selection. The strongest health-based selection out of jobs was found at the heavy level, but the selection process (chain of selection) as a whole was revealed at different ages in the various exposure categories, was different for different diseases, and

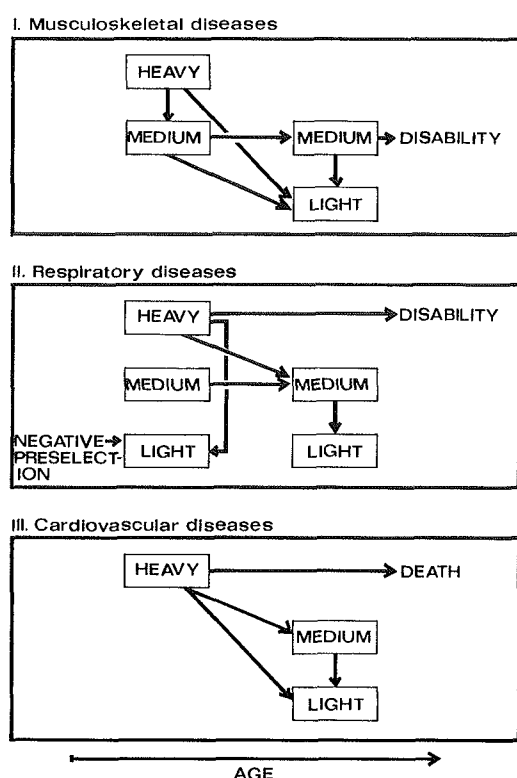


Figure 26. Selection by different diseases between the exposure levels.

was manifested as different stages of disease. The selection processes according to musculoskeletal, respiratory, and cardiovascular diseases between the exposure levels are summarized in figure 26.

Ache or pain in the musculoskeletal system within the last 12 months was more frequent among the foundry and metal product workers than among the electrical workers. Both currently employed and former foundry workers had significantly more earlier diagnosed musculoskeletal diseases than the electrical workers did. The younger age classes of foundry workers (<45 years) had a higher occurrence of musculoskeletal diseases than the metal product workers; in the older age classes the opposite was true.

The former foundry workers had more diagnosed musculoskeletal diseases than the current workers did. There was no such difference among the metal product workers.

The results for the groups of current and former workers in the three industrial branches and those for the combined exposure levels of the three branches showed greater differences in the occurrences of musculoskeletal diseases according to the level of heaviness between the branches than according to the

level of heaviness than within the branches. The heaviness of the industrial branch was also a more definitive criterion than the heaviness of the main occupation within the branch. In addition, the fact that there were transitions from heavy-level jobs to lighter ones and that healthier workers' stayed on the heavy level equalized the occurrences within the branches.

The results indicate that musculoskeletal diseases clearly lead to selection away from heavy-level work. This conclusion was also supported by the rate of disability due to musculoskeletal diseases, which showed a greater excess in the cross-sectional cohort than in the longitudinal cohort.

Both the current and the former foundry workers (in different smoker categories) had higher rates of chronic bronchitis than the corresponding groups of metal product and electrical workers. Selection away from heavy-level exposure was indicated by the finding that the former foundry workers had higher occurrences of chronic bronchitis than the current workers from the age class of 45–54 years on. A similar trend was found for the metal product workers, but the rates were lower. Diagnosed lung diseases were also more frequent at the heavy level than at the medium and light exposure levels. Health selection during employment was also suggested by the disability rates for respiratory diseases. Respiratory diseases were more frequent than expected in both the cross-sectional and the longitudinal cohorts, but the excess was greater in the cross-sectional one. Negative health selection was shown as higher occurrences of diagnosed emphysema and bronchitis in the youngest age class of electrical workers than among the foundry and metal product workers of the same age.

Angina pectoris (irrespective of smoking habits) was more prevalent among both the current and former foundry workers than among the electrical workers, whereas the difference between the foundry workers and the metal product workers was not significant. The former foundry workers had somewhat higher occurrences than the current workers. The same was true for the metal product workers. The current electrical workers had higher occurrences than the former electrical workers. This result may reflect negative health selection to the light level from the heavy and medium exposure levels. Analysis according to the complete occupational history showed that the workers at the heavy level had more diagnosed cardiovascular diseases in the younger age classes and the workers at the medium level had more cardiovascular diseases in the older age classes; both findings can be interpreted as the result of selection. Disability due to all cardiovascular diseases and the number of cases of coronary heart disease alone were

significantly lower for the foundry workers than for the active male population. This finding can be explained both by health selection into and out of heavy-level exposure and by the mortality from cardiovascular diseases in the older age groups.

The *third objective* was to seek the age and exposure categories within which the "points of inflection" (the point when the measures of different stages of disease turn from mainly hard measures to mainly soft ones) occurred.

The proportion of heavy-level workers with excellent work capacity decreased the most rapidly with age when compared with the workers at the other exposure levels. The highest point of dissatisfaction (low pay) was found before the age of 30 years, and it turned to discomfort (heavy work) at the age of 30–34 years. Discomfort again changed to disease at about the age of 40 years. Since heavy work and different symptoms led to selection out of heavy-level jobs, disease did not change to disability until near the age of 50 years. Thereafter hard measures were the most prominent.

Low pay had more important meaning to medium-level workers than to heavy-level workers through the age classes. Correspondingly, the proportion of medium-level workers who experienced the work as heavy was clearly smaller than among the foundry workers, and the transition to disease occurred later (at about the age of 44 years). Nevertheless, disease changed to disability early in the next age class (45–49 years).

Light-level workers retained their excellent work capacity until older ages than the heavy-level workers and medium-level product workers did. Light-level workers also had the highest occurrences of low pay (dissatisfaction) through all the age classes. The proportions of heavy work and illness were low. Because light-level work is not physically demanding and because there was negative health selection, disease had slightly higher occurrences than discomfort. Discomfort and disease turned to disability in the age class of 50–54 years.

Thus the points of inflection in age varied according to the exposure level. Hard and soft measures formed a continuum (dissatisfaction - death), and they followed each other as explanations for the termination of employment.

Consequently, a chain of selection during the workers' lifetimes was formed not only by changes in the heaviness of the work, but also by health changes during the life cycle. The quality of the study design, cohort formation, and follow-up and the use of the complete occupational history determine the type of results obtained from the complex whole.

IX. FOLLOW-UP OF MORTALITY AND MORBIDITY

1. Objective of the follow-up

The purpose of this study was to clarify the stability of the results on mortality and long-term morbidity through an extended follow-up (1950–1987) in a population originally affected by high health selection.

2. Material and methods

The material comprised three cohorts of metal industry workers (6415 iron foundry workers, 3901 metal product workers, and 5398 workers manufacturing electrical devices). The men, hired between 1950 and 1976, were followed until the end of 1987. The methodological cohort comprised 1292 workers who had been hired earlier and were still working in 1950. They were also followed to 1987.

The vital status of the cohort members was traced through the Population Information System, of Finland. The causes of death were obtained from Statistics Finland. They were coded according to the eighth revision of the International Classification of Diseases (94). The Social Insurance Institution provided disability data until the end of 1987. The causes of disability were similarly coded according to the International Classification of Diseases. Data on medication receiving special compensation under the national sickness insurance law were also obtained until the end of 1987 from the Social Insurance Institution. The analyses of mortality and morbidity were based only on register data; therefore, new data on occupational histories or on life-style factors were not collected.

In the mortality analysis the age-specific observed and expected numbers of deaths and the standardized mortality ratios were calculated. The expected numbers of deaths were calculated from the national incidences on causes of deaths with the use of the median years of the deaths in the longitudinal (1977) (204) and the cross-sectional (1974) (205) cohorts. Incidence densities (per 100 000 person-years) were also used to compare the causes of death in the three cohorts.

The incidence densities per 1000 person-years were calculated for disability pensions and for diseases granted special compensation for medication by national sickness insurance law, separately. The age-standardized incidence rates were also computed. The total age distribution of person-years in the three cohorts was used as the standard.

The Poisson-distribution model was used to test the significance of the cause-specific observed number of deaths against the expected number (173). The incidence densities of mortality, disability, and medication were tested between the cohorts by the Mantel-Haenszel chi-square test for incidence density data (174).

3. Mortality

The total mortality of the three cohorts became higher during the further follow-up until the end of 1987 (tables 34-36). The foundry workers' mortality rates statistically significantly exceeded the expected values throughout the age categories until the age of 75 years (table 34). The excess was due to several disease groups. All types of violent death remained in excess. The statistical significance of cardiovascular diseases and respiratory diseases increased during the extended follow-up. The same was true for tumors, especially for lung cancer and cancer of the digestive organs.

The analysis of occupation-specific mortality showed the highest mortality rates for floor molders (167 observed, 130.1 expected, SMR 128, 95% CI 104-156), fettlers (observed 158, expected 128.1, SMR 123, 95% CI 105-144), and laborers (observed 842, expected 580.1, SMR 145, 95% CI 136-155). In the group of floor molders the excess mortality was caused by violent deaths (observed 52, expected 30.8, SMR 169, 95% CI 102-261), and respiratory diseases (observed 12, expected 5.3, SMR 227, 95% CI 117-397). Among the fettlers the excess was mainly due to violent deaths (observed 49, expected 28.1, SMR 174, 95% CI 104-272). The laborers had an increased number of deaths caused by cardiovascular diseases (observed 339, expected 280.2, SMR 121, 95% CI 101-144); the increase originated both from ischemic heart disease and from cerebrovascular diseases. This group also had 42 respiratory deaths (expected 27.7, SMR 151, 95% CI 109-205). Mortality from tumors was in excess among the laborers [lung cancer: observed 73, expected 40.8, SMR 179, 95% CI 118-259; gastrointestinal cancer: observed 44, expected 22.4, SMR 197, 95% CI 113-315, stomach cancer being 22, expected 12.4, SMR 178, 95% CI 112-269], 7 being cancers of the esophagus (expected 2.9, SMR 241, 95% CI 97-497), and 9 being cancer of the pancreas (expected 10.7, SMR 84, 95% CI 38-160)]. All types of violent death were more frequent among the laborers than was expected (observed 220, expected 117.5, SMR 187, 95% CI 148-233).

Only slight changes had taken place in the mortality of the metal product workers during the recent

follow-up. The number of the observed deaths was as frequent as expected (table 35). Mortality from tumors had increased mainly due to cancer of the digestive organs (36 observed, 24.3 expected, SMR 148, 95% CI 104-205). Of them 19 were stomach cancers (expected 13.3, SMR 142, 95% CI 86-222), and 8 were cancers of the pancreas (expected 6.4, SMR 125, 95% CI 54-246).

Occupation-specific total mortality rates showed a statistically significant excess only for the laborers (observed 128, expected 99.6, SMR 129, 95% CI 101-161). It was caused by violent deaths and tumors. In the group of inspectors and testers 4 lung cancers were observed (expected 0.9, SMR 435, 95% CI 118-1113). Among the metal plate workers, sheet metal workers and plumbers 11 lung cancers were observed (expected 7.2, SMR 152, 95% CI 76-272). In this occupational group 10 gastrointestinal cancers were observed (4.1, SMR 247, 95% CI 118-454); of them 7 were cancer of the stomach (expected 2.2, SMR 313, 95% CI 126-644). The welders and flame cutters had gastrointestinal cancers slightly more often (5 cases) than expected (1.7, SMR 299, 95% CI 97-699). The number of violent deaths exceeded the corresponding expected number in several occupational categories; however, the only statistically significant excess occurred for the painters, metal platers, and coaters (observed 13, expected 6.7, SMR 190, 95% CI 101-325).

For the electrical workers the total mortality rate exceeded the expected value (table 36). The excess mainly originated in the age class of 55-64 years. Violent deaths were more frequent than was expected. Mortality from suicides decreased, but deaths from accidents increased. The number of respiratory deaths were nearly twice the expected number in the age class of 55-64 years. Eighty tumors were observed in the age group of 55 years or more, whereas 54.4 were expected (SMR 147, 95% CI 108-195). Of these 35 were lung cancers (22.9 expected, SMR 153, 95% CI 106-213) and 23 were cancer of the digestive organs (11.5 expected, SMR 200, 95% CI 127-300). Of the 35 gastrointestinal cancers only 13 were cancer of the stomach (expected 10.9), 5 were cancer of the esophagus (expected 1.6, SMR 313, 95% CI 101-729), and 7 were cancer of the pancreas (expected 5.2, SMR 135, 95% CI 54-277).

Almost all the occupational categories had higher total mortality rates than expected on the basis of the national rates, but only a few of the differences reached statistical significance. Among the warehouse workers and packers 124 deaths occurred, whereas 85.2 were expected (SMR 146, 95% CI 106-194). For the truck drivers and crane operators the corresponding values were 46 and 28.8 (SMR 159, 95% CI 105-231), respectively. Excess mortality in

Table 34. Foundry workers' mortality from certain diseases in the age-specific comparison with the expected (E) number of deaths calculated on the basis of death rates for the Finnish male population. (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 163	12.3	22 *	9.7	18 *	4.0	8	3.6	6	1.6	3	0.1	—
25-34	38 356	74.4	123 ***	52.1	90 ***	21.6	32 *	11.2	18	14.1	28 **	1.0	2
35-44	40 698	153.4	260 ***	63.7	130 ***	21.8	41 ***	12.9	18	23.9	56 ***	3.1	13 ***
45-54	28 525	290.5	397 ***	62.3	107 ***	19.8	23	11.2	14	25.5	53 ***	8.6	15 *
55-64	12 418	297.1	363 ***	25.1	42 **	7.6	6	4.9	8	11.0	21 **	14.7	21 *
65-74	3 143	163.4	195 *	6.5	10	1.8	3	1.6	4	2.6	2	13.6	19
≥75	357	44.5	39	1.3	4	0.2	—	0.3	1	0.7	3	6.6	3
Total	134 660	1035.6	1399 ***	220.6	401 ***	76.9	113 ***	45.6	69 **	79.3	166 ***	47.7	73 ***
SMR		135		182		147		151		209		153	
95%CI		128 - 142		164 - 200		121 - 177		118 - 192		179 - 244		120 - 192	

Age (years)	Person-years	Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 163	0.5	3	0.1	—	0.3	2	0.8	—	0.0	—	0.0	—
25-34	38 356	8.2	11	2.7	4	3.4	4	4.7	9	0.2	1	0.7	0
35-44	40 698	51.6	64 ^a	35.2	43	10.2	11	16.2	22	2.5	3	3.5	7
45-54	28 525	146.3	175 *	113.7	118	17.5	29 *	47.2	64 *	19.1	26	11.0	13
55-64	12 418	168.8	170	128.0	130	22.7	12	68.1	90 *	30.3	41	13.2	28 ***
65-74	3 143	92.3	98	61.7	59	15.5	22	39.3	49	17.0	28 *	8.8	11
≥75	357	25.2	23	12.4	16	5.7	5	8.0	4	2.1	3	2.1	—
Total	134 660	492.8	544 *	353.8	370	75.1	85	184.4	238 ***	71.3	102 ***	39.3	59 **
SMR		110		105		113		129		143		150	
95% CI		101 - 120		94 - 116		90 - 140		113 - 147		117 - 174		114 - 194	

^aP≈ 0.05, Poisson distribution, *P<0.05, **P<0.01, ***P<0.001

Table 35. Metal product workers' mortality from certain diseases in the age-specific comparison with the expected (E) number of deaths calculated on the basis of death rates for the Finnish male population (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 986	13.2	16	10.4	11	4.3	4	3.9	2	1.7	5 *	0.1	—
25-34	26 011	50.5	47	35.4	36	14.7	13	7.6	9	9.6	13	0.7	—
35-44	22 550	85.0	99	35.3	41	12.1	14	7.1	6	13.3	17	1.7	1
45-54	13 151	133.9	153 ^a	28.7	34	9.1	16 *	5.1	5	11.8	10	4.0	6
55-64	6 417	153.5	143	13.0	13	4.0	4	2.5	2	5.7	7	7.6	8
65-74	2 453	127.5	120	5.0	2	1.4	1	1.3	1	2.0	—	10.6	56
≥75	533	66.3	51	1.9	1	0.3	—	0.5	1	1.0	—	9.9	7
Total	83 101	629.9	629	129.6	138	45.8	52	28.0	26	44.9	52	34.6	28
SMR		100		106		114		93		116		81	
95% CI		92 - 108		89 - 126		85 - 149		61 - 136		86 - 152		54 - 117	

Age (years)		Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	11 986	0.6	2	0.1	—	0.3	1	0.9	2	0.0	—	0.1	—
25-34	26 011	5.6	2	1.8	1	2.3	—	3.2	2	0.1	—	0.5	—
35-44	22 550	28.6	36	19.5	19	5.7	9	9.0	11	1.4	4	1.9	2
45-54	13 151	67.4	60	52.4	40	8.1	8	21.8	36 **	8.8	12	5.1	11 *
55-64	6 417	87.2	82	66.1	59	11.7	14	35.2	31	15.7	12	6.8	11
65-74	2 453	72.0	72	48.2	43	12.1	13	30.7	26	13.3	11	6.8	9
≥75	533	37.5	28	18.5	12	8.4	6	12.0	13	3.1	4	3.1	3
Total	83 101	298.9	282	206.6	174	48.5	51	112.7	121	42.5	43	24.3	36 *
SMR		94		84		105		107		101		148	
95% CI		84 - 106		72 - 98		78 - 138		89 - 128		73 - 136		104 - 205	

^aP=0.05, *P<0.05, **P<0.01, Poisson distribution.

Table 36. Electrical workers' mortality from certain diseases in the age-specific comparison with the expected (E) number of deaths calculated on the basis of death rates for the Finnish male population (O = observed, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Age (years)	Person-years	All deaths		Violent deaths		Suicides		Motor vehicle accidents		Other accidental deaths		Respiratory diseases	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	22 371	24.7	35 *	19.5	29 *	8.0	10	7.2	13 *	3.1	5	0.2	0
25-34	40 818	79.2	75	55.5	49	23.0	17	11.9	13	15.0	10	1.1	1
35-44	26 864	101.3	110	42.0	60 *	14.4	18	8.5	8	15.8	30 **	2.0	4
45-54	13 863	141.2	127	30.3	31	9.6	14	5.4	4	12.4	10	4.2	5
55-64	5 357	128.2	180 ***	10.8	26 ***	3.3	7	2.1	6 *	4.8	12 *	6.4	12 *
65-74	1 486	77.2	89	3.1	4	0.9	3	0.8	1	1.2	0	6.4	4
≥75	285	35.5	33	1.0	—	0.2	—	0.3	—	0.5	—	5.3	4
Total	111 044	587.3	649 *	162.1	199 **	59.3	69	36.1	45	52.8	67	25.6	30
SMR		111		123		116		125		127		117	
95% CI		102 - 119		106 - 141		91 - 147		91 - 167		98 - 161		79 - 167	

Age (years)	Person-years	Cardiovascular diseases		Coronary heart disease		Cerebrovascular diseases		Tumors		Lung cancer		Cancer of the digestive organs	
		E	O	E	O	E	O	E	O	E	O	E	O
15-24	22 371	1.1	1	0.1	1	0.5	—	1.6	3	0.0	—	0.1	1
25-34	40 818	8.7	10	2.9	4	3.6	3	5.0	3	0.2	—	0.7	1
35-44	26 864	34.1	28	23.3	15	6.7	6	10.7	4	1.7	—	2.3	4
45-54	13 863	71.1	55	55.3	42	8.5	6	23.0	18	9.3	5	5.4	6
55-64	5 357	72.8	83	55.2	56	9.8	11	29.4	39	13.1	18	5.7	13 *
65-74	1 486	43.6	45	29.2	31	7.3	5	18.6	31 *	8.1	13	4.1	7
≥75	285	20.1	17	9.9	8	4.5	6	6.4	10	1.7	4	1.7	3
Total	111,044	251.5	239	175.8	157	41.0	37	94.6	108	34.0	40	20.0	35 **
SMR		95		89		90		114		118		175	
95% CI		83 - 108		76 - 104		64 - 124		94 - 138		84 - 160		122 - 243	

*P<0.05, **P<0.01, ***P<0.001, Poisson distribution.

the group of warehouse workers and packers was mainly due to gastrointestinal cancers (observed 9, expected 3.0, SMR 299, 95% CI 104-664) and violent deaths (observed 33, expected 22.0, SMR 150, 95% CI 103-211). The truck drivers and crane drivers had an increased number of violent deaths (observed 15 and expected 6.3, SMR 237, 95% CI 109-445). These violent deaths were of nonoccupational origin.

In the cross-sectionally based cohorts the total SMR was 95 for the foundry workers, 91 for the metal product workers, and 100 for the electrical workers. No cause of death reached statistical significance during the extended follow-up (table 7).

4. Disability

Comparison of the incidence densities of disability pensions between the three industrial branches showed that the earlier observed differences had become greater (table 37). The foundry workers had significantly higher rates than the metal product workers and electrical workers ($P < 0.001$, Mantel-Haenszel chi-square test for incidence density). The difference for both branches originated from the younger age classes. The metal product workers also had higher rates than the electrical workers ($P < 0.01$); this difference was more concentrated in the older age classes (appendix, table 9).

An increase in the incidence density rates of disability pensions was seen for cardiovascular and musculoskeletal diseases. Both the foundry workers and the metal product workers had significantly higher rates than the electrical workers (table 37).

The greatest increase had occurred in respiratory diseases. The difference between the foundry workers and the metal product workers, as well as between the foundry workers and the electrical workers, had become highly significant ($P < 0.001$); the difference between the metal product workers and the electrical workers had also remained ($P < 0.05$). The incidence rate of chronic bronchitis, emphysema, and bronchial asthma was similar for the foundry workers and for the metal product workers (Mantel-Haenszel $\chi^2 = 0.40$), whereas the rate was statistically significantly higher when compared with that of the electrical workers (Mantel-Haenszel $\chi^2 = 12.17$, $P < 0.001$). The difference between the metal product workers and the electrical workers was also significant (Mantel-Haenszel $\chi^2 = 6.95$, $P < 0.01$). When these disease groups were analyzed separately, the observed differences between the exposure levels were caused by chronic bronchitis and emphysema, but not by bronchial asthma.

Table 37. Significances of differences in the incidence densities for cause-specific disability pensions in the three cohorts.

Comparison	Rate ratio	$\chi^2_{(1)}$	
All causes			
Foundry versus metal product workers	1.3	24.94	***
Foundry versus electrical workers	1.5	74.74	***
Metal product versus electrical workers	1.2	6.45	**
Mental disorders			
Foundry versus metal product workers	1.8	26.88	***
Foundry versus electrical workers	1.7	26.49	***
Metal product versus electrical workers	0.9	0.47	
Cardiovascular diseases			
Foundry versus metal product workers	1.0	0.01	
Foundry versus electrical workers	1.4	9.53	**
Metal product versus electrical workers	1.4	7.67	**
Coronary heart disease			
Foundry versus metal product workers	1.1	0.32	
Foundry versus electrical workers	1.5	5.95	*
Metal product versus electrical workers	1.3	2.25	
Respiratory diseases			
Foundry versus metal product workers	1.3	1.40	***
Foundry versus electrical workers	2.4	14.62	***
Metal product versus electrical workers	1.9	5.97	*
Musculoskeletal diseases			
Foundry versus metal product workers	1.2	2.81	
Foundry versus electrical workers	1.7	24.32	***
Metal product versus electrical workers	1.4	7.24	**

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

The differences in the incidence density rates of the disability pensions between the cross-sectionally based cohorts had also become wider. The foundry workers had higher incidences than the electrical workers ($P < 0.01$). Similarly, the metal product workers had higher incidences than the electrical workers ($P < 0.05$). These differences were due to the corresponding differences in the incidence density rates of musculoskeletal diseases.

5. Chronic diseases

The incidence densities of specially compensated medicines were followed from 1964 to the end of 1987. The total number of specially compensated medications was 1294 among the foundry workers and the number of person-years was 114 444. The corresponding values were 659 and 71 960 for the metal product workers and 764 and 96 083 for the

electrical workers, respectively. There were no statistically significant differences between the three industrial branches with respect to the total incidence rates.

The cause-specific analysis showed that the age-standardized incidence density for specially compensated medication (incidence density/1000 person-years) was not significantly different for bronchial asthma in the cohorts of foundry workers (0.8), metal product workers (0.9), and electrical workers (0.8). It was not possible to have compensated medication for any other respiratory diseases.

The age-standardized incidence of rheumatoid arthritis was similar for each industrial branch: 0.6 for the foundry workers, 0.5 for the metal product workers, and 0.5 for the electrical workers.

In the category of cardiovascular diseases special compensation is granted for medication for myocardial insufficiency, coronary heart disease, arrhythmias, and hypertension. The age-standardized incidence of myocardial insufficiency was statistically significantly higher for the foundry workers (2.3) than for the electrical workers (1.8) ($P < 0.05$, Mantel-Haenszel chi-square test for incidence density). The difference between the foundry workers and the metal product workers (2.2) or between the metal product workers and the electrical workers was not significant. Medication for coronary heart disease was more frequent among the foundry workers (1.1) than among the metal product workers (0.7) ($P < 0.01$) and slightly more frequent than among the electrical workers (0.9). The age-standardized incidence of arrhythmias was similar for the foundry workers (0.3), the metal product workers (0.2), and the electrical workers (0.2). The same was true for hypertension, the rates being 4.5, 4.8, and 4.8, respectively.

Medication for psychoses was statistically significantly more common ($P < 0.001$) among the foundry workers (1.9) than among the metal product workers (1.0) or the electrical workers (1.3).

6. Discussion

The importance of methodological factors was clearly seen during the extended follow-up. In the longitudinal cohort the mortality and morbidity rates were more increased in the older age classes than in the earlier follow-up period. The excesses were also somewhat higher. On the other hand, the earlier observed increase in the mortality rates of the cross-sectional cohorts had diminished. Therefore, the internal structure, such as age, periods of follow-up, and periods of latency had changed and the effect of occupational exposures was no longer detectable in the cross-sectional cohorts, whereas it was becoming

easier to detect in the longitudinal cohorts.

The cause-specific results from the longitudinal cohort showed that musculoskeletal diseases disabled the workers from the heavy level and the medium level, to which the workers had switched over from the heavy level due to musculoskeletal symptoms or diagnosed diseases.

The long-term effects of dust exposure on the manifest respiratory diseases were seen in the present study as increased mortality at the heavy level of exposure and an increased disability at the heavy level and medium level of exposure.

The earlier follow-up showed that the heavy-level workers had increased mortality from cardiovascular diseases. This result was supported by the findings of the present follow-up. In addition, the disabling effect of cardiovascular diseases was also clearly seen at the heavy and medium levels of exposure.

The results of the follow-up were similar for occupation-specific mortality to those of the basic phase of the study. Among the foundry workers the floor molders, fettlers, and laborers had the highest rates. The causes of death responsible for the excess had also remained the same (ie, respiratory diseases, lung cancer and gastrointestinal cancers). They were also consistent with the results of other reports published during the extended follow-up period (206, 207). The risk for cardiovascular diseases was also observed. Exposure to carbon monoxide in iron foundries has been reported to increase morbidity and mortality from cardiovascular diseases (208).

The metal product workers continued to have low mortality rates. The cause-specific results were consistent with both the earlier results (excessive rates for lung cancer and gastrointestinal cancers among the metal plate workers, sheet metal workers, welders and flame cutters) and those obtained from other studies (209, 210).

The electrical workers as a whole had a slightly excess mortality from respiratory diseases and tumors in the older age categories. However, only few occupation-specific excesses were found. No evidence has been found for leukemia or brain tumors in any occupational group studied among electrical workers elsewhere (211, 212).

7. Concluding remarks

The extended follow-up of the mortality and morbidity of metal workers ascertained the validity of the earlier results, even though both variables were strongly affected by health selection. Methodological factors such as cohort definition and follow-up length also proved to be important in the follow-up.

REFERENCES

- Koskela R-S. Occupational mortality and morbidity in relation to selective turnover. *Scand J Work Environ Health* 1982;8 suppl 1:34-9.
- Koskela R-S, Järvinen E, Korhonen H, Mutanen P. Health selection among metal workers. *Scand J Work Environ Health* 1983;9:155-61.
- Koskela R-S, Järvinen E, Kolari PJ. Effect of cohort definition and follow-up length on occupational mortality rates. *Scand J Work Environ Health* 1984;10:311-6.
- Koskela R-S, Korhonen H, Järvinen E, Kolari PJ, Mutanen P. Different stages of disease, changes in heaviness of work and life cycle. *Scand J Work Environ Health* 1984;10:451-4.
- Koskela R-S, Kolari PJ, Järvinen E, Korhonen H. Completeness of occupational history and occurrences of work-related diseases. *Scand J Work Environ Health* 1984;10:455-9.
- Buechley R, Dunn JE Jr, Linden G, Breslow L. Death certificate statement of occupation: its usefulness in comparing mortalities. *Public Health Rep* 1956;71:1105-11.
- Fox AJ, Collier PF. Low mortality rates in industrial cohort studies due to selection for work and survival in the industry. *Br J Prev Soc Med* 1976;30:225-30.
- Alderson MR. Some sources of error in British occupational mortality data. *Br J Ind Med* 1972;29:245-54.
- Heasman MA, Liddell FDK, Reid DD. The accuracy of occupational vital statistics. *Br J Ind Med* 1958;15:141-6.
- Kearns JL. Changes in occupation and in health. *Trans Soc Occup Med* 1970;20:113-8.
- Liddell FDK. The measurement of occupational mortality. *Br J Ind Med* 1960;17:228-33.
- Modan B. Some methodological aspects of a retrospective follow-up study. *Am J Epidemiol* 1965;82:297-304.
- Seal HL. A statistical review of the evidence for the existence of temporary selection. *J Inst Actuaries* 1959;85(Pt II):165-210.
- Belbin RM. Difficulties of older people in industry. *Occup Psychol* 1953;27:177-90.
- Belbin RM. Older people and heavy work. *Br J Ind Med* 1955;12:309-19.
- Richardson IM. Age and work: a study of 489 men in heavy industry. *Br J Ind Med* 1953;10:269-84.
- Smith JM. Age and occupation: an examination of 1961 census data. *Occup Psychol* 1968;42:133-8.
- Smith JM. Age and occupation: The determinants of male occupational age structures - hypothesis H and hypothesis A. *J Gerontol* 1973;28:484-90.
- Welford AT. Industrial work suitable for older people: some British studies. *Gerontologist* 1966;6:4-9.
- Goldsmith JR. What do we expect from an occupational cohort? *J Occup Med* 1975;17:126-7.
- Goldsmith JR, Thresh M. Mortality and industrial employment: III Industries with high standard mortality ratios for persons with social security coverage in 1960 and 1965. *Am J Epidemiol* 1977;106:109-24.
- Goldsmith JR. Mortality and industrial employment: II Industries with high mortality among young workers based on a social security sample. *J Occup Med* 1977;19:249-54.
- Goldsmith JR, Hirschberg DA. Mortality and industrial employment: I Mortality during 1965-1972 among those employed in 1965 and covered by social security - preliminary report. *J Occup Med* 1976;18:161-4.
- Lundberg O. Methods of estimating morbidity and prevalence of disablement by use of mortality statistics. *Acta Psychiatr Scand* 1973;49:324-331.
- Cornfield J, Haenszel W. Some aspects of retrospective studies. *J Chronic Dis* 1960;11:523-34.
- Feinstein AR. Sources of 'transition bias' in cohort statistics. *Clin Pharmacol Ther* 1971;12:704-21.
- Mancuso TF, Coulter EJ. Methods of studying the relation of employment and long-term illness - cohort analysis. *Am J Public Health* 1959;49:1525-36.
- Mancuso TF, Coulter EJ. Methodology in industrial health studies: the cohort approach, with special reference to an asbestos company. *Arch Environ Health* 1963;6:210-26.
- Mancuso TF, El-Attar A. Dynamic changes in industrial cohort studies. *Ind Med Surg* 1966;35:1059-67.
- Milham S Jr. Methods in occupational mortality studies. *J Occup Med* 1975;17:581-5.
- Thompson DJ, Kodlin D. A note on follow-up for survival in the presence of movement. *J Am Stat Assoc* 1961;56:119-24.
- Collins JF, Redmond CK. The use of retirees to evaluate occupational hazards. *J Occup Med* 1976;18:595-602.
- Collins JF, Redmond CK. The use of retirees to evaluate occupational hazards: II. Comparison of cause specific mortality by work area. *J Occup Med* 1978;20:260-6.
- Fox AJ, Collier PF. A survey of occupational cancer in the rubber and cablemaking industries: analysis of deaths occurring in 1972-74. *Br J Ind Med* 1976;33:249-64.
- Fox AJ, Collier PF. Mortality experience of workers exposed to vinyl chloride monomer in the manufacture of polyvinyl chloride in Great Britain. *Br J Ind Med* 1977;34:1-10.
- Hernberg S. Epidemiology in occupational health. In: Zenz C, editor. *Developments in occupational medicine*. Chicago (IL): Year Book Medical Publishers, 1980:4-40.
- Koskela R-S, Hernberg S, Kärävä R, Järvinen E, Nurminen M. A mortality study of foundry workers. *Scand J Work Environ Health* 1976;2 suppl 1:73-89.
- Rockette HE. Cause specific mortality of coal miners. *J Occup Med* 1977;19:795-801.
- Sartwell PE. Retrospective studies. A review for the clinician. *Ann Intern Med* 1974;81:381-6.
- Taylor PJ. Epidemiology in the design of long term studies. *J Soc Occup Med* 1974;24:48-53.
- Chiazze L Jr. Problems of study design and interpretation of industrial mortality experience. *J Occup Med* 1976;18:169-70.
- Enterline PE. Pitfalls in epidemiological research. An examination of the asbestos literature. *J Occup Med* 1976;18:150-6.
- Gaffey WR. A critique of the standardized mortality ratio. *J Occup Med* 1976;8:157-60.
- Redmond CK, Breslin PP. Comparison of methods for assessing occupational hazards. *J Occup Med* 1975;17:313-7.
- McMichael AJ. Standardized mortality ratios and the "healthy worker effect": scratching beneath the surface. *J Occup Med* 1976;18:165-8.
- Wen CP, Tsai SP. Anatomy of the healthy worker effect - a critique of summary statistics employed in occupational epidemiology. *Scand J Work Environ Health* 1982;8 suppl 1:48-52.
- Choi BCK. Definition, sources, magnitude, effect modifiers, and strategies of reduction of the healthy worker effect. *J Occup Med* 1992;34:979-88.
- Arrighi HM, Hertz-Picciotto I. Definitions, sources, magnitude, effect modifiers, and strategies of reduction of the healthy worker effect [letter]. *J Occup Med* 1993;35:890-1.

49. Haines T, Shannon H. Sample size in occupational mortality studies. *J Occup Med* 1983;25:603-8.
50. Osmond C, Gardner MJ. Age, period and cohort models applied to cancer mortality rates. *Stat Med* 1982;1:245-59.
51. Weiss W. Lung cancer due to chloromethyl ethers: bias in cohort definition. *J Occup Med* 1989;31:102-5.
52. Pearce N. Methodological problems of time-related variables in occupational cohort studies. *Rev Epidemiol Sante Publique* 1992;40 suppl 1:S43-54.
53. Steenland K, Deddens J, Salvan A, Stayner L. Negative bias in exposure-response trends in occupational studies: modeling the healthy worker survivor effect. *Am J Epidemiol* 1996;143:202-10.
54. Shindell A, Weisberg RF, Giefer EE. The "healthy worker effect" - fact or artifact? *J Occup Med* 1978;20:807-11.
55. Wen CP, Tsai SP, Gibson RL. Anatomy of the healthy worker effect: a critical review. *J occup Med* 1983;25:283-9.
56. Wang J-D, Miettinen OS. Occupational mortality studies: principles of validity. *Scand J Work Environ Health* 1982;8:153-8.
57. Weed DL, Tyroler HA, Shy C. The healthy worker effect in actively working communications workers. *J Occup Med* 1987;29:335-9.
58. Fox AJ, Goldblatt PO, Adelstein AM. Selection and mortality differentials. *J Epidemiol Community Health* 1982;36:69-79.
59. Fox AJ, Goldblatt PO. Longitudinal study: sociodemographic mortality differentials. London: Government Statistical Service, 1982. Office of Population Censuses and Surveys, series LS no 1.
60. Vinni K, Hakama M. Healthy worker effect in the total Finnish population. *Br J Ind Med* 1980;37:180-4.
61. Sterling TD, Weinkam JJ. Extent, persistence, and constancy of the healthy worker or healthy person effect by all and selected causes of death. *J Occup Med* 1986;28:348-53.
62. Gilbert ES. Some confounding factors in the study of mortality and occupational exposures. *Am J Epidemiol* 1982;116:177-88.
63. Decoufle P, Wood DJ. Mortality patterns among workers in a gray iron foundry. *Am J Epidemiol* 1979;109:667-75.
64. Lloyd JW, Ciocco A. Long-term mortality study of steelworkers: I. Methodology. *J Occup Med* 1969;11:299-310.
65. Seltzer CC, Jablon S. Effects of selection on mortality. *Am J Epidemiol* 1974;100:367-72.
66. Anderson F, Cowan NR. Survival of healthy older people. *Br J Prev Soc Med* 1976;30:231-2.
67. Rouse S, Svanborg A. Previous job and health at age of 70. *Scand J Soc Med* 1981;9:25-31.
68. Pukkala E, Teppo L, Hakulinen T. Keuhkosyöpäsairastavuus eri ammattialoilla Suomessa [Lung cancer incidence in different occupations in Finland]. *Sosiaalilääk Aikak* 1979;16:363-71.
69. Valkonen T. Socioeconomic mortality differentials in Finland. Helsinki: University of Helsinki, Department of Sociology, 1982. Working papers no. 28, 1982.
70. Fox AJ, Adelstein AM. Occupational mortality: work or way of life. *J Epidemiol Community Health* 1978;32:73-8.
71. Jeune B. Mortality of male members of the danish semi-skilled and unskilled workers' union in 1973. *Int J Epidemiol* 1977;6:247-57.
72. Kitagawa GM, Hauser PM. Differential mortality in the United States. Cambridge, MA: Harvard University Press, 1973.
73. Nagi MH, Stockwell EG. Socioeconomic differentials in mortality by cause of death. *Health Serv Rep* 1973;88:449-56.
74. Olsen J, Sabroe S. Health selection among members of a Danish trade union. *Int J Epidemiol* 1979;8:155-9.
75. Sauli H. Mortality. Occupational mortality in 1971-75. Helsinki: Statistics Finland, 1979. Studies no. 54.
76. Stockwell EG. A critical examination of the relationship between socioeconomic status and mortality. *Am J Public Health* 1963;53:956-64.
77. Yeracaris CA, Kim JH. Socioeconomic differentials in selected causes of death. *Am J Public Health* 1978;68:342-51.
78. Ott MG, Holder BB, Langner RR. Determinants of mortality in an industrial population. *J Occup Med* 1976;18:171-7.
79. Valkonen T. Sosioekonomiset terveyserot Suomessa ja niiden selittämisen ongelmia [Socioeconomic differences in health in Finland and problems in explaining them]. *J Soc Med* 1995;32:311-20. English summary.
80. Lichtenstein P, Harris JR, Pedersen NL, McClearn GE. Socioeconomic status and physical health, how are they related? An empirical study based on twins reared apart and twins reared together. *Soc Sci Med* 1993;36:441-50.
81. Holme I, Helgeland A, Hjermann I, Leren P, Lund-Larsen PG. Coronary risk factors in various occupational groups: the Oslo study. *Br J Prev Soc Med* 1977;31:96-100.
82. Lynch P, Oelman BJ. Mortality from coronary heart disease in the British army compared with the civil population. *Br Med J* 1981;283:405-7.
83. Ackerman JH, Vaeth MF. The relationship between unemployment and health. *Ohio State Med J* 1978;74:639-41.
84. Moser KA, Fox AJ, Jones DR. Unemployment and mortality in the OPCS longitudinal study. *Lancet* 1984;2:1324-9.
85. Martikainen PT. Unemployment and mortality among Finnish men, 1981-5. *BMJ* 1990;301:407-11.
86. Järvinen E. Ammattia, kuolleisuutta ja keuhkosyöpäsairastavuutta käsittelevien tutkimusten ongelmia [Problems arising in research on occupational mortality and lung cancer morbidity]. *Sosiaalilääk Aikak* 1981;18:82-5.
87. Blohmke M, Depner R, Koschorreck B, Stelzer O. Soziale Faktoren und Krankheit bei Arbeitnehmern. *Fortschr Med* 1974;92:445-6.
88. Cobb S, Brooks GW, Kasl SV, Connelly WE. The health of people changing jobs: a description of a longitudinal study. *Am J Public Health* 1966;56:1476-81.
89. Cobb S, McFarland D, Kasl SV, Brooks GW. On the relationship among variables in a longitudinal study of people changing jobs. In: Proceedings of the 5th International Scientific Meeting of the International Epidemiological Association. Belgrade: Savremena Administracija Publishing House, 1970:260-4.
90. Kasl SV, Cobb S, Gore S. Changes in reported illness and illness behavior related to termination of employment: a preliminary report. *Int J Epidemiol* 1972;1:111-8.
91. Knutsson A, Akerstedt T. The healthy worker effect: self-selection among Swedish shift workers. *Work Stress* 1992;6:163-7.
92. Ahlman K, Backman A-L, Hannunkari I, Järvinen E, Koponen M, Koskela R-S, Partanen T, Seppäläinen AM, Starck J. Kivityöntekijöiden työolosuhteet ja terveydentila [Work conditions and health of granite workers]. Helsinki: Finnish Institute of Occupational Health, 1975. Publications of the Social Insurance Institution AL: 4/1975. Eng-

- lish summary.
93. Ahlman K, Backman A-L, Koskela R-S, Luoma K. Satamatyöntekijöiden työolot ja terveydentila [The health and work conditions of dock workers] Helsinki: Finnish Institute of Occupational Health, 1975. Finnish Institute of Occupational Health study reports no. 105. English summary.
 94. Koskela R-S, Luoma K, Hernberg S. Turnover and health selection among foundry workers. *Scand J Work Environ Health* 1976;2 suppl 1:90-105.
 95. Menotti A, Puuddu V. Ten-year mortality from coronary heart disease among 172,000 men classified by occupational physical activity. *Scand J Work Environ Health* 1979;5:100-8.
 96. Paffenbarger RS Jr, Hale WE, Brand RJ, Hyde RT. Work-energy level, personal characteristics, and fatal heart attack: a birth-cohort effect. *Am J Epidemiol* 1977;105:200-13.
 97. Yu T, Roht LH, Wise RA, Kilian DJ, Weir FW. Low-pack pain in industry. *J Occup Med* 1984;26:517-24.
 98. Östlin P. Occupational career and health. Methodological considerations on the healthy worker effect. *Acta Universitatis Upsaliensis. Comprehensive summaries of Uppsala dissertations from University of Uppsala, the Faculty of Medicine* 224. Uppsala: University of Uppsala, 1989.
 99. Eisen EA, Wegman DH, Louis TA, Smith TJ, Peters JM. Healthy worker effect in a longitudinal study of one-second forced expiratory volume (FEV₁) and chronic exposure to granite dust. *Int J Epidemiol* 1995;24:1154-62.
 100. Hernberg S. Fact and fiction in occupational epidemiology: the Lucas Lecture 1982. *J R Coll Physicians Lond* 1983;17:139-43.
 101. Melkas T. Tuki- ja liikuntaelinten vaivat ja työkyvyttömyys. Tuki- ja liikuntaelinten rappeutumistaudit ja reumaattiset kiputilat pysyvän työkyvyttömyyden syynä Suomessa. [Musculoskeletal disorders and work disability]. Helsinki: Social Insurance Institution, 1980. Publications of the Social Insurance Institution AL:14. English summary.
 102. Broder I, Corey P, Davies G, Hutcheon M, Mintz S, Inouye T, Hyland R, Leznoff A, Thomas P. Longitudinal study of grain elevator and control workers with demonstration of healthy worker effect. *J Occup Med* 1985;27:873-80.
 103. Chan-Yeung M, Enarson DA, MacLean L, Irving D. Longitudinal study of workers in an aluminum smelter. *Arch Environ Health* 1989;44:134-9.
 104. Ernst P, Dales RE, Nunes F, Becklake MR. Relation of airway responsiveness to duration of work in a dusty environment. *Thorax* 1989;44:116-20.
 105. Knox EG. Computer simulation of industrial hazards. *Br J Ind Med* 1973;30:54-63.
 106. Bunn AR. Ischaemic heart disease mortality and the business cycle in Australia. *Am J Public Health* 1979;69:772-81.
 107. Bunn AR. II. IHD mortality and the business cycle in Australia. *Am J Public Health* 1980;70:409-11.
 108. Kasl SV. Mortality and the business cycle: some questions about research strategies when utilizing macro-social and ecological data. *Am J Public Health* 1979;69:784-8.
 109. Lew EA. Mortality and the business cycle: how far can we push an association? *Am J Public Health* 1979;69:782-3.
 110. Menken JA, Sheps MC. On relationships between longitudinal characteristics and cross-sectional data. *Am J Public Health* 1970;60:1506-14.
 111. Schulte PA, Singal M, Stringer WT, Kominsky JR, Landrigan PJ. The efficacy of a population-based comparison group in cross-sectional occupational health studies. *Am J Epidemiol* 1982;116:981-9.
 112. Vanhoorne MH, De Smet FP, De Fruyt FK, Seghers KE, De Bacquer DA. A mailed-questionnaire survey of ex-workers: a tool to evaluate the healthy-worker effect in cross-sectional studies. *Int J Occup Environ Health* 1995;1:252-6.
 113. Wong O. Further criticisms on epidemiological methodology in occupational studies. *J Occup Med* 1977;19:220-2.
 114. Goldblatt P, Fox J, Leon D. Mortality of employed men and women. *Am J Ind Med* 1991;20:285-306.
 115. Howe GR, Chiarelli AM, Lindsay JP. Components and modifiers of the healthy worker effect: evidence from three occupational cohorts and implications for industrial compensation. *Am J Epidemiol* 1988;128:1364-75.
 116. Monson RR. Observations on the healthy worker effect. *J Occup Med* 1986;28:425-33.
 117. Burack TS, Burack WR, Knowlden NF. Cancer: II. Distortions in standardized rates. *J Occup Med* 1983;25:737-44.
 118. Rothman KJ. Induction and latent periods. *Am J Epidemiol* 1981;114:253-9.
 119. Whittemore AS. The age distribution of human cancer for carcinogenic exposures of varying intensity. *Am J Epidemiol* 1977;106:418-27.
 120. Stewart W, Hunting K. Mortality odds ratio, proportionate mortality ratio, and healthy worker effect. *Am J Ind Med* 1988;14:345-53.
 121. Gamble J, Spirtas R. Job classification and utilization of complete work histories in occupational epidemiology. *J Occup Med* 1976;18:399-404.
 122. Schneider S. Past approaches to retrospective epidemiological occupational exposure assessment: the use and misuse of exposure assessment. *Appl Occup Environ Hyg* 1991;6:547-9.
 123. Post WK, Heederik D, Kromhout H, Kromhout D. Occupational exposures estimated by a population specific job exposure matrix and 25 year incidence rate of chronic nonspecific job exposure matrix. *Eur Respir J* 1994;7:1048-55.
 124. Stewart PA, Stewart WF. Occupational case-control studies: II. Recommendations for exposure assessment. *Am J Ind Med* 1994;26:311-26.
 125. Belson WA. The design and understanding of survey questions. Aldershot, Hants: Gower Publishing Co. Ltd., 1981.
 126. Jyrinki E. Kysely ja haastattelu tutkimuksessa [Questionnaires and interviews in research]. Helsinki: Oy Gaudeamus Ab, 1974.
 127. Kübler-Ross E. Raportti kuolemista [On death and dying]. Helsinki: Otava, 1970.
 128. Pershagen G, Axelsson O. A validation of questionnaire information on occupational exposure and smoking. *Scand J Work Environ Health* 1982;8:24-8.
 129. Uhlenhuth EH, Haberman SJ, Balter MD, Lipman RS. Remembering life events. In: Strauss JS, Babigian HM, Roff M, editors. The origins and course of psychopathology. New York (NY): Plenum Press, 1977:117-34.
 130. Baumgarten M, Siemiatycki J, Gibbs GW. Validity of work histories obtained by interview for epidemiologic purposes. *Am J Epidemiol* 1983;118:583-91.
 131. Rosenstock L, Logerfo J, Heyer NJ, Carter WB. Development and validation of a self-administered occupational health history questionnaire. *J Occup Med* 1984;26:50-4.
 132. Tockman MS. Epidemiology in the workplace: The problem of misclassification. *J Occup Med* 1982;24:21-4.
 133. Axelsson O. A note on observational bias in case-reference

- in occupational health epidemiology. *Scand J Work Environ Health* 1980;6:80-2.
134. Gaffey WR. Epidemiological studies in industry. *J Occup Med* 1973;15:782-5.
135. Smedby B. The role of sociologist in medical care research. *Acta Socio-Medica Scand* 1971;3:187-96.
136. Social Insurance Institution. Statistical yearbook of the Social Insurance Institution, Finland, 1979. Helsinki: Social Insurance Institution, 1980. Publications by the Social Insurance Institution T1:15.
137. Kaplan GA, Camacho T. Perceived health and mortality: a nine-year follow-up of the Human Population Laboratory cohort. *Am J Epidemiol* 1983;117:292-304.
138. Aneshensel CS, Frerichs RR, Clark VA, Yokopenic PA. Telephone versus in-person surveys of community health status. *Am J Public Health* 1982;72:1017-21.
139. d'Houtand A, Field MG. The image of health: variations in perception by social class in a French population. *Sociol Health Illness* 1984;6:30-60.
140. Siemiątycki J, Campbell S, Richardson L, Aubert D. Quality of response in different population groups in mail and telephone surveys. *Am J Epidemiol* 1984;120:302-14.
141. Colvez A, Blanchet M. Potential gains in life expectancy free of disability: a tool for health planning. *Int J Epidemiol* 1983;12:224-9.
142. Hadler NM. Occupational illness: the issue of causality. *J Occup Med* 1984;26:587-93.
143. National Board of Health. Tauti- ja kuolinsyyluokitus. [The WHO international statistical classification of diseases, injuries and causes of death]. Helsinki: National Board of Health, 1969.
144. Pyörälä K, Punsar S, Reunanen A, Heinonen OP, Puro K, Aromaa A. Kansaneläkelaitoksen sepelvaltimotautitutkimus. Rintakipuoireiden ja EKG-löydösten esiintyvyys alkututkimuksessa. [Social Insurance Institution's coronary heart disease study: prevalence of chest pain symptoms and ECG findings in nine Finnish population groups]. Helsinki: Social Insurance Institution, 1974. Publications of the Social Insurance Institution AL:1. English summary.
145. Koskela R-S, Luoma K, Häkkinen I. Puuvillatyöntekijöiden kuolleisuus, työkyvyttömyys ja vaihtuvuus. [Mortality, disability and turnover of cotton mill workers]. Helsinki: Finnish Institute of Occupational Health, 1979. Finnish Institute of Occupational Health study reports no 150. English summary.
146. Backman A-L. Moniseulontatutkimuksen hyödyistä. [The feasibility of multiphasic screening]. Helsinki: Finnish Institute of Occupational Health, 1976. Reviews no 8. English summary.
147. Arp EW Jr, Wolf PH, Checkoway H. Lymphocytic leukemia and exposures to benzene and other solvents in the rubber industry. *J Occup Med* 1983;25:598-602.
148. Statistics Finland. Standard industrial classification. Helsinki: Statistics Finland, 1972. Handbooks no 4.
149. Sininen kirja XII. Directory of the economic life of Finland. Helsinki: Sininen kirja Oy, 1974.
150. Statistics Finland. Liikevaihtoverolliset yritykset vuonna 1974. [Statistics on enterprises liable to pay turnover tax]. Helsinki: Statistics Finland, 1974. Statistical report YR1977:13.
151. Hernberg S. The Finnish foundry project: background and general methodology. *Scand J Work Environ Health* 1976;2 suppl 1:8-12.
152. Tola S, Koskela R-S, Hernberg S, Järvinen E. Lung cancer mortality among iron foundry workers. *J Occup Med* 1979;21:753-60.
153. Rose GA, Blackburn H. Cardiovascular survey methods. Geneva: World Health Organization, 1968.
154. Huhti E. Prevalence of respiratory symptoms, chronic bronchitis and pulmonary emphysema in a Finnish rural population. *Acta Tuberc Scand* 1965;61 Suppl LXI.
155. Suomen Metalliteollisuuden Työnantajaliitto. Ohjeita palkkatilastoilmoitusta varten. [Instructions for reporting salary statistics]. Helsinki, Suomen Metalliteollisuuden Työnantajaliitto, 1979.
156. Statistics Finland. Classification of occupations. Helsinki: Statistics Finland, 1981. Handbooks no. 14.
157. Vihma T, Launis M, Stambej U. Pienteollisuuden työolojen kartoitus. Osa 1. Työolojen ergonominen kartoitusohje [A survey of working conditions in small industrial enterprises: I Ergonomic manual constructed for the survey]. Helsinki: Finnish Institute of Occupational Health, 1977. Finnish Institute of Occupational Health study reports no 133. English summary.
158. Siltanen E, Koponen M, Kokko A, Engström B, Reponen J. Dust exposure in Finnish foundries. *Scand J Work Environ Health* 1976;2 suppl 1:19-31.
159. Virtamo M, Tossavainen A, Ruishalme J. Valimoaineet [Exposure to chemicals in Finnish foundries]. Helsinki: Finnish Institute of Occupational Health, 1975. Finnish Institute of Occupational Health study reports no. 109. English summary.
160. Finnish Institute of Occupational Health. Tilasto työhygienisistä mittauksista v. 1977-1980 [Statistics on industrial hygienic measurements in 1977-1980]. Helsinki: Finnish Institute of Occupational Health, 1982. Reviews no. 59.
161. Miettinen O. Confounding and effect-modification. *Am J Epidemiol* 1974;100:350-3.
162. Asp S. Confounding by variable smoking habits in different occupational groups. *Scand J Work Environ Health* 1984;10:325-6.
163. Axelsson O, Sundell L. Mining, lung cancer and smoking. *Scand J Work Environ Health* 1978;4:46-52.
164. Axelsson O. Aspects of confounding in occupational health epidemiology [letter]. *Scand J Work Environ Health* 1978;4:85-9.
165. Steenland K, Beaumont J, Halperin W. Methods of control for smoking in occupational cohort mortality studies. *Scand J Work Environ Health* 1984;10:143-9.
166. WHO. World health statistics annual 1965: vital statistics and causes of death. Geneva: World Health Organization, 1968.
167. WHO. World health statistics annual 1970: vital statistics and causes of death. Geneva: World Health Organization, 1973.
168. Social Insurance Institution of Finland. Kansaneläkelaitoksen tilastollinen vuosikirja 1974 [Statistical yearbook of the Social Insurance Institution, Finland, 1974]. Helsinki: Social Insurance Institution, 1975. Publications by the Social Insurance Institution T1:10.
169. Social Insurance Institution of Finland. Kansaneläkelaitoksen tilastollisia vuosikatsauksia 1974 [Social Insurance Institution's statistical review 1974]. Helsinki: Social Insurance Institution, 1975. Publications of the Social Insurance Institution T3:3C.
170. Central Pension Security Institute. Tilastotietoja työeläkkeen saajista vuodelta 1976 [Statistics about persons receiving employment pensions 1976]. Helsinki: Central Pension Security Institute, 1977.
171. Pressat R. Demographic analysis. Chicago (IL): Aldine-Atherton Inc, 1972.
172. Central Pension Security Institute. Tilastotietoja työeläkkeen saajista vuodelta 1976 [Statistics about persons receiving employment pensions 1976]. Helsinki: Central Pension Security Institute, 1977.

- keen saajista vuodelta 1979 [Statistics on persons receiving employment pensions 1979]. Helsinki: Central Pension Security Institute, 1980.
173. Geigy scientific tables; vol. 2. 8th ed. Basel: Ciba-Geigy Limited, 1982.
 174. Rothman KJ, Boice JD Jr. Epidemiologic analysis with a programmable calculator. Boston (MA): Epidemiology Resources, Inc, 1982.
 175. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *JNCI* 1959;22:719-48.
 176. Kärävä R, Hernberg S, Koskela R-S, Luoma K. Prevalence of pneumoconiosis and chronic bronchitis in foundry workers. *Scand J Work Environ Health* 1976;2 Suppl 1:64-72.
 177. Medical Research Council's Committee on the Aetiology of Chronic Bronchitis. Standardized questionnaires on respiratory symptoms. *BMJ* 1960;2:1665 (a).
 178. Medical Research Council's Committee on the Aetiology of Chronic Bronchitis: instructions for the use of the questionnaire on respiratory symptoms. London, British Research Council, 1960.
 179. Medical Research Council's Committee on the Aetiology of Chronic Bronchitis. Definition and classification of chronic bronchitis. *Lancet* 1965;1:775-9.
 180. Laurila EH. Suomen kansantulo vuosina 1926-1949 [National accounting in Finland in 1926-1949]. Helsinki: Statistics Finland, 1950. Bulletin statistics 1950:11-12.
 181. Lindberg V. Suomen kansantulo vuosina 1926-1938. [National accounting in Finland in 1926-1938]. Helsinki: Bank of Finland, 1943. Suomen Pankin suhdannetutkimusosaston julkaisuja B:1.
 182. Statistics Finland. Kansantalouden tilinpito [National accounting 1964-1974/I-II]. Helsinki: Statistics Finland, 1974.
 183. Statistics Finland. Suomen kansantalouden tilinpito vuosina 1948-1964: taulut. [National accounting in Finland in 1948-1965: tables]. Helsinki: Statistics Finland, 1968.
 184. Winslow JJB. Time and causation in studies of long-term exposure to environmental factors. *Arch Environ Health* 1975;30:417-22.
 185. Blot WJ, Brown LM, Pottern LM, Stone BJ, Fraumeni JF Jr. Lung cancer among long-term steel workers. *Am J Epidemiol* 1983;117:706-16.
 186. Fletcher AC, Ades A. Lung cancer mortality in a cohort of English foundry workers. *Scand J Work Environ Health* 1984;10:7-16.
 187. Gibson ES, McCalla DR, Kaiser-Farrell C, Kerr AA, Lockington JN, Hertzman C, Rosenfeld JM. Lung cancer in a steel foundry: a search for causation. *J Occup Med* 1983;25:573-8.
 188. Ames RG, Gamble JF. Lung cancer, stomach cancer, and smoking status among coal miners: a preliminary test of a hypothesis. *Scand J Work Environ Health* 1983;9:443-8.
 189. Meyer MB, Luk GD, Sotelo JM, Cohen BH, Menkes HA. Hypothesis: the role of the lung in stomach carcinogenesis. *Am Rev Respir Dis* 1980;121:887-92.
 190. Dolan BP, Levine AM, Capman Dolan D. Small cleaved follicular center cell lymphoma: seven cases in California plumbers. *J Occup Med* 1983;25:613-5.
 191. Flodin U, Andersson L, Anjou C-G, Palm U-B, Vikrot O, Axelsson O. A case-referent study on acute myeloid leukemia, background radiation and exposure to solvents and other agents. *Scand J Work Environ Health* 1981;7:169-78.
 192. Hilt B, Heldaas SS, Langård S. Can occupational exposure contribute to the development of malignant melanoma of the skin? *Scand J Work Environ Health* 1983;9:52-3.
 193. Järholm B, Lillienberg L, Sällsten G, Thiringer G, Axelsson O. Cancer morbidity among men exposed to oil mist in the metal industry. *J Occup Med* 1981;23:333-7.
 194. Beaumont JJ, Weiss NS. Lung cancer among welders. *J Occup Med* 1981;23:839-44.
 195. Hirayama T. Metal-material workers and lung cancer in Japan. *Ann N Y Acad Sci* 1976;271:269-72.
 196. Stern RM. Assessment of risk of lung cancer for welders. *Arch Environ Health* 1983;38:148-55.
 197. Tokudome S, Kuratsune M. A cohort study on mortality from cancer and other causes among workers at a metal refinery. *Int J Cancer* 1976;17:310-7.
 198. Tokudome S, Kuratsune M. Mortality from cancer and other causes among workers at a metal refinery. *J UOEH* 1983;Suppl 5:101-8.
 199. Morton WE, Treyve EL. Histologic differences in occupational risk of lung cancer incidence. *Am J Ind Med* 1982;3:441-57.
 200. Sorahan T, Waterhouse JAH. Mortality study of nickel-cadmium battery workers by the method of regression models in life tables. *Br J Ind Med* 1983;40:293-300.
 201. Hernberg S, Kärävä R, Koskela R-S, Luoma K. Angina pectoris, ECG findings and blood pressure of foundry workers in relation to carbon monoxide exposure. *Scand J Work Environ Health* 1976;2 Suppl 1:54-63.
 202. Aromaa A, Heliövaara M, Impivaara O, Knekt P, Maatela J, Joukamaa M et al. Terveys, toimintakyky ja hoidontarve Suomessa: Mini-Suomi-terveystutkimuksen perustulokset. [Health, functional limitations and need for care in Finland: basic results from the Mini-Finland health survey]. Helsinki and Turku: Social Insurance Institution, 1989. Publications of the Social Insurance Institution AL:32. English summary.
 203. Svensson H-O. Low back pain in forty to fortyseven year old men: a retrospective cross-sectional study [dissertation]. Göteborg: University of Göteborg, 1981.
 204. World Health Organization (WHO). World health statistics annual 1977: vital statistics and causes of death. Geneva: WHO, 1981.
 205. World Health Organization (WHO). World health statistics annual 1974: vital statistics and causes of death. Geneva: WHO, 1977.
 206. Becher H, Jedrychowski W, Flak E, Gomola K, Warendorf J. Lung cancer, smoking, and employment in foundries. *Scand J Work Environ Health* 1989;15:38-42.
 207. Sorahan T, Faux AM, Cooke M. Mortality among a cohort of United Kingdom steel foundry workers with special reference to cancers of the stomach and lung, 1946-90. *Occup Environ Med* 1994;51:316-22.
 208. Koskela R-S. Cardiovascular diseases among foundry workers exposed to carbon monoxide. *Scand J Work Environ Health* 1994; 20:286-93.
 209. Eisen EA, Tolbert PE, Monson RR, Smith TJ. Mortality studies of machining fluid exposure in the automobile industry: I A standardized mortality ratio analysis. *Am J Ind Med* 1992;22:809-24.
 210. Sjögren B, Hansen KS, Kjuus H, Persson P-G. Exposure to stainless steel welding fumes and lung cancer: a meta-analysis. *Occup Environ Med* 1994;51:335-6.
 211. Pearce N, Reif J, Fraser J. Case-control studies of cancer in New Zealand electrical workers. *Int J Epidemiol* 1989;18:55-9.
 212. Beall C, Delzell E, Cole P, Brill I. Brain tumors among electronics industry workers. *Epidemiology* 1996;7:125-30.

APPENDIX

OCCUPATIONAL GROUPS, THE BREAKDOWN OF THE OCCUPATIONS AND SOME OF THE RESULTS OF THE STUDY

Table 1. Occupational breakdown of the study subjects in the cohorts according to their main occupation.

Occupation	Foundry workers		Metal product workers		Electrical workers	
	N	%	N	%	N	%
Floor molders		12.8	.	.	.	.
Machine molders	382	6.0	.	.	.	.
Coremakers	182	2.8	.	.	.	.
Casters	145	2.3	.	.	.	.
Ingot casters	27	0.4	.	.	.	.
Fettlers	690	10.8	.	.	.	.
Knock-out men	282	4.4	.	.	.	.
Furnacemen	230	3.6	.	.	.	.
Other foundry workers	115	1.8	.	.	.	.
Tool makers	.	.	100	2.6	159	2.9
Tool setters	.	.	52	1.3	19	0.4
Inspectors, testers	.	.	111	2.8	252	4.7
Turners	.	.	579	14.8	124	2.3
Machine workers	.	.	141	3.6	188	3.5
Machine fitters	.	.	708	18.2	180	3.3
Assemblers	.	.	.	.	453	8.4
Electrical and electronic equipment assemblers	.	.	31	0.8	765	14.2
Electricians	.	.	43	1.1	457	8.5
Metal plate workers	.	.	271	6.9	2	0.0
Sheet metal workers	.	.	64	1.6	20	0.4
Welders and flame cutters	.	.	403	10.3	70	1.3
Plumbers	.	.	45	1.2	1	0.0
Painters	2	0.0	135	3.5	39	0.7
Metal grinders, shotblasters	.	.	37	0.9	104	1.9
Metal platers and coaters	5	0.1	31	0.8	67	1.2
Woodworkers	1	0.0	1	0.0	.	.
Warehouse workers, packers	20	0.3	220	5.6	813	15.1
Maintenance workers	20	0.3	77	2.0	188	3.5
Truck drivers, crane operators	198	3.1	162	4.2	250	4.6
Machine operators	.	.	9	0.2	.	.
Apprentices, students	11	0.2	69	1.8	33	0.6
Laborers	3 285	51.2	612	15.7	1 214	22.5
Total	6 415	100.0	3 901	100.0	5 398	100.0

Table 2. Classification of the occupational groups similar in character.

Industrial branch	Occupational group
Foundry workers	(1) floor molders, (2) machine molders, (3) coremakers, (4) casters, ingot casters, (5) fettlers, (6) knock-out men, (7) furnacemen, (8) laborers, (9) others
Metal product workers	(1) tool makers, (2) tool setters, turners, machine operators, metal grinders and shotblasters, machine workers, (3) inspectors and testers, (4) machine fitters, electrical and electronic equipment assemblers, (5) metal plate workers, sheet metal workers, plumbers, (6) warehouse workers and packers, (7) welders and flame cutters, (8) painters, metal platers and coaters, (9) electricians, woodworkers, maintenance workers, (10) truck drivers and crane operators, (11) apprentices and students, (12) laborers, (13) others
Electrical workers	(1) tool makers, (2) tool setters, turners, machine workers, metal grinders and shotblasters, (3) inspectors and testers, (4) machine fitters, assemblers, electrical and electronic equipment assemblers, (5) electricians, (6) metal plate workers, sheet metal workers, plumbers, (7) welders and flame cutters, (8) painters, metal platers and coaters, (9) warehouse workers and packers, (10) maintenance workers, (11) truck drivers and crane operators, (12) apprentices and students, (13) laborers, (14) others

Table 3. Classification of occupational groups into typical and nontypical occupations and laborers.

Industrial branch	Occupational class	Occupational group
Foundry workers	Typical occupations	Floor molders, machine molders, coremakers, casters, ingot casters, fettlers, knock-out men, other foundry workers
	Nontypical occupations and laborers	Painters, metal platers and coaters, woodworkers, warehouse workers and packers, maintenance workers, truck drivers and crane operators, apprentices and students, laborers
Metal product workers	Typical occupations	Tool makers, tool setters, inspectors and testers, turners, machine workers, machine fitters, assemblers, electrical and electronic equipment assemblers, metal plate workers, sheet metal workers, welders and flame cutters, plumbers, painters, metal grinders and shotblasters, metal platers and coaters, machine operators
	Nontypical occupations	Electricians, woodworkers, warehouse workers and packers, maintenance workers, truck drivers and crane operators
	Laborers	Laborers, apprentices and students
Electrical workers	Typical occupations	Machine fitters, assemblers, electrical and electronic equipment assemblers, electricians
	Nontypical occupations	Tool makers, tool setters, inspectors and testers, turners, machine workers, metal plate workers, sheet metal workers, welders and flame cutters, plumbers, painters, metal grinders and shotblasters, metal platers and coaters, warehouse workers and packers, maintenance workers, truck and crane drivers
	Laborers	Laborers, apprentices and students

Table 4. Classification of the occupational groups into heavy, medium, and light exposure level.

Exposure level	Occupational group
Heavy	Floor molders, machine molders, casters, fettlers, knock-out men
Medium	Coremakers, ingot casters, furnacemen, tool makers, tool setters, turners, machine workers, machine fitters, metal plate workers, welders and flame cutters, plumbers, painters, metal grinders and shotblasters, metal platers and coaters, woodworkers, truck drivers and crane operators, machine operators, apprentices and students, laborers in foundries, laborers in the manufacture of metal products
Light	Other foundry workers, inspectors and testers, assemblers, electrical and electronic equipment assemblers, electricians, warehouse workers and packers, maintenance workers, laborers in the manufacture of electrical devices

Table 5. Occupational groups taken from the census code and classified for exposure level.

Exposure level	Occupational group
Heavy level	Agricultural and horticultural work and breeding of animals, game protection and hunting, fishing, forestry work, mining and quarrying, smelting and metallurgical and foundry work, other construction work (eg, bricklayers, rod layers, concrete shutterers and finishers)
Medium level	Deck and engine-room crew, locomotive operation, road transport work, postal and other messenger work, textile work, shoe and leather work, iron and metalware work, woodwork, painting and lacquering work, glass, ceramic, and clay work, food and beverage work, chemical processing and related work, tobacco industry work, other manufacturing work, packing and wrapping work, stationary engine and motorpower work, dock and warehouse work, manual work not elsewhere classified, laundering, dry cleaning, and pressing work, sport, work not elsewhere classified
Light level	Scientific, humanistic, and artistic work, administrative, managerial and clerical work, sales work, managerial work of agriculture and forestry and horticulture, ship officers' work, air traffic work, transport service work, traffic supervision, post and telecommunication work, other transport and communication work, cutting, serving, and upholstering work, fine mechanical work, electrical work, graphic work, public safety and protection work, housekeeping, restaurant service, building maintenance and cleaning, hygiene and beauty treatment work, photographic work, travel service work, other service work

Table 6. Mortality from certain diseases for the cross-sectional cohorts (workers who were still at work in 1950 but who had been hired earlier) in 1950-1978. The expected numbers were calculated from the Finnish male population death rates (based on age-specific rates in 1965). (O = observed, E = expected).

Cause of death	Foundry workers		Metal product workers		Electrical workers	
	E	O	E	O	E	O
All deaths	296.9	257 *	177.5	147 *	44.0	47
Natural deaths	266.8	228 *	157.9	128 *	37.3	43
Violent deaths	30.1	29	19.6	19	6.7	4
Suicides	10.2	12	6.3	11	2.2	—
Motor vehicle accidents	7.8	2	4.9	2	1.7	3
Other accidental deaths	3.1	13 **	2.2	4	0.7	1
Respiratory diseases	14.7	16	8.8	5	1.8	4
Cardiovascular diseases	156.5	136	92.9	73 *	21.9	28
Coronary heart disease	104.7	82 *	61.7	47	15.0	18
Cerebrovascular diseases	30.4	19 *	18.4	11	4.0	2
Tumors	58.4	57	34.1	31	10.0	6
Lung cancer	21.6	27	12.4	11	4.7	4
Cancer of digestive organs	16.3	18	9.6	6	1.7	2

*P<0.05, **P<0.01, Poisson distribution.

Table 7. Mortality from certain diseases for the cross-sectional cohorts (workers who were still at work in 1950 but who had been hired earlier) in 1950-1987. The expected numbers were calculated from the Finnish male population death rates (based on age-specific rates in 1974). (O = observed, E = expected).

Cause of death	Foundry workers		Metal product workers		Electrical device workers	
	E	O	E	O	E	O
All deaths	420.1	397	249.6	227	70.7	71
Natural deaths	378.9	358	223.8	204	61.3	67
Violent deaths	41.2	39	25.8	23	9.4	4
Suicides	12.5	12	7.9	12	3.0	—
Motor vehicle accidents	10.6	3	6.6	3	2.3	3
Other accidental deaths	15.7	22	9.8	6	3.5	1
Respiratory diseases	30.1	28	17.9	13	4.5	5
Cardiovascular diseases	227.5	206	134.3	117	36.7	43
Coronary heart disease	148.6	122	87.5	72	24.5	28
Cerebrovascular diseases	38.1	32	22.6	17	6.0	3
Tumors	87.2	94	51.1	49	14.0	12
Lung cancer	33.8	41	19.6	21	5.3	7
Cancer of digestive organs	19.0	25	11.1	8	3.0	2

Table 8. Cause-specific incidence densities (ID) of disability pensions during the follow-up period of 1969-1978.

Age (years)	Person- years	Mental disorders		Cardiovascular disorders		Coronary heart disease		Respiratory diseases		Musculoskeletal diseases		Others	
		Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years
Foundry workers													
16–34	18 675	63	3.37	3	0.16	—	0.00	—	0.00	13	0.70	16	0.86
35–44	16 191	50	3.09	13	0.80	6	0.37	5	0.31	32	1.98	57	3.52
45–54	9 552	38	3.98	74	7.75	48	5.03	16	1.68	78	8.17	67	7.01
55–64	3 017	10	3.31	82	27.18	42	13.92	29	9.61	64	21.21	29	9.61
Total	47 435	161	3.39	172	3.63	96	2.02	50	1.05	187	3.94	169	3.56
Metal product workers													
16–34	16 623	19	1.14	2	0.12	—	0.00	—	0.00	5	0.30	9	0.54
35–44	7 471	15	2.01	10	1.34	4	0.54	1	0.13	10	1.34	21	2.81
45–54	3 861	18	4.66	35	9.07	20	5.18	8	2.07	26	6.73	21	5.44
55–64	1 593	2	1.26	48	30.13	22	13.81	18	11.30	39	24.48	19	11.93
Total	29 548	54	1.83	95	3.22	46	1.56	27	0.91	80	2.71	70	2.37
Electrical workers													
16–34	25 941	39	1.50	1	0.04	—	0.00	—	0.00	5	0.19	27	1.04
35–44	9 213	19	2.06	8	0.87	3	0.33	1	0.11	13	1.41	16	1.74
45–54	3 758	15	3.99	26	6.92	15	3.99	3	0.80	14	3.73	26	6.92
55–64	1 188	10	8.42	24	20.20	16	13.47	6	5.05	17	14.31	21	17.68
Total	40 100	83	2.07	59	1.47	34	0.85	10	0.25	49	1.22	90	2.24

Table 9. Cause-specific incidence densities (ID) of disability pensions during the follow-up period of 1969-1987.

Age (years)	Person- years	Mental disorders		Cardiovascular disorders		Coronary heart disease		Respiratory diseases		Musculoskeletal diseases		Others	
		Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years	Number	ID/1000 person- years
Foundry workers													
16–34	25 788	79	3.06	3	0.12	—	0.00	—	0.00	17	0.66	26	1.01
35–44	27 453	96	3.50	28	1.02	16	0.58	10	0.36	52	1.89	92	3.35
45–54	19 557	94	4.81	134	6.85	78	3.99	42	2.15	138	7.06	124	6.34
55–64	6 679	21	3.14	136	20.36	73	10.93	49	7.34	131	19.61	58	8.68
Total	79 477	290	3.65	301	3.79	167	2.10	101	1.27	338	4.25	300	3.77
Metal product workers													
16–34	23 657	26	1.10	4	0.17	—	0.00	2	0.08	5	0.21	15	0.63
35–44	17 573	34	1.93	16	0.91	7	0.40	1	0.06	20	1.14	37	2.11
45–54	9 372	33	3.52	54	5.76	27	2.88	13	1.39	60	6.40	37	3.95
55–64	3 343	9	2.69	82	24.53	43	12.86	26	7.78	65	19.45	30	8.97
Total	53 945	102	1.89	156	2.89	77	1.43	42	0.78	150	2.78	119	2.21
Electrical workers													
16–34	41 507	53	1.28	4	0.10	1	0.02	1	0.02	6	0.14	34	0.82
35–44	21 643	37	1.71	15	0.70	5	0.23	3	0.14	25	1.16	38	1.76
45–54	10 737	43	4.01	52	4.84	30	2.79	11	1.02	36	3.35	54	5.03
55–64	3 108	14	4.51	45	14.48	26	8.37	8	2.57	47	15.12	37	11.90
Total	76 995	147	1.91	116	1.51	62	0.81	23	0.30	114	1.48	163	2.12