ORIGINAL ARTICLE

Mortality among Japanese construction workers in Mie Prefecture

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Aims: A historical cohort mortality study was conducted among 17 668 members of the Construction Workers' Health Insurance Society of Mie Prefecture in Japan, in order to verify the relation between occupations and mortality status.

Methods: The cohort was followed from 2 April 1973 to 1 April 1998. Standardised mortality ratios (SMR) were calculated for all members and each job classification.

Results: 98.7% of the members were traced successfully until the date when the follow up terminated. When all members were considered together, significant excess mortality was observed for "accidents and adverse effects". Significant excess mortalities were also observed for lung cancers among scaffold men and ironworkers, for cancer of the oesophagus among plumbers, and for "chronic liver disease and cirrhosis" among scaffold men and painters.

Conclusion: Results suggest that more detailed investigations, which would include some minor job classifications should be undertaken. This is an updated cohort study which was partially completed in 1997.

Construction is one of the largest industries in Japan, employing 6.71 million workers in 2000. Construction workers are potentially exposed to hazardous chemical and physical agents such as asbestos, organic solvents, noise, vibration, and materials specific to particular trades. In addition, job injuries occur frequently on construction sites. However, as there has been little epidemiological literature in this field, the relations between mortality among construction workers and hazardous agents are not well understood.

A previous historical cohort study reported in 1997[1] was conducted to evaluate the relation between occupations and mortality status among members of the Construction Workers' Health Insurance Society of Mie Prefecture in Japan. As only 70% of the members were successfully followed until the termination date of the study, the validity of the study was limited. Furthermore, because the number of deaths was relatively small, the authors did not evaluate death risks by individual job classification.

In order to improve the validity of the above mentioned study, follow up was continued and the termination year delayed from 1993 to 1998. This report presents the findings from the updated study of the mortality pattern among the same cohort. The standardised mortality ratio (SMR) analysis technique was used in this study.

The Health Insurance Society was founded in 1970 in Mie Prefecture, located in the central part of Japan. Insured members as of 2001 totalled approximately 18 300 persons which corresponded to almost 25% of all the construction workers in Mie Prefecture. Insured members consisted of 4000 employers (21.9%), 5500 employees (30.1%), 7800 self employed workers without employees (42.6%), and 1000 family workers (5.5%).

In Japan every individual is expected to carry some kind of health insurance. The public medical insurance system is divided into two categories, employees' health insurance and "national health insurance (NHI)". The purpose of the employees' health insurance is to provide employees and their families with health and lifestyle stability. The Japanese government is responsible for these individuals by law. This system applies to all employed individuals of most of the formal companies. The premiums vary with the amount of salary and are paid equally by the employer and the insured. The NHI plan was created for those individuals (farmers, self employed, unemployed or employed by small scale enterprises) who are not covered by employees' health insurance. NHI includes the health insurance societies which are subscribed to by employers and employees of small scale enterprises, self employed workers without employees, and family workers within special trades. There are several health insurance societies restricted to the construction trade in Mie Prefecture. They are competitive and their insurance dues and benefits are similar. The health insurance society involved in the present study is the largest one in Mie Prefecture.

Small scale construction enterprises (less than 30 employees) constitute as much as 96% of all establishments in the Japanese construction industry.[2] They employed 64% of the Japanese construction workers in 1996.[2] Compared with other industries, occupational health services have not been supplied adequately for workers in the construction industry in Japan because: (1) the major portion of the construction industry is composed of small scale enterprises; (2) the worksites change frequently; and (3) self employed workers and family workers are usually outside of the coverage of Occupational Safety and Health Act. Therefore it was difficult to organise occupational health activities. Furthermore, record keeping for occupational history relevant to hazard exposure and for medical examination was incomplete. Because of these constraints, which do not differ from those of other countries, little research has been performed to study the mortality of construction workers. To address this lack of research, the current study was conducted with the cooperation of the Health Insurance Society and many legal affairs bureaus.

SUBJECTS AND METHODS

The cohort was restricted to the male members of the Construction Workers' Health Insurance Society of Mie

Abbreviations: NHI, national health insurance; PMR, proportionate mortality ratio; SMR, standardised mortality ratio

Table 1 Proportional distribution of the numbers and person years by major job classifications in mortality study of Mie Construction Workers' Health Insurance Society

Job classification	Number	Percent	Person years	Percent
Carpenter	7187	40.7	116113.2	47.0
Plasterer	1695	9.6	27078.5	11.0
Ironworker	966	5.5	11493.5	4.7
Electrician	946	5.4	10546.5	4.3
Painter	711	4.0	8688.7	3.5
Plumber	625	3.5	6758.1	2.7
Sheet metal worker	481	2.7	6905.5	2.8
Interior finish worker	471	2.7	8263.5	3.3
Others	4586	27.8	51177.9	20.7
Total	17668	100.0	247025.4	100.0

Prefecture, who had belonged to the society for at least one year between 2 April 1973 and 1 April 1993. The cohort was followed up to 1 April 1998. Because the data from the establishment of the society in 1970 to 1 April 1973 were not kept completely in the society, we set the starting follow up date on 2 April 1973.

At the first stage of this study, we reviewed the membership files of the society, checked date of birth, date of entry into the society, date of exit from the society or death diagnosis, and job classification of each subject, and updated the database.

Because the society could not provide the vital status of the withdrawn members, we relied on another information source to investigate the subjects lost to follow up. Lists of the members who withdrew from the society during the study period were sent to the legal affairs bureaus of the districts where the members lived before their withdrawals in order to determine vital status. The officers of the bureaus recorded vital status onto the list from the resident registration files and returned the lists, together with copies of death certificates if the subjects died. With the collaboration of the bureaus, most of the withdrawn members were successfully followed up to 1 April 1998 or their death dates if these were earlier. Among the members who stayed in the society, when a death event took place we obtained a copy of death certificate from the society. All causes of death derived from the death certificates were coded according to the Ninth Revision of the International Classification of Diseases (ICD-9).

The person years and SMRs were calculated with the Statistical Analysis System (SAS)[3] computer program published in 1997.[4] The age range, from 15 to 94, and the 25 year study period were divided equally into 16 five-year age groups and five five-year periods, respectively, giving a total of 80 cells. For each individual, the date of entry into follow up for calculation of person years was defined as the date of the first full year of membership. The observed numbers of deaths, both all causes and cause specific, were compared with the expected numbers of deaths based on the age specific mortality rates of Mie Prefecture for all of the 80 cells.

Statistical significance was determined using the Poisson distribution and 95% confidence intervals (CI). Based on the relation between the Poisson distribution and the χ^2 distribution,[5] exact 95% confidence intervals for the mean of the observed deaths were calculated by the SAS function "CINV".[3] The limits of those confidence intervals were divided by the expected deaths to yield 95% confidence intervals for the true SMRs.[6] The latter were assumed to be a constant, because the reference mortality rates were based on relatively large general populations. One tailed p values were calculated by the SAS function "POISSON".[3] These methods have been described in detail elsewhere.[7]

The whole study population was divided into 43 job classifications according to "Standard Job Classifications for Japan".[8] With the same method, all causes and cause specific SMRs were calculated by individual job classification. The powers of the study were calculated with the SAS function "POISSON",[3] using the probability of type I error, α of 0.05.

RESULTS

There were 17 668 male members in the Construction Workers' Health Insurance Society of Mie Prefecture between 2 April 1973 and 1 April 1993, who had been in the society for at least one year after the beginning of the follow up. A total of 17 430 (98.7%) members were followed until 1 April 1998, when the follow up terminated. During this period, 1466 members were deceased. The 238 members (1.3%) who withdrew from the society before 1 April 1998, were considered lost to follow up and were excluded from the study at the date of their withdrawal.

Table 1 shows the proportional distributions of the numbers and person years among the study population by major job classification. The job classification "others" includes interior finish workers, stonemasons, architects, woodworkers, sash makers, stevedores, landscape workers, and so on.

Table 2 depicts the observed number of deaths and cause specific SMRs for the whole study population and three major job classifications: carpenters, plasterers, and ironworkers ("steel-frame workers" is used instead of "ironworkers" in Japan Job Classification System [8]).

Among the whole study population, the SMR of "accidents and adverse effects" was significantly increased (SMR = 1.19, $p < 0.05$, 95% CI: 1.01 to 1.40). The 153 deaths from "accidents and adverse effects" included 90 deaths from transportation injuries (ICD-9: E800–848), four deaths by poisoning (E850–869), 28 by falls (E880–888), and 31 by other accidents (E870, E890–928). From the information on causes of death, however, we could not judge whether these accidents were on or off job. SMRs for specific accidents could not be calculated because no data for the standard population, national or prefectural, were published in Japan. Observed numbers of deaths from all causes and heart disease were significantly lower than corresponding expected values (SMR = 0.90, $p < 0.001$, 95% CI: 0.85 to 0.94; and SMR = 0.80, $p < 0.001$, 95% CI: 0.69 to 0.91, respectively).

A total of 7187 carpenters were included in the study population. The all causes and cause specific SMRs are similar to those of the whole study population. The SMR of "accidents and adverse effects" was increased but without statistical significance (SMR = 1.19, 95% CI: 0.94 to 1.49). Observed numbers of deaths from all causes and heart disease were significantly lower than corresponding expected values (SMR = 0.85, $p < 0.001$, 95% CI: 0.80 to 0.92; and SMR = 0.76, $p < 0.01$, 95% CI: 0.62 to 0.92, respectively). One death from methothelioma occurred in this group.

Table 2 Observed number of deaths and cause specific SMRs

Cause of death (ICD-9)	All members of the society			Carpenters			Plasterers			Ironworkers		
	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI
All causes (000–999)	1466	0.90***	0.85 to 0.94	740	0.85***	0.80 to 0.92	146	1.03	0.87 to 1.21	63	1.07	0.82 to 1.37
All malignant neoplasms (140–208)	506	0.98	0.90 to 1.07	262	0.99	0.87 to 1.12	48	1.11	0.82 to 1.47	23	1.14	0.72 to 1.71
Cancer of oesophagus (150)	14	0.84	0.46 to 1.41	8	0.96	0.41 to 1.88	0	–	–	0	–	–
Cancer of stomach (151)	129	0.96	0.80 to 1.13	69	0.97	0.75 to 1.23	14	1.21	0.67 to 2.03	2	0.40	0.05 to 1.46
Cancer of liver (155, 159.1C)	79	0.90	0.68 to 1.07	44	0.96	0.70 to 1.29	4	0.53	0.14 to 1.35	5	1.27	0.41 to 2.97
Cancer of pancreas (157)	30	0.94	0.63 to 1.34	14	0.86	0.47 to 1.44	1	0.37	0.01 to 2.06	2	1.55	0.19 to 5.58
Cancers of trachea, bronchus, and lung (162)	109	1.08	0.88 to 1.30	54	1.02	0.77 to 1.33	13	1.61	0.86 to 2.75	11	2.88**	1.44 to 5.15
Heart disease (393–398, 410–429)	205	0.80***	0.69 to 0.91	105	0.76**	0.62 to 0.92	22	1.00	0.63 to 1.52	6	0.68	0.25 to 1.47
Ischemic heart disease (410–414)	91	0.81*	0.65 to 1.00	49	0.82	0.61 to 1.08	9	0.98	0.45 to 1.85	4	1.03	0.28 to 2.63
Heart failure (428)	96	0.87	0.71 to 1.07	46	0.77	0.57 to 1.03	12	1.23	0.63 to 2.14	2	0.55	0.07 to 1.98
Cerebrovascular disease (430–438)	211	0.93	0.81 to 1.06	106	0.84	0.69 to 1.02	18	0.95	0.56 to 1.50	10	1.47	0.71 to 2.71
Pneumonia and bronchitis (466.0, 480–486, 490, 491)	81	1.00	0.79 to 1.24	46	0.99	0.73 to 1.33	10	1.63	0.78 to 2.99	3	1.35	0.28 to 3.95
Chronic liver disease and cirrhosis (571)	57	1.05	0.79 to 1.36	25	0.91	0.59 to 1.35	7	1.38	0.55 to 2.84	2	0.89	0.11 to 3.21
Accidents and adverse effects (E800–E949)	153	1.19*	1.01 to 1.40	76	1.19	0.94 to 1.49	18	1.41	0.83 to 2.23	7	1.30	0.52 to 2.67
Suicide (E950–E959)	66	1.00	0.77 to 1.27	30	0.95	0.64 to 1.35	6	0.81	0.30 to 1.76	4	1.34	0.36 to 3.42

*p<0.05; **p<0.01; ***p<0.001.

The second largest job classification in the study population was composed of 1695 plasterers. Although no significant increased number of deaths was found among this trade, most of the cause specific SMRs were higher than those of the whole study population and carpenters.

The third largest job classification in the study population was composed of 966 ironworkers. The observed number of deaths from "cancers of trachea, bronchus, and lung" was about three times the expected value (SMR = 2.88, $p < 0.01$, 95% CI: 1.44 to 5.15).

Table 3 shows the observed number of deaths and all cause SMRs among some other job classifications (observed number >10). One statistically significantly lower mortality was observed for tatami (traditional Japanese floor mat) makers (SMR = 0.51, $p < 0.05$, 95% CI: 0.27 to 0.87). The SMR of all deaths among stonemasons was increased with borderline statistical significance (SMR = 1.36, 95% CI: 0.99 to 1.82). Several significant excess cause specific SMRs were detected from these trades (not shown in the table), which included cancer of the oesophagus among plumbers (SMR = 6.90, $p < 0.05$, 95% CI: 1.42 to 20.16), "cancers of trachea, bronchus, and lung" among scaffold men (SMR = 6.22, $p < 0.05$, 95% CI: 1.28 to 18.17), and "chronic liver disease and cirrhosis" among painters and scaffold men (SMR = 3.29, $p < 0.05$, 95% CI: 1.07 to 7.68; and SMR = 10.90, $p < 0.01$, 95% CI: 2.25 to 31.85, respectively).

For all of the major cause specific deaths among the whole study population, the study had at least 95% power of detecting a minimum relative risk of 2.0. Among carpenters, except for cancer of the oesophagus, the powers were larger than 90%. Among plasters, the powers for four cause specific deaths (cancer of the stomach, heart failure, cerebrovascular disease, and "accidents and adverse effects") were higher than 83%. Among ironworkers, the power for all cancers was 97%. For all other cause specific deaths among ironworkers, there were not enough powers to detect a minimum relative risk of 2.0. Among all job classifications presented in table 3, the powers for all deaths were greater than 92%.

DISCUSSION

The previous cohort study of the Construction Workers' Health Insurance Society of Mie Prefecture in Japan reported the patterns of excess SMR from "accidents and adverse effects".[1] Since the rate of loss to follow up was high, the proportionate mortality ratio (PMR) technique was used in this study as a supplement to SMR. The current study also detected a significantly increased SMR from "accidents and adverse effects" among the whole study population, but the value of the SMR (1.19) was lower than that of the previous result (1.30). The result of the current study may be an underestimated result because we extended the person years of the deceased who withdrew before 1 April 1998 to the date of deaths without considering their working status. The ages of the 153 deceased ranged from 19 to 81 years. Twenty five (16%) subjects died after their 65th birthdays. Most were likely to be retired before death. We supposed that their chances of incurring accidents might reduce after retirement. SMRs for accidents during employment and after could not be calculated as retirement dates were not available for the present study.

In addition to fatal injuries, construction workers may be exposed to many occupational hazards, including potential exposure to known respiratory carcinogens, such as asbestos, silica, and some kinds of wood dust. We could not detect any other increased mortality from the whole study population except the "accidents and adverse effects". This may be explained by the "healthy worker effect", a negative selection bias. However, an approximately threefold significant excess SMR for "cancers of trachea, bronchus, and lung" was found in ironworkers. Two previous studies observed significantly increased PMRs for lung cancer among US ironworkers,[9 10] but

Table 3 Observed number of deaths and all cause SMRs among some minor job classifications

Job classification	Number	Obs	SMR	95% CI
Electrician	946	40	0.88	0.63 to 1.19
Painter	711	49	1.16	0.86 to 1.54
Plumber	625	39	1.06	0.76 to 1.45
Sheet metal worker	481	44	0.89	0.64 to 1.19
Joiner	471	59	0.81	0.61 to 1.04
Labourer	290	49	1.11	0.82 to 1.47
Stonemason	289	45	1.36	0.99 to 1.82
Wood worker	234	13	0.59	0.31 to 1.00
Landscape worker	201	14	0.97	0.53 to 1.62
Roofer	199	16	0.98	0.56 to 1.60
Tatami† maker	165	13	0.51*	0.27 to 0.87
Scaffold man	146	11	1.55	0.77 to 2.76

*p<0.05; †traditional Japanese floor mat.

the values (1.29 and 1.28) were not very large. No similar study has been reported from Japan or other countries.

In Japan, asbestos is still widely used as an industrial raw material. The import of asbestos to Japan has increased rapidly since the 1950s and reached approximately 350 000 tons per year in 1974. In 1998, although decreased, the amount of imported asbestos was 120 813 tons.[11] Of the imported asbestos, 93.0% was used for construction material.[12] Consequently, many construction workers have been and are still being exposed to asbestos in their working environment.

It is known that pleural plaques occur with increased frequency in persons exposed to asbestos dust. A previous study of pleural and parenchymal abnormalities on chest radiograph[13] was conducted within the same health insurance society. The chest radiographs taken in 1988, 1989, 1991, 1992, 1994, and 1995 as a part of annual medical examinations in the society were used for this study. The prevalence of pleural plaques was second highest among ironworkers (9.3%). The prevalence of pleural plaques among heat insulation workers was highest (25.0%) but as the number in this trade which were included in the present study is small, no significant SMR could be detected. The prevalence of pleural plaques among all workers who underwent the annual medical examination was 2.0%.

Ironworkers are often engaged in the construction, renovation, or demolition of buildings with metal structures, which are sometimes covered with asbestos containing material. Many ironworkers perform welding and torch cutting. They use fireproof blankets made of asbestos to shield the material adjacent to welding from ignition. Besides exposure to asbestos containing material, lung cancer among ironworkers may also be associated with their exposure to welding fumes.[13]

In 1987, the percentages of current smokers among ironworkers of the society and the total Japanese male population were 67.2%[14] and 61.6%,[15] respectively. As the SMR for lung cancer among ironworkers was very high, it could not entirely have been a result of smoking habits.

Other findings of this study include excess risks for the following construction trades: increased risk for lung cancer among scaffold men; increased oesophagus cancer mortality among plumbers; and increased risk of death caused by liver cirrhosis among painters and scaffold men. All of these results, however, were contributed by small numbers of deaths. Therefore, they might occur by chance.

Only a few cohort studies on construction workers used SMR techniques. A previous mortality study in Japan[16] revealed that the mortalities for all cancers (SMR = 1.4, $p < 0.001$) and cerebrovascular diseases (SMR = 1.3, $p < 0.02$) among the members of the Construction Workers' Health Insurance Society of Tokyo were significantly higher than those of the population consisting of craftsmen, manufacturing workers, and the overall labour force of Japan.

A Hong Kong study[17] found a lower overall SMR (0.87) for male construction workers, compared to the general male Hong Kong population. However, SMRs were increased in specific malignant and non-malignant causes of death.

A Swedish study[18] found a significantly increased SMR (1.03, $p < 0.05$) for work related accidents among the whole study population. The SMRs for all deaths (0.74) and all cancers (0.88) were lower than our results. An earlier Swedish study[19] also reported lower SMRs for all deaths (0.68), cancer (0.84), "cancers of trachea, bronchus, and lung" (0.86), and "non-malignant diseases of the respiratory system" (0.46). Both of these studies used the whole general Swedish population as the standard population and thus showed strong healthy worker effects.

Several other studies used the proportionate mortality ratio (PMR) technique to detect mortality risks instead of SMR. In occupational cohort studies, the PMR is usually larger than the corresponding SMR. Therefore, it is easier to detect increased mortality risks with PMR. However, the proportional mortality of the disease under study is strongly influenced by changes in the mortality from other causes.

A PMR study reported from the UK[20] found significantly increased PMRs for death from all cancers (1.21), lung cancer (1.34), and "accidents, poisoning, and violence" (1.15) at the 1% level. Deaths occurring in England and Wales were used as the comparison population.

A PMR study of construction workers in the USA[9] analysed occupation and industry codes on death certificates from 19 states to evaluate mortality risks among people usually employed in the construction industry. The mortality of the experience of construction workers was compared with that of all workers in those states. Significant excess PMRs were observed for all cancers, many site specific cancers, and falls.

A recent PMR study in the USA which evaluated mortality patterns among all male construction workers in North Carolina,[21] reported significantly increased mortalities from lung cancer (PMR = 1.13), transportation accidents (PMR = 1.06), and accidental falls (PMR = 1.32). The PMRs were based on North Carolina male death rates and USA death rates.

In summary, this report presents information on the mortality patterns of construction workers by individual work trade. Because of the healthy worker effect and limited power of the study, the real risks were difficult to detect by means of the SMR technique based on the general population. The present study suggests that more detailed investigations which would include some minor job classifications should be undertaken.

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Answers to multiple choice questions on *Epidemiological assessment of health effects from chemical incidents* by P Cullinan on pages 568–572

(1) true; (2) false; (3) false; (4) false
(5) true; (6) false; (7) true; (8) false