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Original Article

The Current State of Workers' Pneumoconiosis in Relationship to Dusty Working Environments in Okayama Prefecture, Japan

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This study involved the examination of 1,006 chest x-ray films of workers from the industries devoted to shipyard welding, stone grinding, and refractory crushing in southern Okayama prefecture. Of the reviewed films, analysis was focused on subjects with a profusion rate of 0/1 as well as pneumoconiotic subjects (exhibiting profusion rates of 1/0 or greater) in order to discover cases in the beginning stages. One-hundred-and-seventy-four films illustrated a profusion rate of 0/1 or greater, and the proportion of this profusion rate was revealed to be highest in shipyard welders. Even some workers under 40 years of age were found to have already developed pneumoconiosis. Of these 1,006 subjects, 30 volunteers permitted us to measure their personal dust exposure concentrations. The measured concentration of the shipyard welders' dust exposure (respirable dust; 3.3-86.3 mg/m^3, total dust; 7.5-117.0 mg/m^3) was higher than those of the other 2 industries. Statistical differences among the industries were observed in the respirable dust concentrations. A statistically significant positive correlation was demonstrated between the working duration in dusty environments and the rate of profusion. The present findings suggest the need for taking adequate measures in Okayama in order to prevent workers from developing, or to help retard the progression of, pneumoconiosis.

Key Words: pneumoconiosis, profusion, dust exposure, shipyard welder, Japan

Pneumoconiosis is known as one of the leading occupational diseases caused by inhalation of dust particles for prolonged periods. In Japan, the incidence of pneumoconiosis is said to have decreased in recent years through improvement in working environments, but new cases of pneumoconiosis or its complications still number over 1,000 every year [1]. The especially increasing prevalence of pneumoconiosis among arc welders is becoming a problem that is yet to be solved.

In Okayama prefecture are some industries, for example, firebrick making, stone products manufacturing, and shipbuilding, which involve exposure to dust. Recently, it has come to our notice that more and more new cases are seen in retired dust-exposed workers, implying that they had developed pneumoconiosis at work, though radiographic abnormalities during periodic screen-

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ings had failed to alert doctors to these individuals' actual conditions. We attempted to assess the current status of pneumoconiosis in Okayama prefecture, recognizing, however, a lack of official statistical data available concerning the exact number of pneumoconiotic patients at present. Even the data regarding new annual cases are inaccurate because approximately half of the workers with dust exposure have failed to take legitimate health examinations for pneumoconiosis (unpublished data). There is little information on the actual extent of occupational dust exposure to workers [2-4] who have exhibited limited findings in their chest radiographs. We therefore conducted the present study in order to determine the prevalence of pneumoconiosis, particularly paying attention to a potential pre-pneumoconiotic group. We also assessed the working environments of dusty workplaces within Okayama prefecture.

Subjects and Methods

Interpretation of chest x-ray films. In Japan, a mandatory health examination for pneumoconiosis is performed every 1 to 3 years (as determined by work and health conditions) in people who are by definition occupationally exposed to dust particles according to the Pneumoconiosis Law. This study examined 1,006 chest x-ray films of workers from the industries of shipyard welding, stone grinding, and refractory crushing in southern Okayama prefecture. These industries accounted for 55% of the total dust-exposed workers in the prefecture (unpublished data). The films were taken during health examinations for pneumoconiosis from 1999-2000 and were reread by 2 specialists in pneumoconiosis independently. Diagnoses of pneumoconiosis were based on the 1982 Japanese Classification of Radiographs of Pneumoconioses [5] that agreed with the ILO 1980 International Classification of Radiographs of Pneumoconiosis in regard to category [6]. The final determinations were made by mutual agreement of the 2 readers. Of the 1,006 films, we analyzed those illustrating profusion categories of 0/1 or greater, putting particular emphasis on the profusion rate of 0/1 subjects that are not primarily considered as pneumoconiotic cases and that have never drawn any attention according to official surveys but have nonetheless exhibited a higher probability of developing pneumoconiosis.

Measurement of personal dust exposure. Of the 1,006 subjects, 30 volunteers, 10 shipyard welders, 10 stone grinders, and 10 refractory crushers allowed us to measure their personal dust exposure concentrations using personal dust monitors (model: PS-43, Sibata Scientific Technology Ltd., Tokyo, Japan). Air samples were collected from the breathing zone, and the sampling flow rate was 1 L/min. The mean (range) sampling time was 58 (31-70) min and the cut-off value was 7.07 μm, which meant particles below this value were considered respirable dust. Results were evaluated by the Occupational Exposure Limits (OELs) for respirable dust and total dust, which were published by the Japan Society for Occupational Health, and upper limits for dust, including silica, were calculated using the following equations [7]:

$$\text{Respirable dust exposure limit (mg/m}^3\text{)} = \frac{2.9}{0.22 \times (\%\text{ free silica}) + 1}$$

$$\text{Total dust exposure limit (mg/m}^3\text{)} = \frac{12}{0.23 \times (\%\text{ free silica}) + 1}$$

Personal information on age, tenure of dust-affected work, working hours per day, usage of protective masks, and smoking habits were also obtained.

Statistical analysis. Data analysis was conducted by SPSS for Windows 10.0J [8], and a P value under 0.05 was considered statistically significant. Kruskal-Wallis test, Mann-Whitney U test, and Spearman's correlation coefficient were employed where appropriate.

Results

Current status of the prevalence of pneumoconiosis. Table 1 shows the characteristics of all reread films. One hundred and seventy-four films (17.3% of the total films) illustrated a profusion rate of 0/1 or greater. The percentages of profusion 0/1 films were 75.4%, 16.1%, and 53.1% in shipyard welders, stone grinders, and refractory crushers, respectively. The high profusion levels of 4A or 4B were seen in the stone grinders and the refractory crushers. Especially in the stone grinders, higher profusions such as those of 1/0, 1/1, 2/1, 2/2, and 3/2 existed almost in the same proportion (data not shown).

Fig. 1 demonstrates the distributions of 164 films with profusion rates of 0/1 and 1/0 or greater by age (10 films

Table 1 Characteristics of the reviewed films

Occupation	Number of Workplaces	Number of Films	Profusion 0/1 or greater[a]	Profusion 1/0 or greater[a]	Profusion 0/1 in 0/1 or greater[b] (%)
Shipyard welder	23	791	69(8.7)	17(2.1)	75.4
Stone grinder	10	107	56(52.3)	47(43.9)	16.1
Refractory crusher	33	108	49(45.4)	23(21.2)	53.1
Total	66	1,006	174(17.3)	87(8.6)	50.0

[a], Data are presented as the number of the reviewed films; the values in parentheses represent percentage. [b], Data are presented as percentage of profusion 0/1 in profusion 0/1 or greater.

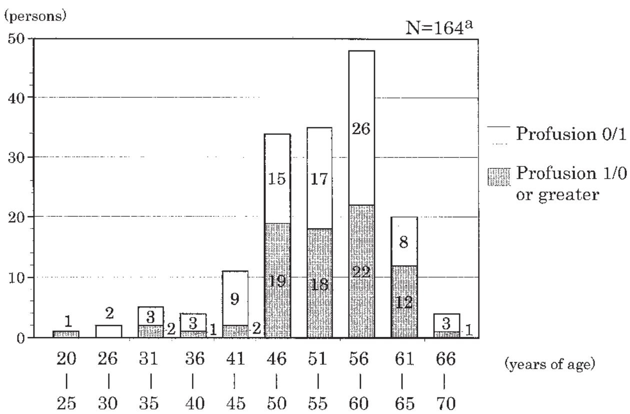

Fig. 1 Distribution of pneumoconiosis cases by age. Values in the bar represent the number of cases. [a], Ten out of 174 cases were excluded because the information regarding their ages was unavailable.

were excluded because of lack of information regarding age). The proportion of pneumoconiosis cases did not increase with age. Seven percent of the cases were found in lower age categories — less than 40 years old, in which 33.3% had already developed pneumoconiosis, all of them were shipyard welders or stone grinders.

Personal dust exposure concentration. Measurement of personal dust exposure was performed from December 2000 to May 2001. Shipyard welders were working outdoors, while on the other hand stone grinders and refractory crushers were working indoors. The workers, voluntarily participating in the measurement, were all male with the exception of one female. Their mean (range) age was 49 (27–62) years old, tenure of dust-affected work 22 (1.3–45) years, and working hours 7.7 (7.0–10) h per day. The proportions of smokers, ex-smokers, and non-smokers were 63.3%, 16.7%, and 20.0%, respectively. Sixty percent of the shipyard welders were current smokers, as well as 60% of the stone grinders, and 70% of the refractory crushers. There was no difference in proportion of current smokers among the 3 groups. Mean (range) Brinkmann index (values calculated by the number of cigarettes smoked per day × smoking years) of the smokers was 558 (160–1200). All workers except one had worn protective masks while working.

Table 2 shows personal dust exposure levels by occupation. Exposure levels of 83.3% of the workers examined exceeded the corresponding OELs of their particular occupation in respect to both respirable and total dust concentrations. Only subjects examined from the field of refractory crushers exhibited exposure concentrations below the OELs established for their occupation. The Kruskal-Wallis test and Mann-Whitney U test were employed to analyze the difference in dust concentration among each type of occupation. Statistical differences among the industries were not observed in terms of total dust concentrations but in the respirable dust concentrations. The measured concentration of the shipyard welders' dust exposure was higher than those of the other 2 industries. To minimize the difference in the kinds of dusts generated in various workplaces, the measured exposure concentrations were divided by OELs, and hereafter referred to as adjusted dust indices. There were significant differences in adjusted respirable dust indices between each industry. Ratios of respirable dust concentrations to total dust concentrations were also calculated and the value of the shipyard welders were significantly higher than those of the others ($P < 0.01$).

Association between dust exposure and profusion rates. The association between dust exposure and profusion rates was evaluated by means of the adjusted dust exposure values calculated as follows:

Adjusted dust exposure value = Adjusted respirable or total dust indices × Working hours per day (hours) × Tenure (years)

Spearman's correlation coefficients were calculated

Table 2 Personal dust exposure concentration by occupation

Dust concentration	Occupation: Shipyard welder (n = 10)	Stone grinder (n = 10)	Refractory crusher (n = 10)
Occupational exposure limit[a] Respirable dust (mg/m^3)	1	0.5	1.3 2.0 (0.6—2.5)
Total dust (mg/m^3)	4	2.0	5.4 8.0 (2.3—10.4)
(Significance: welder vs crusher **, welder vs grinder **)			
Measured respirable dust concentration (mg/m^3)	16.4 14.0 (3.3—86.3)	2.9 3.8 (0.5—14.2)	2.0 1.7 (0.5—7.6)
Measured total dust concentration (mg/m^3)	24.4 19.5 (7.5—117.0)	14.3 13.5 (4.6—75.2)	10.6 10.3 (3.6—43.5)
(Significance: welder vs crusher **, welder vs grinder *, grinder vs crusher *)			
Adjusted respirable dust index	16.4 14.0 (3.3—86.3)	6.0 8.0 (1.0—29.5)	1.5 1.6 (0.2—8.1)
Adjusted total dust index	6.1 4.9 (1.9—29.3)	7.2 6.8 (2.3—38.0)	2.0 3.4 (0.4—17.6)

All data are expressed as geometric mean and median (range). [a], Data on occupational exposure limit for shipyard welders and stone grinders are expressed as single values. $^*P < 0.05$, $^{**}P < 0.01$ (Mann-Whitney U test).

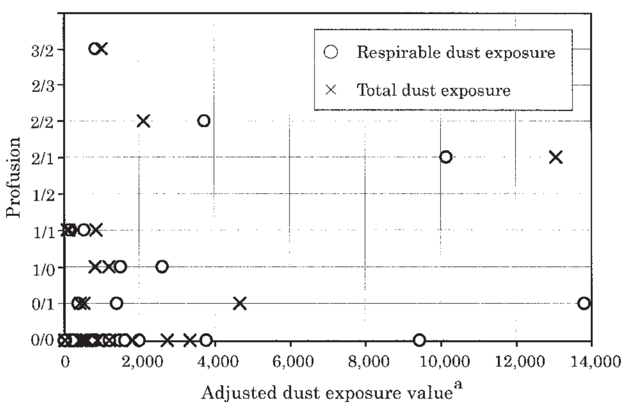

Fig. 2 Association between adjusted dust exposure and profusion. [a], Values were calculated by means of the following equation: Adjusted dust exposure value = Adjusted respirable or total dust indices × Working hours per day (hours) × Tenure (years). Four out of 30 cases were excluded because of incomplete data.

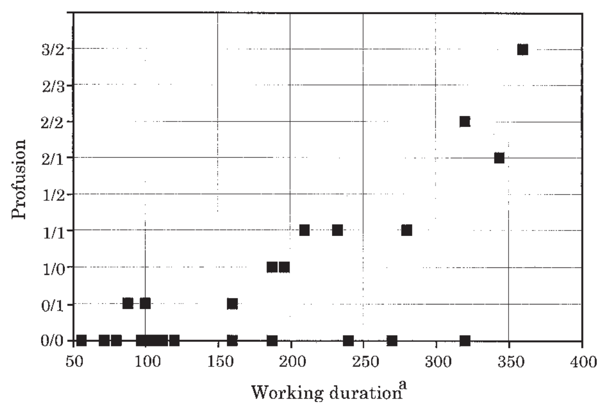

Fig. 3 Association between working duration and profusion. [a], Values were calculated by means of the following equation: Working duration = Working hours per day (hours) × Tenure (years). Four out of 30 cases were excluded because of incomplete data.

between the estimated respirable or total dust exposure and the profusion rates of the workers whose dust concentrations were measured (Fig. 2). The correlation coefficients for respirable and total exposure were 0.149 and 0.223, respectively, and they were not significant. However, the correlation coefficient (r = 0.574) revealed a statistical significance (Fig. 3) when we examined the relationship between total dust-affected working duration (evaluated by the following formula) and the rates of profusion.

Working duration = Working hours per day (hours) × Tenure (years)

In addition, the association between the Brinkmann index and profusion rates was not statistically significant.

Discussion

On the whole, the incidence of pneumoconiosis has recently decreased in Japan, but is increasing among arc welders [1]. According to the data reported by the Health and Welfare Statistics Association, pneumoconiosis and its complications still rank second among annually occurring occupational diseases [9]. In this survey, we studied the prevalence of pneumoconiosis and the current conditions of dust-affected workplaces in southern Okayama prefecture.

By screening the chest x-ray films of workers in dust-affected workplaces, we found that 17.3% of the total number of reviewed films revealed radiographic abnormalities, of which approximately half showed a rate of profusion of 0/1. Sixty percent of these cases showing a 0/1 profusion rate came from shipyard welders. This percentage of abnormalities in the welders group lends credence to the current condition in Japan in which welders are increasingly at more risk of contracting pneumoconiosis than are worker of other occupations [1]. In the current process of health examination for pneumoconiosis, chest x-ray films are first read by ordinary physicians, and if the films are categorized as "no finding of pneumoconiosis" in this stage, they will not then be read by specialists in pneumoconiosis and will therefore be ignored. However, these non-pneumoconiotic films can be classified into 2 groups: one is the "no finding at all" group, classified as 0/0 profusion or less, while the other is "few findings but not yet pneumoconiotic" group, referred to as 0/1 profusion. Members of the latter group may develop pneumoconiosis if they are poorly controlled. To our knowledge, the 0/1 profusion cases have not been an issue in either the published literature or for occupational health professionals specializing in pneumoconiosis prevention. However, the present study provided evidence that profusion rates, one of the factors indicating the extent of pneumoconiosis, correlated with estimated dust exposure duration rather than cumulative respirable or total dust amount, as demonstrated in Fig. 2 and 3. This means the person whose x-ray films illustrated profusions of 0/1 have a stronger possibility of developing pneumoconiosis during long periods of exposure to dust particles. It is commonly known that most pneumoconiosis is neither reversible nor curable; therefore, taking appropriate measures at a very early stage is imperative for prevention of further probable disease progression, and chest x-ray evidence of profusion 0/1 should be considered as an indicator of the necessity of monitoring action. We recommend that identification of workers at high risk for developing pneumoconiosis should begin as soon as they display a profusion rate of 0/1.

Liou *et al.* reported that the prevalence of pneumoconiotic abnormalities was 14.4% in workers who were employed in dust-affected environments for more than 10 years, 5.1% for 5–10 years, and 2.0% for less than 5 years [10]. In the present findings, some pneumoconiotic cases existed among workers under 40 years old, even as young as in their 20's, though information on the dust exposure tenure of the persons whose films were screened was not available. It has been reported the duration from initial dust exposure to radiographically detectable opacities is usually 10 years or more [11], but pneumoconiosis can sometimes produce respiratory symptoms, and death may occur within 5 years [4]. Therefore, the above-mentioned cases of our study need close follow-up.

In regard to the state of dust exposure, we noticed that 83.3% of the workers had amounts of respirable and total dust exposure exceeding the OELs. This finding indicates the inadequacy of managing the dusty working environments of these industries. Therefore, an enhancement of dust exposure monitoring and control is essential in these workplaces. Furthermore, our study also demonstrated that the respirable dust concentration in the shipyard welders was the highest of the 3 groups, even though they were working outdoors. At present, the Working Environment Measurement Law of Japan does not require dust monitoring in shipyards, and this may possibly lead employers and employees to neglect prevention of dust generation in the working environment. When we visited the shipyard after making an appointment, all welders were observed to wear protective masks. But it is uncertain whether they wear them all the time, especially during the summer. The uncertainties of adequate mask protection might partly explain why there are many cases of welders' pneumoconiosis in Japan. In general, the respiratory effects of welding are considered reversible if exposure to dust is discontinued. However, arc welders' pneumoconiosis is sometimes accompanied with shortness of breath, cough, and interstitial fibrosis, and even causes death [12]. Additionally a decline in the rate of lung function was found to be smaller in welders who used local exhaust ventilation or personal protection compared with those who did not [13], and the deterioration of lung function did not appear to improve during the period of follow-up if exhaust ventilation was not used [14].

A study revealed that only 19.1% of the workers had appropriate knowledge of the hazards and health effects induced by dust particles [3]. In this survey though almost all workers had worn masks, we met a worker whose mask was full of dust and had completely lost its effectiveness, and who did not know that the filter on the mask should be replaced when its function had deteriorated. So far, there has been no information available on the general conditions of each dust-exposed workplace, such as the size of the work area, location, and adequacy of ventilation, and regarding personal protective devices, such as the frequency of mask filter replacement and the availability of replacement filters. However, such information is of the utmost importance for protecting workers against dust exposure. Thus it is vital that the proper administrative authorities fully disseminate this information to workers in all high-risk industries. According to the Pneumoconiosis Law of Japan, preventing dust-exposed workers from developing pneumoconiosis is among the highest priorities in protecting the health of the workers, and it requires every effort of the local Labor Bureau, the health professionals, the employers, as well as the employees in supervising and controlling the dust levels of the working workplace, and in providing information on the health effects of dust exposure. We, therefore, strongly recommend that a regular site visits to the workplaces be carried out by officials from the local Labor Bureau and by occupational health professionals.

Results of this study may not be generalizable to dust-affected working environments as a whole because the workplaces or workers observed in this study were small in number and did not represent a random sample of all workplaces in Okayama prefecture that involve dusty working environments. Moreover, since information regarding the past exposure levels of these subjects was not available in the present survey, and the environments of some workplaces might have been improved in recent years, the current dust exposure levels of the employees may possibly not reflect precise estimation of cumulative dust exposure. Also, the sampling time for personal dust exposure was relatively short (averaging 1h). Though it is desirable to determine the 8-h time-weighed average of exposure concentrations, Kumagai *et al.* have reported that occupational exposure conditions can be adequately evaluated within a sampling period of 1h [15].

In conclusion, the number of pneumoconiotic cases, particularly in arc welders, can be decreased if more attention is paid to profusion 0/1 cases which are not read in official pneumoconiosis examinations, if masks are worn properly by all workers, and if working environments are improved. A preventive intervention study in Okayama is under consideration.

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