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Lung cancer mortality update and prevalence of smoking among copper miners and smelters

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Objectives The aim of this investigation was to study the cancer mortality of Chinese copper miners and smelters further, with particular reference to that from lung cancer, and smoking prevalence.

Methods From an earlier follow-up (1970—1985) of the mortality of the two cohorts, all new death cases registered since 1985 were recorded, and the mortality analysis was extended through 1992. A questionnaire survey of smoking habits was carried out in three samples, randomly chosen from the copper miners (N = 1125), smelters (N = 603), and local residents (N = 1517) of Tongling city.

Results Lung cancer was significantly increased among the copper miners [standardized mortality ratio (SMR) 152, 95% confidence interval (95% CI) 123—187], but not among the copper smelters (SMR 102, 95% CI 53—178). Smoking was more prevalent among copper miners than among local male residents (71.7 versus 64.3%, $P < 0.001$), whereas among the smelters it was significantly less prevalent (57.4 versus 64.3%, $P < 0.005$). Similar patterns were found for the average number of cigarettes smoked daily among the miners (21.6 ± 7.2), smelters (15 ± 7.1), and local male residents (19.2 ± 7.3).

Conclusions In addition to occupational exposures, cigarette smoking may partly play a role in influencing mortality from lung cancer among Chinese copper miners and smelters.

Key terms cancer risk, cigarette smoking, cohort study, occupational exposure.

Copper miners (N = 7031) and copper smelters (N = 1965) were studied longitudinally in Tongling city (China) between 1970 to 1985. We have previously reported that, compared with the general population of Tongling city, there was an increased risk of lung cancer for the copper miners [standardized mortality ratio (SMR) 147, $P < 0.05$], but not for the smelters (SMR = 90, $P > 0.05$), although the overall cancer mortality of the latter group was high (SMR 148, $P < 0.05$) (1, 2). In this paper we report an extension of the mortality analysis up to 1992, together with the results of a survey of the smoking habits of the cohorts and of the general population.

Subjects and methods

Two cohorts of subjects were recruited. The methods have been described in detail elsewhere (1, 2). In brief, the two cohorts consisted of all male workers in copper mines and a smelter factory in Tongling, China. These

men had worked for at least one year from 1 January 1969 to 30 June 1985. The occupational records were obtained from the departments of personnel or labor and salary. Information on each subject was retrieved from the records, including name, date of birth, dates of starting and leaving employment, descriptions and dates of all jobs undertaken, and vital status. The death certificates were copied from the local hospitals. Their mortality between 1970 and 1985 was compared with that of Tongling city residents. From 1985, the data bases of two cohorts have been stored in a computer, and all new deaths in the two cohorts have been reviewed prospectively and put into data bases. Standardized mortality ratios were calculated. The statistical significance of the standardized mortality ratio was tested, and the 95% confidence intervals (95% CI) were obtained on the assumption of a Poisson distribution (3).

In 1990—1991, a questionnaire survey of smoking habits was sent to three representative samples,

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randomly chosen from copper miners, smelters, and local residents of Tongling city. The numbers of subjects were 1125, 603, and 1517, respectively. These subjects were selected by cluster sampling methods (4). The selection was based on a list of the subjects' work units within cohorts. Using such cluster sampling, we could collect the data easily. The subjects were interviewed with questionnaires including name, date of birth, and duration and amounts of cigarettes smoked. The difference in the smoking rates between the groups were examined with a chi-square test (5). We did not include the deceased subjects to avoid some potential recalling bias. The proportion of deaths was 17% for the copper miners and 8% for the copper smelters. We visited the subjects at their homes, if necessary, to obtain a 100% response rate for the questionnaires.

Results

There was an excess of mortality for all sites of cancer among the copper miners and copper smelters (table 1). The risk of lung cancer among the copper smelters was not significant (SMR 102, 95% CI 53–178), while there was a significant increase for liver cancer (SMR 178, 95% CI 105–281). The standardized mortality ratio for lung cancer among the copper miners was significantly elevated to 152, and the miners also had an increased

risk of death from stomach cancer (SMR 141, 95% CI 116–169).

Of the 1125 interviewed miners, 807 were smokers, while there were 346 smokers among the 603 smelters. The prevalence of smoking among the copper miners was higher than that of the local male residents (71.7 versus 64.3%, $P < 0.001$), but the prevalence of smoking among the copper smelters was significantly lower (57.4 versus 64.3%, $P < 0.005$) (table 2). Similar patterns were found for the average number of cigarettes smoked daily by the miners [21.6 (SD 7.2)], smelters [15 (SD 7.1)], and local male residents [19.2 (SD 7.3)].

Discussion

The Tongling copper mine is one of the largest and oldest copper mines in China. It was expanded to large-scale production after 1950. In 1953, the Tongling smelter factory was built to accommodate the copper mineral ores. During the 1950s, both of these facilities employed a larger number of workers, administered by the Tongling color metal company. These workers had almost the same characteristics, such as birth place, education, economic status, age, and year at the time of starting work in the mines and factory. They were the majority of subjects in the two cohorts, respectively. Therefore a comparison of the standardized mortality ratios of the

Table 1. Cancer mortality update from 1970 to 1992.

	New cases since 1985						All cases					
	Miners			Smelters ^a			Miners			Smelters ^a		
	Observed deaths (N)	Standardized mortality ratio	95% confidence interval	Observed deaths (N)	Standardized mortality ratio	95% confidence interval	Observed deaths (N)	Standardized mortality ratio	95% confidence interval	Observed deaths (N)	Standardized mortality ratio	95% confidence interval
All sites of cancer	201	134**	116–154	21	131	81–200	397	129**	117–142	69	142**	111–180
Esophagus	35	134	93–186	3	88	18–256	66	125	97–159	13	166	88–284
Stomach	45	137*	100–183	4	84	23–214	114	141**	116–169	21	147	91–225
Liver	41	107	76–145	5	156	50–364	67	99	77–126	18	178*	105–281
Lung	47	156**	115–208	7	113	45–233	89	152**	123–187	12	102	53–178

^a Data up to December 1991.

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

Table 2. Smoking prevalence^a by 10-year age groups.

Age (years)	Copper miners			Local residents			Copper smelters		
	Number	Smokers		Number	Smokers		Number	Smokers	
		N	%		N	%		N	%
20–29	77	41	53	140	33	24	36	11	31
30–39	453	292	64	479	276	58	259	147	57
40–49	221	170	77	532	412	77	193	115	60
50–59	277	234	84	248	172	69	77	46	60
60–69	93	67	72	106	76	72	36	27	75
70–79	4	3	75	12	6	50	2	0	0
Total	1125	807	71.7	1517	975	64.3	603	346	57.4
	$\bar{d} = 0.081$		$S_{\bar{d}} = 0.018$				$\bar{d} = -0.071$		$S_{\bar{d}} = 0.023$
	$\chi^2 = 20.02$		$P < 0.001$				$\chi^2 = 9.87$		$P < 0.005$

^a The smoking prevalences of the miners and smelters were both compared with that of local male residents.

two groups seemed suitable. In the underground of the mines, the level of radioactivity was $0.55 \cdot 10^{-11}$ curie $\cdot$ l $^{-1}$, which was under the occupational exposure limit of China, and the dust density was approximately $10 \text{ mg} \cdot \text{m}^{-3}$ on the average. Earlier estimates of the arsenic level in the work environments of the smelter factory showed no significant difference from the local living environment; the Tongling copper mineral ores contained almost no arsenic. But after the 1970s, the ores from other copper mines were smelted in this factory, and the arsenic level showed an increase of two to four times in this work environment over a control area.

By the end of the follow-up, it was found that 368 miners and 141 smelters could not be traced and the rates lost to follow-up were 5% for the miners and 7% for the smelters. In the investigation of workers' smoking habits, however, we were able to interview all these subjects, including the retired ones who were visited in their homes, to avoid any loss. The questionnaire study included the living subjects; it used no data on the smoking habits of the subjects who died before the investigation in order to decrease some recalling bias. Nevertheless, the randomized sampling methods were the same for all three groups, and the smoking habits of these subjects should still be comparable. The results reflect the differences of the smoking habits between the copper miners and smelters.

In earlier results from 1970 to 1985, the mortality from lung cancer among copper smelters was not high (5 observed versus 5.56 expected), probably because the cohort was younger. This cohort was followed through 1991, but no significant change in the mortality pattern of lung cancer was observed among these workers. We found that there was a higher risk of lung cancer among the copper miners (89 observed versus 58.55 expected). The employees in the Tongling copper mines and smelting factory could smoke freely. When the copper smelters were working, however, smoking was restricted due to the evil-smelling fumes from copper smelting. In addition, the copper miners tended to smoke more frequently during inactive periods underground, the hazards of smoking could have been increased because of poor ventilation in the underground workplace.

Cigarette smoking is a risk factor for lung cancer, chronic obstructive pulmonary disease, coronary heart disease, and stroke (6). It is commonly believed that men in Asian countries tend to smoke heavily, and the prevalence of smoking could reach 68.9% in China (7). Numerous studies have shown that cancer caused by occupational exposure could be compounded by smoking (8–12). A recent cohort study of occupational cancer in China indicated that smoking can synergistically increase the risk of occupational lung cancer (13). Many epidemiologic studies of copper smelters have shown an excess of lung cancer (14–18). The Swedish results revealed

an increased risk of lung cancer in the lowest arsenic exposure categories. A higher proportion of cigarette smoking among these smelters may have contributed to these observations (18–20).

Arsenic exposure in one copper-smelting factory was considered a factor promoting cancer (17). Our study showed a lower prevalence of smoking among smelters than that of the comparison group. Perhaps this lower prevalence could explain the fact that there was no excess of lung cancer mortality among our copper smelters. In other words, it could have led to negative confounding (21). Some studies have indicated that radioactivity can be a risk factor for lung cancer among metal miners (8, 10, 22, 23). In the Tongling copper mines, the level of radioactivity was below the occupational exposure limit (2). These miners were exposed mainly to silica dust. Silica is suspected of being a carcinogen (24). In addition to the occupational exposures (25), we believe that cigarette smoking could have played a role in the excess of lung cancer due to the high prevalence of smoking found among the copper miners, although this effect of smoking on the lung cancer of the miners may be partial because it did not entirely account for the standardized mortality ratio being more than 150 for lung cancer (21). Therefore, a nested case-referent study needs to be carried out to estimate the exact effects the smoking had on lung cancer among the copper miners. The results of the smoking habits of the copper miners and smelters in this investigation could provide clues to their different mortality from lung cancer. A campaign promoting smoking cessation, especially in workshops, should be advocated for workers in the Tongling copper mines.

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