RESPIRATORY FUNCTION IN CADMIUM BATTERY WORKERS

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SYNOPSIS

The pulmonary function of 45 battery workers exposed to cadmium were studied. Another 21 control subjects matched by sex, age, ethnic group and smoking history were similarly examined. Blood and urine cadmium concentrations of the battery workers were considerably higher than the control levels. These were consistent with the high cadmium-in-air levels in the battery factory. The vital capacity (VC), total lung capacity and transfer factor were lower among the female battery workers. They also had much higher cadmium exposure than their male counterparts. In the females, with increasing employment time and urine cadmium levels, the prevalence of respiratory symptoms increased. The results suggest that in the absence of smoking, chronic cadmium exposure may be associated with a mild restrictive defect.

INTRODUCTION

Much has been reported about the effects of cadmium (Cd) exposure on the respiratory system among workers in industry (1). Respiratory symptoms can be observed in acute exposures to high concentrations of Cd as well as in chronic low exposure situations.

Previous reports (2, 3) on the extent of Cd exposure in an alkaline storage battery factory dealt with the possible effects on the kidneys, including β2-microglobulin excretion. In the present study, the pulmonary function of the Cd-exposed workers in the same factory was examined.

METHODS

The study covered 36 female and nine male battery workers. The females were mainly involved in the plateforming, spotwelding and tabletmaking processes in the electrode assembly section. The males were mainly supervisors and machine setters, and had lower Cd exposure than the females. The Cd exposure histories of the battery workers ranged from a few months to just over eight years.

Fifteen female and six male non Cd-exposed subjects (controls), matched as previously (2, 3) by age, ethnic group and smoking history, were drawn from two nearby electronic factories. Non-exposure to Cd was confirmed by history. None of the females smoked.

As in the previous study (3), the battery workers included six original female spotwelders with high blood Cd levels and one male assistant supervisor who were transferred to other sections six months prior to the present study.

Blood and urine Cd determinations as well as environmental assessments were as reported previously (3).

Forced expiratory volume in one second ($FEV_{1.0}$), forced vital capacity (FVC) and maximum midexpiratory flow rate (MMFR) were measured in the standing position with a Warren E Collins spirometer. Vital capacity (VC), residual volume (RV) and functional residual capacity (FRC) were measured in the sitting position, using the rebreathing helium dilution method with a Warren E Collins modular lung analyser. Total lung capacity (TLC) was derived from the VC and RV. Transfer factor (DLCOss) was measured by the steady state end tidal sampling method using a Morgan CO infrared gas analyser.

In addition, full size posteroanterior chest x-rays, haemoglobin (Hb) estimation and height and weight measurements were taken. The presence of respiratory symptoms (viz cough, breathlessness and chest pain), if any, was noted.

RESULTS

The total airborne Cd dust concentrations in the electrode assembly section were high (Table 1). The 95% lower confidence limits exceeded the Threshold Limit Value (TLV) of 0.05 mg/m^3 and some of the levels exceeded the Short Term Exposure Limit (STEL) of 0.2 mg/m^3 (4). The workers were provided with suitable respirators.

The blood and urine Cd concentrations were spread over a wide range and thus log normal distributions were assumed in analysing all data. Consistent with the high Cd-in-air levels, the blood and urine Cd concentrations of the battery workers were considerably higher than those of the controls ($p<0.001$ for all comparisons) (Table 2). The average $\bar{X}g$ blood Cd concentrations were 87.59 and 56.10 μg/l for the female and male battery workers respectively, while the corresponding urine Cd levels were 50.08 and 12.40 μg/gm creatinne (Cr) respectively. The six female battery workers who were transferred to Cd-free jobs still had high blood and urine Cd levels — $\bar{X}g$ of 136.42 μg/l and 75.13 μg/gm Cr respectively.

TABLE 1
CADMIUM-IN-AIR CONCENTRATIONS

Process	No of Samples	Cd-in-air level (mg/m^3) (Total dust)			
		Geometric Mean	Geometric SD	LCL*	UCL*
Tablet making	4	0.27	2.60	0.06	1.23
Plateforming	4	0.18	1.32	0.11	0.28
Spotwelding	4	0.19	1.35	0.12	0.31

* LCL and UCL: 95% lower and upper confidence limits.

TABLE 2
BLOOD AND URINE CADMIUM IN BATTERY WORKERS AND CONTROLS

Measurement*	Battery Workers	Controls
Female		
No of subjects:	36	15
Blood Cd:	87.59	4.06
	(1.79)	(1.44)
Urine Cd:	50.08	1.57
	(1.89)	(3.06)
Male		
No of subjects:	9	6
Blood Cd:	56.10	5.27
	(1.79)	(1.52)
Urine Cd:	12.40	1.12
	(2.72)	(2.23)

* $\bar{X}g$ and SDg (in brackets) are given;
Blood Cd in μg/l; Urine Cd in μg/gm Cr

The battery workers and controls were comparable with regard to height and weight (Table 3). The female battery workers had lower Hb than the female controls ($0.05 > p > 0.02$). Hb decreased with increasing blood Cd level ($0.05 > p > 0.02$) among the females. However, Hb was not significantly associated with any of the lung function parameters studied. Chest X-rays revealed no significant abnormalities.

The results of the pulmonary function tests are shown in Table 4. The female battery workers had significantly lower VC, TLC and DLCOss than their controls (all $0.05 > p > 0.02$). Although these indices were also lower in the male battery workers, compared to their controls, the differences were not statistically significant. The RV, FRC and $FEV_{1.0}$ of the battery workers were slightly but not significantly lower than their controls. Neither were there significant differences in $FEV_{1.0}$% (as a percentage of FVC).

TABLE 3
HEIGHT, WEIGHT AND HAEMOGLOBIN OF BATTERY WORKERS AND CONTROLS

Measurement*	Battery Workers	Controls
Female		
No of subjects:	36	15
Height (cm):	152.2	155.4
	(4.6)	(5.8)
Weight (kg):	52.6	58.3
	(11.4)	(14.7)
Hb (gm/dl):	12.7	13.5
	(1.0)	(1.3)
Male		
No of subjects:	9	6
Height (cm):	168.2	164.3
	(9.1)	(3.2)
Weight (kg):	61.7	53.8
	(10.7)	(8.11)
Hb (gm/dl):	15.2	15.3
	(0.8)	(0.6)

*: $\bar{X}$ and SD (in brackets) are given

The association between employment time (duration of Cd exposure) and lung function was not apparent, unlike those between employment time and blood and urine Cd levels (Table 5). Blood and urine Cd concentrations increased significantly with increasing employment time for both males and females ($p < 0.005$ for all comparisons). VC, TLC and DLCoss decreased with increasing blood and urine Cd concentrations but the relationships were not statistically significant.

Over 31% of the battery workers had respiratory symptoms compared to none among the controls, but the differences were not statistically significant (Table 6). With the larger sample females, it was possible to demonstrate a significant increase in symptom prevalence with increasing employment time ($0.05 > p > 0.025$) and urine Cd concentration ($0.025 > p > 0.01$). The association was not obvious in the case of blood Cd level.

The females with respiratory symptoms had higher blood and urine Cd levels than the asymptomatic females — $\bar{X}$g 93.00μg/l as against 28.06μg/l for blood Cd and 57.68μg/gm Cr as against 13.64μg/gm Cr for urine Cd (both: $p < 0.001$). There were no significant differences in lung function results between the symptomatic and asymptomatic females.

Except for one female with low TLC, none of the controls had low VC, TLC or DLCOss (ie, more than twice the standard deviation below the respective

TABLE 4
PULMONARY FUNCTION IN BATTERY WORKERS AND CONTROLS

Measurement*	Battery Workers	Control
Female		
No of subjects:	36	15
VC (% pred):	93.1 (16.5)	102.9 (13.1)
TLC (% pred):	85.3 (10.5)	92.5 (10.0)
RV (% pred):	80.7 (22.4)	81.5 (18.5)
FRC (% pred):	82.5 (16.1)	85.4 (9.6)
$FEV_{1.0}$ (% pred):	91.1 (11.2)	95.4 (18.1)
$FEV_{1.0}$%:	90.1 (6.9)	87.7 (5.8)
MMFR (% pred):	90.0 (20.3)	89.0 (15.8)
DLCOss (% pred):	76.2 (22.2)	88.8 (17.5)
Male		
No of subjects:	9	6
VC (% pred):	98.0 (10.6)	102.5 (6.9)
TLC (% pred):	94.1 (7.4)	99.2 (8.5)
RV (% pred):	92.4 (13.5)	108.3 (31.6)
FRC (% pred):	88.3 (12.8)	93.8 (17.2)
$FEV_{1.0}$ (% pred):	97.7 (8.7)	104.5 (6.6)
$FEV_{1.0}$%:	90.0 (9.4)	91.5 (5.3)
MMFR (% pred):	119.0 (35.1)	122.5 (35.3)
DLCOss (% pred):	79.2 (14.1)	88.0 (19.1)

*: $\bar{X}$ and SD (in brackets) are given.
Note: Lung function values (except $FEV_{1.0}$%) are expressed as % predicted (10, 11).

TABLE 5
PULMONARY FUNCTION AND BLOOD AND URINE CADMIUM LEVELS BY DURATION OF CADMIUM EXPOSURE

Measurement*	Duration of Cd exposure (years)		
	0	≤ 5	>5
Female			
No of subjects:	15	23	13
VC (% pred):	102.9 (13.1)	91.6 (10.2)	95.8 (24.4)
TLC (% pred):	92.5 (10.0)	84.3 (9.2)	87.1 (12.7)
RV (% pred):	81.5 (18.5)	76.3 (19.1)	88.3 (26.4)
FRC (% pred):	85.4 (9.6)	79.8 (16.1)	87.2 (15.6)
$FEV_{1.0}$ (% pred):	95.4 (18.1)	91.4 (12.5)	90.7 (9.1)
$FEV_{1.0}$%:	87.7 (5.8)	89.7 (7.5)	90.8 (5.9)
MMFR (% pred):	89.0 (15.8)	89.4 (22.8)	91.2 (15.8)
DLCOss (% pred):	88.8 (17.5)	75.7 (21.2)	76.9 (24.8)
Blood Cd (µg/l):	4.06 (1.44)	73.09 (1.83)	120.65 (1.46)
Urine Cd (µg/gm Cr):	1.57 (3.06)	41.95 (1.99)	68.51 (1.46)
Male			
No of subjects:	6	5	4
VC (% pred):	102.5 (6.9)	96.0 (12.1)	100.5 (9.5)
TLC (% pred):	99.2 (8.5)	93.6 (6.3)	94.8 (9.5)
RV (% pred):	108.3 (31.6)	86.2 (10.9)	100.25 (13.5)
FRC (% pred):	93.8 (17.2)	85.4 (10.1)	92.0 (16.5)
$FEV_{1.0}$ (% pred):	104.5 (6.6)	94.4 (9.8)	101.8 (5.6)
$FEV_{1.0}$%:	91.5 (5.3)	89.8 (7.0)	90.3 (13.0)
MMFR (% pred):	122.5 (35.3)	116.0 (31.4)	122.8 (44.1)
DLCOss (% pred):	88.0 (19.1)	81.8 (8.9)	76.0 (19.9)
Blood Cd (µg/l):	5.27 (1.52)	66.40 (1.44)	45.45 (2.19)
Urine Cd (µg/gm Cr):	1.12 (2.23)	11.15 (3.00)	14.16 (2.75)

*: $\bar{X}$ and SD (in brackets) are given for all test results except blood and urine Cd for which $\bar{X}g$ and SDg (in brackets) are reported.
Note: Lung function values (except $FEV_{1.0}$%) are expressed as % predicted (10, 11).

mean ($\bar{X}$) value of the control group expressed as % of predicted). Three (8.3%) of the female battery workers had low VC, four (11.1%) had low TLC and eight (22.2%) had low DLCOss. However, only two of these subjects (with low TLC and DLCOss) had respiratory symptoms. Four of them had less than one year's exposure to Cd but had blood Cd levels ranging from 23 to 79 µg/1. One male with low VC, had less than one year's Cd exposure and was asymptomatic. His blood Cd level was 36 µg/1. Another male had low TLC and was symptomatic. He had six years' Cd exposure and a blood Cd level of 61 µg/l.

DISCUSSION

The nature of the respiratory effects of chronic Cd exposure is still a subject of much debate. A number of studies seemed to show an association between chronic exposure to Cd fumes or dust and emphysema (1, 5). However, there are also reports with negative findings (1, 6).

In a review of recent literature, Lauwerys (6), concluded that the functional and morphological disturbances attributed to Cd have not been very consistent. He felt that, in the absence of acute over-exposure, the changes induced in the lung are usually mild.

However, Sakurai et al (7), in a study on Japanese Cd alloy workers, showed that chronic pulmonary changes can result without a history of acute or subacute Cd pneumonitis.

The findings in the present study indicate that there may be some association between chronic exposure to relatively high Cd levels and respiratory effects. Reductions in VC, TLC and DLCOss were demonstrated in the battery workers. This was evident especially in the females who had higher Cd exposure than their male counterparts. Among the females, the prevalence of respiratory symptoms increased with increasing employment time and urine Cd concentrations.

Smith et al (5) found that FVC decreased significantly with increasing urine Cd excretion and Cd expo-

TABLE 6
PREVALENCE OF RESPIRATORY SYMPTOMS* BY EXPOSURE DURATION AND BLOOD AND URINE CADMIUM LEVELS

Parameter	Female		Male	
	Total subjects	No with symptoms (%)	Total subjects	No with symptoms (%)
Battery workers	36	10 (27.8)	9	4 (44.4)
Controls	15	0 (0)	6	0 (0)
Cd exposure (years):				
0	15	0 (0)	6	0 (0)
≤5	23	6 (26.1)	4	1 (25.0)
>5	13	4 (30.8)	5	3 (60.0)
Blood Cd (μg/l):				
<10	15	0 (0)	6	0 (0)
10>100	21	6 (28.6)	8	3 (37.5)
≥100	15	4 (26.7)	1	1 (100.0)
Urine Cd (μg/gm Cr):				
<10	15	0 (0)	10	2 (20.0)
10>50	13	3 (23.1)	5	2 (40.0)
≥50	23	7 (30.4)	0	—

*: Subjects were considered symptomatic if one or more of the symptoms of cough, breathlessness or chest pain were present in the previous six months.

sure duration. No significant changes in $FEV_{1.0}$ and maximal mid-expiratory flow (MMEF) were noted. There was radiological evidence of mild to moderate fibrosis in 29% of the high Cd exposure group. Based on these results, the authors concluded that a mild restrictive defect was associated with chronic high Cd exposure. "Diffuse pulmonary sclerosis" has also been reported among female workers in the production of alkaline accumulators (Vorobjeva, 1957, as quoted by Friberg et al (1)).

However, Sakurai et al (7) demonstrated significant deterioration in FVC, $FEV_{1.0}$, peak expiratory flow, maximum expiratory flow rates at low volumes, $FEV_{1.0}$% and respiratory impedance in Cd workers with high exposures. A lower exposure group had reduction only in FVC and $FEV_{1.0}$. These authors suggested that the Cd-induced pulmonary effects are of the chronic obstructive type, mainly affecting the small airways.

Our findings seem to be in agreement with those of Smith et al (5), i.e. they point to a restrictive pattern. The absence of radiological changes and the lack of correlation between symptom prevalence and lung function indicate a mild functional impairment.

It is interesting to note that all our female Cd-exposed subjects were nonsmokers. The high exposure subjects in the study of Smith et al (5) were relatively light smokers, with only 76% smokers or exsmokers and an average of 5.6 cigarettes smoked per day. In the report by Sakurai et al (7), all the high exposure subjects were smokers or exsmokers, with an average of 16.4 cigarettes smoked per day.

Lauwerys et al (8) suggested that cigarette smoking may have a faster deleterious effect than chronic Cd dust inhalation. Stanescu et al (9) attributed their findings of generalised airway obstruction to long term smoking in their Cd exposed subjects. They concluded that in the presence of long term smoking, Cd may be responsible for a more pronounced functional impairment.

We are not certain of the exact role of cigarette smoking as a confounding factor in the study of chronic Cd effects on the lungs. However, it would appear that in the absence of a heavy smoking history, chronic exposure to relatively high Cd levels may result in a mild restrictive defect.

Since the present study, conditions in the battery factory have continued to improve with the implementation of further engineering control measures. It will be interesting to determine if the mild functional impairment found in this study are reversible.

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