

Electrophysiological study of subjects occupationally exposed to lead and with low levels of lead poisoning

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BORDO BM, FILIPPINI G, MASSETTO N, MUSICCO M, BOERI R. Electrophysiological study of subjects occupationally exposed to lead and with low levels of lead poisoning. *Scand j work environ health* 8 (1982): suppl 1, 142-147. The relationship between the length of exposure to lead, blood lead level (PbB), and peripheral nerve damage in a population occupationally exposed to low lead levels was evaluated. Sixty-two foundry workers were studied whose length of exposure ranged from 5 months to 10 a; their mean PbB in the last 2 a had not exceeded 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$). The referents were 27 hospital employees, of comparable ages, not occupationally exposed to lead. The electrophysiological examination consisted of the determination of the motor conduction velocity (MCV) of the median and peroneal nerves, sensory conduction velocity (SCV) of the median and sural nerves, and the latency of the T and H reflexes. The mean MCV, SCV and the amplitude of the sensory action potential (SAP) of the median nerve were significantly lower in the group of exposed workers than in the reference group. When the exposed subjects were divided into three groups according to length of exposure, no difference was observed between the three groups. When they were divided into different groups according to the maximum PbB (max PbB) value, the observed differences with respect to the reference groups were already present in those with a max PbB of $< 50\text{ }\mu\text{g}/100\text{ ml}$ ($< 2.4\text{ }\mu\text{mol/l}$), but were more evident in the subjects with a max PbB of $> 70\text{ }\mu\text{g}/100\text{ ml}$ ($> 3.4\text{ }\mu\text{mol/l}$). Within the group of subjects with a max PbB of 50-69 $\mu\text{g}/100\text{ ml}$ (2.4-3.3 $\mu\text{mol/l}$), the differences with respect to the reference values were more evident for subjects with a short length of exposure ($< 2\text{ a}$). The MCV of the median nerve correlated with the time since the PbB exceeded 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$). In conclusion, the electrophysiological changes observed in lead-exposed subjects do not seem correlated with the length of exposure. Such alterations seem more evident in those subjects whose PbB has been greater than 70 $\mu\text{g}/100\text{ ml}$ (3.4 $\mu\text{mol/l}$) at least once during the preceding 2 a and in those subjects who, at the time of the neurophysiological examination, have a PbB greater than 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$). The apparently greater sensitivity to lead in new employees, compared to workers with a longer exposure time, remains to be clarified.

Key terms: blood lead level, motor conduction velocity, sensory conduction velocity.

In spite of numerous studies that have appeared in the last 10 a, the subclinical peripheral nerve damage consequent to lead exposure is still an unsolved problem. The minimum level of lead exposure at which electrophysiological alterations ap-

pear is still under discussion. Furthermore, it has not been made sufficiently clear whether the electrophysiological changes are directly related to blood lead (PbB) values or rather to length of exposure.

The purpose of this study was to determine the extent to which the length of exposure and the PbB level are related to the values of electrophysiological parameters under low levels of exposure.

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Subjects and methods

The study was carried out with 62 of the 112 male workers in a secondary lead smelter. Only subjects with a mean PbB of less than 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$) in the last 24 months and with a length of exposure of less than 10 a were admitted to the study. As referents, 27 male employees in our hospital (maintenance workers) and not occupationally exposed to lead were recruited.

The exposed subjects and the referents underwent a neurological examination and were questioned about the presence of symptoms referable to peripheral neuropathy, diseases predisposing to neuropathy (diabetes, trauma, spondylarthrosis), alcohol consumption, and exposure to neurotoxic agents other than lead. We measured motor conduction velocity (MCV) of the median and peroneal nerves, sensory conduction velocity (SCV) of the median and sural nerves, and latency of the T and H reflexes.

Biological monitoring has been carried out in the smelter regularly since early 1978. It is based on the quarterly determination of PbB and zinc protoporphyrin (ZPP). The examination is repeated after one month if the PbB value exceeds 60 $\mu\text{g}/100\text{ ml}$ (2.9 $\mu\text{mol/l}$) and/or the ZPP exceeds 120 $\mu\text{g}/\text{ml}$ (19 $\mu\text{mol/l}$); whenever the PbB exceeds 70 $\mu\text{g}/100\text{ ml}$ (3.4 $\mu\text{mol/l}$), the subject is removed from exposure. With this type of monitoring it has been possible to maintain, in the last 2 a, mean PbB values equal to or less than 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$) with only sporadic elevations above 60 $\mu\text{g}/100\text{ ml}$ (2.9 $\mu\text{mol/l}$).

The work conditions of the smelter have improved in the last 10 a. In particular, at the end of the 1960s renovation of the installations began and has resulted in a progressive diminution of environmental lead and individual exposure; these renovations terminated in 1977.

The PbB and ZPP levels from the beginning of employment in the smelter are known for workers employed since the beginning of 1978. Of the other workers, arbitrarily subdivided into two groups (subjects employed at the smelter for 2 to 5 a and those employed between 5 and 10 a), we know only that the past exposure was higher than the present one, but

we know accurately only the exposure of the last 24 months.

The analysis was performed by comparison of the mean values of electrophysiological parameters. The statistical significance was assessed by use of Student's *t*-test.

Results

None of the examined subjects presented a clinical picture of peripheral neuropathy. Moreover, none had been affected by diseases predisposing to neuropathy, none drank more than 1 l of wine daily, and none was exposed to neurotoxic substances other than lead.

Table 1 reports the mean values of the electrophysiological parameters for the lead workers and the referents. The former, as compared with the latter, showed a significant decrease in median nerve MCV, SCV, and sensory action potential (SAP) amplitude and a significant increase in the distal latency of the peroneal nerve.

To evaluate the contribution of the duration of exposure in determining the observed differences, we compared the values of the electrophysiological parameters of the three groups of subjects with different lengths of exposure (table 2). No significant differences were observed among the electrophysiological parameters of the three groups.

The role of PbB was then analyzed. Lead workers were divided into three groups according to their maximum PbB in the last 2 a (table 3). It can be seen from table 3 that even in the group of workers who never had PbB values greater than 50 $\mu\text{g}/100\text{ ml}$ (2.4 $\mu\text{mol/l}$), the median nerve MCV and SCV and the distal latency of the peroneal nerve were modified with respect to the reference values. The same was observed for the 50–69 $\mu\text{g}/100\text{ ml}$ (2.4–3.3 $\mu\text{mol/l}$) group. For 11 workers whose PbB level exceeded 70 $\mu\text{g}/100\text{ ml}$ (3.4 $\mu\text{mol/l}$), at least once in the last 2 a, the median nerve MCV and peroneal distal latency were modified as in the other groups, whereas SCV and SAP amplitude of the median nerve were more reduced.

The pattern of the electrophysiological parameters, according to the maximum PbB value, was then separately considered for workers with a length of exposure of

less than 2 a and in those with an exposure period ranging from 2 to 10 a (table 4). In the group with a shorter exposure time, the subjects with a maximum PbB of 50–69 $\mu\text{g}/100\text{ ml}$ ($2.4\text{--}3.3\text{ }\mu\text{mol/l}$) had a significantly lower median nerve MCV and SCV than subjects with a maximum

PbB of less than 50 $\mu\text{g}/100\text{ ml}$ ($2.4\text{ }\mu\text{mol/l}$). In the group with the longest exposure time, only the SAP amplitude of the median nerve was different between the two subgroups with different maximum PbBs. Table 4 also shows that the subjects with a maximum PbB of 50–69 $\mu\text{g}/100$

Table 1. Means of the electrophysiological parameters of the lead-exposed workers and the referents. (MCV = motor conduction velocity, SCV = sensory conduction velocity, SAP = sensory action potential, MAP = motor action potential)

Parameter	Lead workers			Referents		
	Number	Mean	SD	Number	Mean	SD
Median nerve						
MCV (m/s)	62	59.7	3.5 **	27	63.1	3.3
SCV (m/s)	62	59.8	3.8 **	27	63.5	3.4
Distal latency (ms)	62	3.2	0.44	27	3.3	0.37
SAP latency (ms)	62	3.0	0.37	27	3.0	0.28
MAP amplitude (mV) ^a	62	1.17	0.15	27	1.14	0.18
SAP amplitude (μV) ^a	62	1.35	0.18 *	27	1.45	0.18
Peroneal nerve						
MCV (m/s)	62	51.8	3.2	27	51.4	2.9
Distal latency (ms)	62	3.1	0.52 **	27	2.6	0.32
MAP amplitude (mV) ^a	62	0.91	0.19	27	0.89	0.16
Sural nerve						
SAP latency (ms)	62	3.3	0.30	27	3.4	0.27
SAP amplitude (μV) ^a	62	1.18	0.19	27	1.19	0.13
T latency (ms)	62	32.1	2.4	27	31.4	2.2
H latency (ms)	41	29.9	1.5	27	30.3	1.3
Age (a)	62	32.8	9.1	27	32.6	6.3
Mean PbB ($\mu\text{g}/100\text{ ml}$) ^b	382	41.6	12.4 **	27	15.8	3.2
Length of exposure (a)	62	4.0	2.7	—	—	—

^a Expressed as log amplitude of the evoked potential.

^b 1 $\mu\text{g}/100\text{ ml}$ = $0.048\text{ }\mu\text{mol/l}$.

* $p < 0.05$ & ** $p < 0.01$ (significantly different from referents in the Student's t-test).

Table 2. Means of the electrophysiological parameters of the lead workers by length of exposure. (MCV = motor conduction velocity, SCV = sensory conduction velocity, SAP = sensory action potential)

Parameter	Lead exposure								
	Two years			Two to five years			Five to ten years		
	Number	Mean	SD	Number	Mean	SD	Number	Mean	SD
Median nerve									
MCV (m/s)	20	59.1	3.0	23	60.2	3.4	19	59.9	4.2
SCV (m/s)	20	59.7	3.3	23	60.6	3.3	19	59.0	4.9
SAP amplitude (μV)	20	1.35	0.17	23	1.37	0.18	19	1.32	0.19
Peroneal nerve									
Distal latency (ms)	20	3.1	0.52	23	3.2	0.58	19	3.0	0.46
Age (a)	20	29.8	8.9	23	30.5	5.9	19	38.8	10.2
Mean PbB ($\mu\text{g}/100\text{ ml}$) ^a	83	37.6	12.9	177	43.3	13.0	122	43.7	11.4
Exposure time (a)	20	1.2	0.44	23	3.7	0.83	19	7.4	1.43

^a 1 $\mu\text{g}/100\text{ ml}$ = $0.048\text{ }\mu\text{mol/l}$.

ml (2.4–3.3 $\mu\text{mol/l}$) and a length of exposure of less than 2 a had lower values for median nerve MCV ($p < 0.02$) and SCV ($p < 0.02$) than subjects with the same maximum PbB and a longer length of exposure.

Discussion

The decrease in median nerve MCV and SCV observed for the exposed workers of the present study is in agreement with previous reports (1, 2, 3, 4, 5). All the

authors are in agreement on the selective, greater involvement of the nerves of the upper limbs; our results confirm this data.

However, we found an increased distal latency of the peroneal nerve in exposed workers. The most likely explanation, as suggested by Buchthal & Behese (2), is that it is caused by local compression of the deep peroneal nerve at the dorsum pedis by metal-lined safety shoes. The more marked electrophysiological changes observed in workers with PbB levels above 70 $\mu\text{g}/100\text{ ml}$ (3.4 $\mu\text{mol/l}$) are in

Table 3. Means of the electrophysiological parameters of the lead workers by maximum blood lead (max PbB) level. (MCV = motor conduction velocity, SCV = sensory conduction velocity, SAP = sensory action potential)

Parameter	Maximum blood lead concentration ^a					
	< 50 $\mu\text{g}/100\text{ ml}$ (N = 24)		50–69 $\mu\text{g}/100\text{ ml}$ (N = 27)		$\geq 70\text{ } \mu\text{g}/100\text{ ml}$ (N = 11)	
	Mean	SD	Mean	SD	Mean	SD
Median nerve						
MCV (m/s)	60.0	3.9 **	59.4	3.2 **	59.6	3.4 **
SCV (m/s)	60.6	3.5 **	60.1	3.9 **	57.7	4.2 ** †
SAP amplitude (μV)	1.37	0.19	1.36	0.17	1.26	0.15 **
Peroneal nerve						
Distal latency (ms)	3.0	0.55 **	3.2	0.39 **	3.20	0.70 **
Age	33.0	10.1	31.3	8.4	35.6	8.5
Mean PbB ($\mu\text{g}/100\text{ ml}$)	36.0	10.4	43.8	12.7	50.0	13.9
Exposure time (a)	3.4	2.6	4.0	2.4	5.6	3.1

^a 1 $\mu\text{g}/100\text{ ml}$ = 0.048 $\mu\text{mol/l}$.

** $p < 0.01$ (significantly different from the referents in the Student's t-test); † $p < 0.05$ (significantly different from the group of max PbB < 50 $\mu\text{g}/100\text{ ml}$).

Table 4. Means of the electrophysiological parameters of the lead workers by length of exposure and maximum blood lead (max PbB) level. (MCV = motor conduction velocity, SCV = sensory conduction velocity, SAP = sensory action potential)

Parameter	Lead exposure < 2 a ^a				Lead exposure 2–10 a ^a			
	Max PbB < 50 $\mu\text{g}/100\text{ ml}$ (N = 13)		Max PbB 50–69 $\mu\text{g}/100\text{ ml}$ (N = 6)		Max PbB < 50 $\mu\text{g}/100\text{ ml}$ (N = 11)		Max PbB 50–69 $\mu\text{g}/100\text{ ml}$ (N = 21)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Median nerve								
MCV (m/s)	60.0	3.4	57.1	2.0 *	60.5	3.8	60.2	3.9
SCV (m/s)	60.8	2.8	57.1	3.1 *	60.0	3.2	61.0	4.2
SAP amplitude (μV)	1.38	0.18	1.28	0.13	1.50	0.14	1.37	0.17 *
Peroneal nerve								
Distal latency (ms)	3.1	0.63	3.1	0.24	2.9	0.46	3.2	0.38
Age	29.6	10.0	31.7	8.60	34.6	8.8	33.1	9.6
Mean PbB ($\mu\text{g}/100\text{ ml}$) ^a	35.2	6.8	44.8	9.4	35.4	7.7	43.3	9.6
Exposure time (a)	1.15	0.38	1.3	0.49	5.1	2.1	5.2	2.0

^a 1 $\mu\text{g}/100\text{ ml}$ = 0.048 $\mu\text{mol/l}$.

* $p < 0.05$ (significantly different, with Student's t-test, from the subjects with max PbB < 50 $\mu\text{g}/100\text{ ml}$ but the same length of exposure).

agreement with those reported by Seppäläinen & Hernberg (5) and Seppäläinen et al (4). These data have been accepted in standards for occupational exposure by the European Common Market (6).

The most interesting finding from our study concerns the relationship between the length of exposure and the electrophysiological patterns. Under the conditions of exposure of this study, a decrease in conduction velocity occurs quite rapidly after exposure to lead. Ashby (1) has also pointed out an early onset of electrophysiological changes in a group of lead workers exposed for 2 a or less.

Our study suggests that, when PbB levels exceed $50 \mu\text{g}/100 \text{ ml}$ ($2.4 \mu\text{mol/l}$), the electrophysiological alterations are more evident in workers with a brief exposure length and less significant in subjects with a greater employment time. We cannot exclude that this unexpected finding is the result of a selection process; thus the subjects more resistant to the toxic effects of lead are more prevalent in the group with a longer length of exposure, although, from the information obtained from the company physician, none of the workers employed within the last

10 a has left the smelter because of diseases referable to lead poisoning. A possible explanation for our result is that there is a greater sensitivity of the peripheral nerve to lead during the first exposure period. On the other hand, the subjects with the shortest exposure, some as short as six months, had their PbB of more than $50 \mu\text{g}/100 \text{ ml}$ ($2.4 \mu\text{mol/l}$) at a time closer to that of our examination with respect to their fellow workers with a longer length of exposure. This fact allows us to advance another hypothesis: that electrophysiological changes occur whenever the PbB exceeds a threshold level [about $50 \mu\text{g}/100 \text{ ml}$ ($2.4 \mu\text{mol/l}$)] and that this is a reversible process. This latter suggestion is supported by the finding of a significant correlation between the time elapsed after the PbB level exceeded $50 \mu\text{g}/100 \text{ ml}$ ($2.4 \mu\text{mol/l}$), the MCV values, and the motor action potential (MAP) amplitude logarithm of the median nerve (fig 1). The longer the interval, the more unlikely that electrophysiological alterations will occur.

This correlation analysis was carried out only for subjects under 40 a of age, in whom a physiological slowing of nerve conduction velocity was not expected. The results of our correlation analysis, which was not initially foreseen in this study, are suggestive but not conclusive. So that these hypotheses can be studied further, the previously examined group of workers and a small group of new employees are now undergoing follow-up examinations.

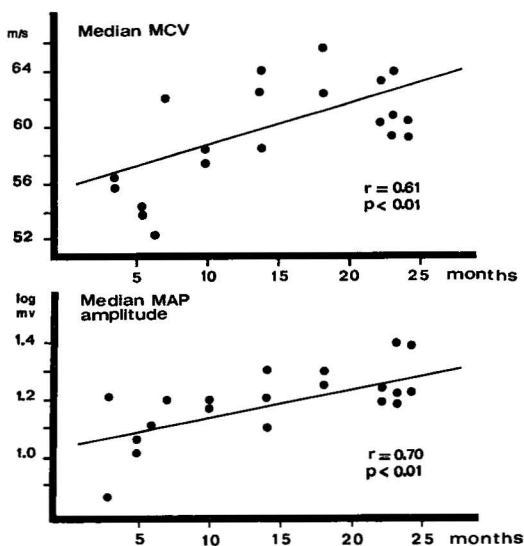


Fig 1. Motor conduction velocity (MCV) and motor action potential (MAP) amplitude of the lead workers plotted according to the interval between recorded blood lead level above $50 \mu\text{g}/100 \text{ ml}$ in the 20 lead-exposed workers under 40 a of age. ($1 \mu\text{g}/100 \text{ ml} = 0.048 \mu\text{mol/l}$)

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