Arh. hig. rada toksikol., **30** *(1979) suppl. pp. 139–143.*

FREE ERYTHROCYTE PROTOPORPHYRIN IN WORKERS EXPOSED TO LEAD

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ABSTRACT

In 163 subjects occupationally exposed to lead and in 32 non-exposed subjects various parameters specific for lead poisoning were measured. The values of aminolevulinic acid (ALA), aminolevulinic dehydratase activity (ALAD) and free erythrocyte protoporphyrin (FEP) were compared with blood lead concentrations in both groups. In all cases FEP measurements showed a very good correlation with blood lead concentrations. Therefore we concluded that the FEP level measured according to Piomelli is the easiest and the most reliable parameter for evaluation of lead absorption and metabolic disorders induced by lead in screening campaigns.

The knowledge of lead induced alterations in the biosynthetic pathway of the haem group has led to the development of techniques which enable to detect, in an easy and accurate way, the level of various compounds which accumulate in blood or urine after continuous exposure to a toxic agent[1-4].

We measured specific parameters in lead poisoning such as aminolevulinic acid (ALA), aminolevulinic dehydratase (ALAD) activity, free erythrocyte protoporphyrin (FEP) and blood lead (PbB) in workers with different occupations. The results are presented in this paper.

SUBJECTS AND METHODS

Out of the 195 examined individuals 32 were not exposed to lead and were taken as a control group. The remaining 163 subjects were occupationally exposed to lead (demolition, ceramic and smelter workers) and comprised a study group.

Blood lead was measured by graphite furnace atomic absorption spectrophotometry with a deuterium background corrector. Aminolevulinic acid (ALA) was measured by the Grabecki technique[3] and aminolevulinic dehydratase (ALAD) activity by the method of Bonsignore[4]. Determinations of free erythrocyte protoporphyrin (FEP) were carried out according to the procedure

of Piomelli[1]. A disadvantage of the latter method lies in the instability of the solutions of protoporphyrin IX used as standard. We therefore used an ethanolic solution (1 μg/ml) of rhodamine B which after excitation by light of 406 nm gives a fluorescence intensity at 605 nm equivalent to that obtained with the 5 μg/100 ml standard solution of protoporphyrin IX.

RESULTS AND DISCUSSION

Table 1 shows the values of biological parameters measured in the control group, i.e. in workers who were not exposed to lead. The mean values for blood lead, FEP level, ALA and ALAD conform closely with the values reported for the general non-exposed population. However, we found that the upper limits of the FEP levels in the normal population were lower than those reported by other authors. Thus, the obtained FEP levels in the non-exposed subjects ranged from 12 to 34 μg/100 ml, whereas Piomelli and co-workers[1] reported values of up to 59 μg/100 ml.

TABLE 1
Biological parameters of non-exposed group (n = 32).

Parameter	Mean	S.D.	Range
Blood lead (μg/100 ml)	11.18	4.83	10.00 – 45.00
FEP (μg/100 ml)	20.40	6.61	12.00 – 34.00
ALA-D (units/ml)	216.90	62.37	130 – 366
ALA (mg/l)	3.20	1.10	1.0 – 5.7
ALA (mg/g creatinine)	2.48	1.00	1.0 – 5.8

We checked the precision of the FEP measurements and the results of 20 determinations on two blood specimens, one with a low and the other with a relatively high FEP content, gave standard deviations of less than 5% of the mean value.

In the workers exposed to lead we also measured various specific parameters, and the obtained results are shown in Tables 2, 3 and 4.

We detected large amounts of blood lead in the subjects employed in a Demolition Ship Factory (Table 2), specially in those classified as smelters--founders who had a mean value of 108.7 μg/100 ml with a S.D. of 23.5. Consequently the FEP values (mean 297 μg/100 ml with a S.D. of 142) were much higher than those obtained for the normal populations as was also the case for the other parameters (ALA and ALAD). The mean values of the studied parameters for the total population working in the demolition factory (blood lead 80.1 μg/100 ml, FEP 169 μg/100 ml, ALAD 68 units/ml and ALA 14.9 mg/g creatinine) strongly indicate an overexposure of these workers to lead.

TABLE 2
Biological parameters in workers exposed to lead in a demolition factory.

Parameter	Smelters (N = 42)	Unskilled workers (N = 10)	Office workers (N = 12)
Blood lead (μg/100 ml)	108.7	58.2	42.7
FEP (μg/100 ml)	298	42	31
ALA-D (units/ml)	44	78	110
ALA (mg/l)	26.8	3.4	2.8
ALA (mg/g creatinine)	20.77	3.10	2.51

Similarly, in the ceramic factories studied (Tables 3 and 4) high concentrations of blood lead were recorded in most of the workers, specially in groups of ceramists, specialists and painters.

From a comparative study of the relationship between FEP levels and blood lead concentrations we concluded that blood lead concentrations of 30–40 μg/100 ml correspond to a relatively small increase in the FEP content. About 20% of the individuals with this blood lead concentration had a FEP level beyond the range of normal physiological variation (i.e. exceeding +2 S.D.).

TABLE 3
Mean values for biological parameters in workers exposed to lead in ceramic factory A.

Subjects	Number	Blood lead (μg/100 ml)	FEP (μg/100 ml)	ALA-D (units/ml)	ALA (mg/l)	ALA (mg/g creatinine)
Ceramists	18	78.4	222	77	11.1	9.74
Specialists	3	71.3	240	82	6.4	5.94
Painters	21	52.5	244	116	10.0	7.94
Furnace men	6	63.5	79	86	5.7	5.58
Others	21	41.2	52	125	3.5	3.16

TABLE 4
Mean values for biological parameters in workers exposed to lead in ceramic factories B and C.

Subjects	Number	Blood lead (units/ml)	FEP (μg/100 ml)	ALA-D (μg/100 ml)	ALA (units/ml)	ALA (mg/l)
Specialists	3	78.1	215	83	19.5	13.91
Ceramists (C)	10	57.2	251	58	21.0	8.53
Ceramists (B)	4	73.8	175	68	4.1	5.47
Painters	9	68.8	166	68	5.2	7.19
Potters	4	57.5	44	104	3.1	3.37

TABLE 5
Correlations between blood lead and other specific parameters (number of observations = 195).

Parameters	Correlation coefficient	Regression equation
Blood lead – FEP	0.671	Y = −35.8507 + (0.3108X)
Blood lead – log (FEP)	0.752	Y = − 1.1983 + (0.0012X)
Blood lead – ALA-D	−0.717	Y = 201.2250 + (−0.1547X)
Blood lead – log (ALA-D)	−0.795	Y = 2.3599 + (−0.0007X)
Blood lead – ALA (mg/l)	0.565	Y = −0.3016 + (0.0022X)
Blod lead – ALA (mg/g creatinine)	0.677	Y = −2.7318 + (0.0177X)

Above this threshold (40 μg/100 ml) the FEP content increased rapidly as did the percentage of individuals with FEP level beyond the normal variation, reaching 100% of individuals with high FEP level when the blood lead concentration is about 90–100 μg/100 ml (Fig. 1). These results show that 50% of a population with blood lead concentrations of about 50 μg/100 ml exhibits metabolic disorders, which speaks in favour of limiting the permissible upper blood lead levels to the values proposed by OSHA[5].

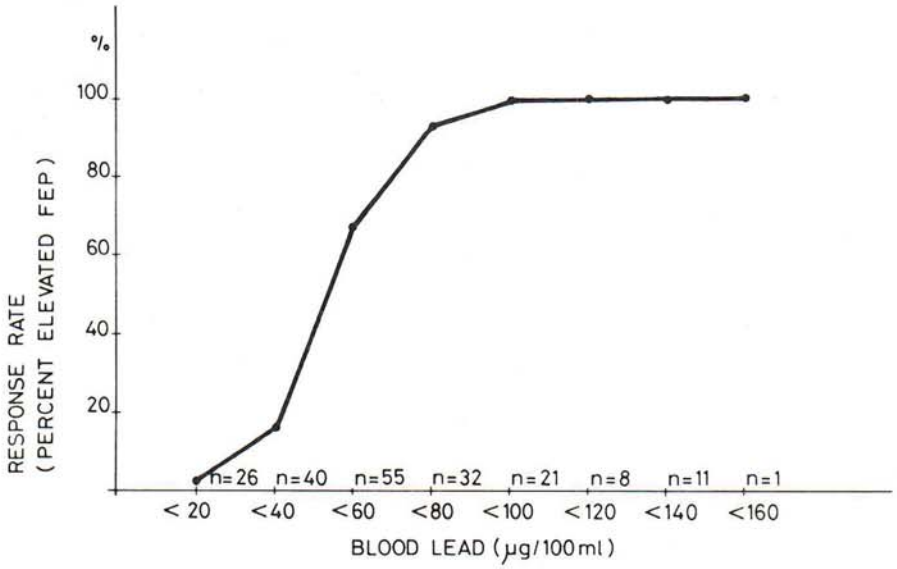

FIG. 1 – Dose response relationship between FEP and blood lead concentration.

The results of statistical analysis showed good correlation to blood lead concentration. However, the assay for the FEP level is simpler, less costly and more rapidly performed than for any of the other studied parameters, and accordingly we presently use this method for mass screening in our laboratory.

On the other hand, the ALA level in relation to blood lead concentration showed a better correlation coefficient when expressed as mg ALA/g creatinine instead of mg ALA/l.

In conclusion, we have found that the FEP level measured according to Piomelli is the most easy and reliable parameter to evaluate absorption of lead and metabolic disorders induced by this metal in mass screening of populations.

ACKNOWLEDGEMENT

We thank Dr Martin de Agar R. for collaboration in the statistical treatment of the data. Our thanks are due to the personnel of the Laboratories of Medicine and Analytical Hygiene for technical assistance.

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