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Field Report

Relationship of Blood Lead Levels to Blood Pressure in Exhaust Battery Storage Workers

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Abstract: Several researches has focused the hypothesis that low blood lead levels could be associated with an increased risk of hypertension. To assess the relation between occupational lead exposure and elevated blood pressure a group of 27 workers, age range from 27 to 62 years, mean (SD) 36.52 (± 8.16) yr; length of employment mean (DS) 2.97 (± 1.67) yr, were recruited as study subjects. The following variables were measured: blood lead concentration (BPb), δ-Aminolevulinic Acid Dehydratase (ALAD) activity, Zinc Protoporphirin (ZPP), creatinine, hematocrit, Body Mass Index (BMI) and Systolic Blood Pressure (SBP) and Diastolic Blood (DBP) Pressure. The results showed that long term occupational exposure was related to a slight increase of systolic and diastolic blood pressure among workers who had been exposed to higher level of lead with respect to workers exposed to lower level of lead. Furthermore, blood lead concentration (BPb) and ZPP resulted higher among workers exposed to higher level of ambient lead, while in the same group of workers ALAD activity resulted more inhibited. The authors concluded long term cumulative lead exposure can significantly increase blood pressure in low level Pb exposed workers.

Key words: Blood lead level, Blood pressure, Low lead exposure, ALAD, ZPP

Introduction

Lead is a metal with many important industrial uses. The relation between lead exposure and blood pressure rise has received a great deal of attention because the implication that mortality from cardiovascular and cerebrovascular disease might be reduced by lowering lead values in the environment. In the past some authors showed an excess of mortality in workers in plants where they were exposed to extremely high levels of lead. More recently however such exposure was reduced substantially and the effect of lower levels of lead exposure in the industrial setting is controversial[1)].

Longitudinal studies were performed to determine if the elevations in blood lead levels precede elevation in blood pressure. Two studies examined this issue of temporality, which is critical to establish a casual relationship between lead exposure and blood pressure elevation. In a study of Boston police officers with levels somewhat higher than the current general population, there was a statistically significant association between a high (>30 μg/dl) blood lead level and subsequent elevation in systolic pressure after 5 yr. Two meta-analyses that examined the studies of blood lead and blood pressure are in agreement that there is a correlation between the two parameters, though the magnitude and clinical significance is debatable[2)]. In addition, other studies[3, 4)] did not indicate any relationship between exposure to lead and blood pressure.

Parkinson found no excess mortality among those exposed to lead in the workplace[5)].

In this study we followed a cohort of 50 workers in a

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exhaust lead battery storage and we hypothesized that the average PbB levels would be correlated positively with SBP (systolic blood pressure) and DBP (diastolic blood pressure).

Materials and Methods

This study was conducted in 2004 at a exhaust lead battery storage factory located in the neighbour area of Messina.

A total of 50 male workers were enrolled. The exclusion criteria were presence of hypertension defined as SBP >140 mmHg, DBP >90 mmHg, diabetes, coronary heart disease, cerebrovascular and peripheral vascular disease, renal disease, and other diseases that could influence blood pressure and employment at the lead battery storage factory for at least seven months.

A total of 23 workers were excluded because they had been either working in the lead—exposed factory for ≤6 months (10 workers), were suffering from cardiovascular disease or hypertension (6 workers), receiving medication for various illnesses (7 workers).

As a result, 27 workers, age range from 27 to 62 yr, mean (SD) 36.52 (± 8.16) yr; length of employment mean (DS) 2.97 (± 1.67) yr, were recruited as study subjects. None used any respiratory protection devices.

The sections of working environment of the exhaust battery storage plant was contaminated with lead dust at concentration from 21 to 45 $\mu g/m^3$ (Table 3). The airborne lead level in the five sections of the plant was consistent with standard level by the American Conference of Governmental Industrial Hygienist (ACGIH) stated 0.05 mg/m^3 .

All subjects gave informed consent before the inclusion to the study.

All participants were interviewed by well-trained occupational physicians, and information about sociodemographic characteristics, disease history, alcohol consumption, cigarette smoking, dietary patterns (ethnic products intake), residential area (whether there are any industries or factories nearby), occupational history (of the last 3 yr for possible lead-exposed occupation).

Body mass index (BMI) was calculated as the ratio of body weight to height squared and expressed as kg/m^2.

One trained medical doctor determined blood pressure of study participants from the right arm while the subject was in a sitting position. Three measurements were taken at 5-min intervals after the subjects had rested for 20 min. A standard mercury sphygmomanometer was used for all measurements. The pressures at the first and fifth Korotkoff sounds were recorded as systolic and diastolic blood pressures, respectively. The average of three readings was used in data analysis.

Biological monitoring

The venous whole blood specimens was collected using a lead-free heparinized vacutainer. Blood samples were stored at 4 ˚C until the analysis, which was done within 2 wk. Blood lead (BPb, haemoglobin, plasma total cholesterol, trigliceride, high density lipoprotein, creatinine, urea nitrogen, calcium, phosphorus, δ-Aminolevulinic Acid Dehydratase (ALAD) activity and Zn-Protoporphirine (ZPP), were analysed.

Blood lead concentrations (BPb) was measured using a flameless atomic absorption spectrophotometer connected to a data processor. All specimens were analysed three times, and the average was taken when the relative standard deviation was less than 7%. External and internal quality controls were applied in each series of analysis[3]. Regarding the reference value of blood lead for European Community, a high blood lead level was defined as a blood lead level greater than 15 $\mu g/dl$.

Statistical analysis

The results have been expressed by averages and the standard deviations. Assumption of normal distribution for continuous variables was tested by Kolmogorov-Smirnov test. Non-normally distributed variables were compared by Mann-Whitney test among the independent averages.

The correlation between a few study parameters has been analysed by coefficient of the ranks of Spearman. p-values less than 0.05 were considered to indicate statistical significance and p-values were based on two-sided test.

Results

The authors sampled 27 individuals in the present study. Demographic characteristics, occupational exposure, BMI, and blood pressure of the subjects are shown in Table 1.

Among the 27 workers, the average blood lead level was (mean ± standard deviation) 42.33 (± 15.16) $\mu g/dl$, average systolic blood pressure was 129.85 ± 20.99 mmHg, average diastolic blood pressure was 80.56 ± 13.33 mmHg. Table 2 shows PbA in the five sections of the exhaust battery storage plant. Since the highest mean concentration of PbA were found in the shatter check section, the authors classified the sample under studying as in two groups, the first comprising the workers at shatter check section and the latter comprising workers at other sections (Table 3) for evaluation purpose. The sociodemographic and biological characteristics of the two groups of workers are shown in Table 3. The differences in exposure patterns were not significant.

Table 1. General and biological characteristics of study subjects (n=27)

Age (yr)	36.52 ± 8.16[a]
Length of employment	2.97 ± 1.67
BMI(Kg/m^2)	24.89 ± 3.51
Blood lead level (μg/dl)	42.33 ± 15.16
History of ethnic drug use	
Yes	13 (48.1)[b]
No	14 (51.9)[b]
Smoking status	
Yes	11 (40.7)[b]
No	16 (59.3)[b]
Lead-exposure hobby	
Yes	
No	27 (100)[b]
Systolic blood pressure	129.85 ± 20.99
Diastolic blood pressure	80.56 ± 13.33
ZPP	39.04 ± 15.13
ALAD activity	26.22 ± 10.98
Urea	32.35 ± 14.12
Creatinine	1.01 ± 0.27
HCT	42.74 ± 3.83
Haemoglobine (Hb)	14.64 ± 1.43

[a]Mean ± standard deviation, [b]numbers in parentheses, percent.

All of the mean PbB values in the workers were below ACGIH biological exposure indices (BEI) of 30 μg/dl. The mean PbB values in workers in the first shatter check site were significantly higher than those in other sections (p=0.13). Compared with the other section workers, ZPP in the shatter check site workers was significantly increased (p=0.14), whereas ALAD activity were significantly inhibited (p=0.08). Table 3 shows the parameters, considered in the present study, that could interfere the SBP and DBP. As shown in the table, first shatter check section workers and other section workers did not differ significantly in age, body mass index, serum creatinine levels. The SBP in the shatter check site workers was significantly higher than the other group of workers (p=0.02). The DBP yielded similar findings: it was significantly higher in the shatter check section workers compared to the other group (p=0.02). Table 4 shows Spearman correlation coefficient and the level of significance among variables in the whole group understudying.

Discussion

The present study investigated the effects of occupational lead exposure on blood pressure change among 27 workers employed in an exhaust lead battery storage factory. The Authors divided the study population in two groups on the basis of airborne lead concentration and conducted an internal comparison. In addition, measurement of blood biomarkers of lead exposure, such as ZPP and ALAD activity, were added to screening test item.

Table 2. Airborne lead concentrations (μg/m^3)in the five sections of the exhaust lead battery storage plant

Sections of the exhaust battery storage plant	Mean Lead concentration
Shatter check site	45
Processing shed	25
Fusing haven conduction	23
Refining plant conduction	21
Ingot-made plant conduction	21

The results showed that long term occupational exposure was related to a slight increase of systolic and diastolic blood pressure among workers who had been exposed to higher level of lead with respect to workers exposed to lower level of lead. Furthermore, blood lead concentration (BPb) and ZPP resulted higher among workers exposed to higher level of ambient lead, while in the same group of workers ALAD activity resulted more inhibited.

According to these preclinical studies, researches conducted on humans demonstrate that chronic exposure to high lead levels, that existed earlier in this century, were associated with an increased incidence of hypertension and cardiovascular disease[7]. Today, these severe effects of lead exposure are rarely observed in developed countries, while recent studies conducted in the general population, where lead exposure are very low, have indicated that increased BPb is associated with small increases in blood pressure, and this relationship appears to extend to BPb below 10 μg/dl[8].

Several studies performed in occupational setting reported modest increases in blood pressure among workers exposed to concentration of lead allowable under the ACGIH lead standard.

Schuhmacher[9] showed a significant rise of blood pressure with the increases in blood lead levels in 36 male subjects who were occupationally exposed to lead. Hertz-Picciotto[10] suggested a small positive association between blood lead and blood pressure in both occupational group and general population. Dos Santos[11] noted a significant correlation between SBP and DBP, mean blood pressure and duration of exposure to lead and BPb in 226 workers, 166 of whom were occupationally exposed to lead in battery factories or in battery rebuilding. Maheswaran[12] in a cross sectional study on 809 male workers occupationally exposed to lead, examined the association between environmental lead exposure and rose blood pressure. The authors showed that SBP rose with increase blood lead levels from 127 mmHg in men with BPb levels less than 21 μg/dl to 133 mmHg in men

Table 3. Environmental and biological variables in the first shatter check site and other site workers

	Shatter check section	Other section workers	p_{value}
No of workers	13 (48.15)[b]	14 (51.85)[b]	0.28
Age	35.62 ± 7.52	37.36 ± 8.91	0.58
Length of employment (yr)	2.32 ± 1.66	3.57 ± 1.49	0.04
BMI	25.32 ± 4.07	24.48 ± 2.99	0.68
PbB (μg/dl)	46.92 ± 4.59	38.07 ± 4.91	0.13
ZPP (μg/dl)	43.53 ± 3.63	34.86 ± 5.72	0.14
ALAD	22.38 ± 6.77	29.78 ± 7.05	0.08
Hb (g/dl)	15.01 ± 1.49	14.30 ± 1.34	0.20
Systolic Blood Pressure	138.92 ± 26.19	121.43 ± 9.49	0.02
Diastolic Blood Pressure	86.54 ± 15.59	75.00 ± 7.84	0.02
Azotemia	36.14 ± 15.52	28.83 ± 12.19	0.01
Creatinine	1.00 ± 0.26	1.01 ± 0.28	0.98
HTC	43.32 ± 4.37	42.21 ± 3.33	0.46
Smoking status			
Yes	5 (18.5)[b]	6 (22.2)[b]	0.82
No	8 (29.6)[b]	8 (29.6)[b]	
Alcohol consumption			
Yes	7 (25.9)[b]	6 (22.2)[b]	0.57
No	6 (22.2)[b]	8 (29.6)[b]	

PbA, air lead concentration; PbB, blood lead concentration; Zpp, zinc protoporphyrin; ALAD, delta-aminolevulinic acid dehydratase; Hb, hemoglobin.
[a]Mean ± standard deviation, [b]numbers in parentheses, percent.

Table 4. Spearman's rank correlation coefficient and the level of significance

	Age	Job	Length of employ-ment	Smoking	Alcohol	SBP	DBP	ALAD	BPb	ZPP	Urea
Age	1.000	0.109	−0.087	0.157	0.016	0.158	0.213	0.385[a]	−0.189	−0.256	−0.062
Job		1.000	0.384[a]	−0.045	0.11	−0.424[a]	−0.441[a]	0.343	−0.297	−0.292	
Lenght of employment			1.000	−0.29	0.198	−0.35	−0.128	−0.142	0.183	0.24	
Smoking				1.000	0.257	0.265	0.266	0.333	−0.26	−0.216	0.131
Alcohol					1.000	−0.064	−0.157	0.289	−0.183	−0.068	
SBP						1.000	0.79[b]	−0.287	0.337	0.263	0.288
DBP							1.000	−0.402[a]	0.426[a]	0.424[a]	0.134
ALAD								1.000	−0.760[b]	−0.725[b]	
BPb									1.000	0.955[b]	0.08
ZPP										1.000	0.034
Ureate											1.000

[a]P<0.05, [b]P<0.001.

with levels exceeding 50 μg/dl.

The environmental monitoring of the factory revealed that the highest level was evidenced in the shatter check site, with a concentration of 45 $\mu g/m^3$, while the lowest level of 21 $\mu g/m^3$ was estimated in the ingot-made plant site.

According to afore mentioned studies, shatter section workers, showed a small but significant increase of blood pressure comparing to workers employed in the other sections of the factory, as showed in the Table 3.

Although the airborne concentrations of Pb are considered safe, the present study showed that shatter check site workers presented a BPb level significantly higher than BPb level of the other site workers. Consistent with BPb level, ZPP resulted significantly higher in the shatter check site workers with respect to other site workers, while ALAD activity resulted more inhibited in the first group of workers comparing with the second.

This finding is in agreement with other Authors that observed a high correlation (r=0.62) between environmental lead concentration and blood lead level[13]. On the other hand, BPb level may fluctuate from time to time, and it has been suggested that BPb levels represent a current short term (about 3–5 months) exposure. To overcome such a limitation, in the present study was included workers who had worked for >6 months and ZPP and ALAD activity were estimated.

Elevated levels of ZPP and decreased ALAD activity represent biological markers of heme synthesis inhibition and can reveal the effect of lead also at BPb concentration below current Italian occupational health protection standard. So they could be considered as a measure of end organ effect. In addition to the Spearman correlation result, in the present study it was showed that BPb and decrease ALAD activity did not correlate with blood pressure, even if BPb resulted higher and ALAD more inhibited in the shatter section worker with respect to other section worker. On the other hand, an increase in ZPP was significantly associated with increasing DBP in the study population ($r=0.424$, $p<0.05$).

ALAD and ZPP are sensitive biomarkers of Pb exposure and/or effect and they better reflect biologically active or chelatable Pb in the body compared to Pb. Current ZPP level in the peripheral blood directly depends on the Pb amount in the bone marrow during the preceding 4 months, in analogy with the red blood cell life span, and it is not at all influenced by very recent increases in BPb level because ferrochelatase which is responsible for the ZPP level, is no longer active in the mature red blood cells that reach the peripheral blood. On the other hand, ALAD remains active in the peripheral blood and thus reflects both current and long term cumulative Pb exposure level in the individual[14]. This may explain why ZPP correlates better than ALAD, and particularly BPb, with increasing blood pressure, that appears to be mostly dependent on long term cumulative Pb exposure in humans. However, a study showed that ZPP was a considerably better predictor than BPb of increasing systolic and diastolic blood pressure in subjects without occupational exposure to lead[15].

The role of Pb as an occupational pollutant stressor for elevated blood pressure could well be confounded by the presumed role of other risk factors such as age, BMI, alcohol consumption, smoking habits, HCT, plasma trigliceride and cholesterol[16–18].

In the present study blood pressure did not increase in significant correlation to these factors. On the other hand, the 27 workers included in the present study were healthy men and nobody was suffering from high cholesterol, trigliceride levels or HCT. In addition, the two groups of workers appeared homogeneous concerning age, BMI, alcohol consumption, smoking habits. In conclusion, the present study suggested that blood pressure was correlated with APb and BPb concentration which have been considered to be safe, and are the result of low level cumulative exposure to lead. Moreover, the study indicates that blood lead levels contribute independently to the elevation of blood pressure.

These findings should be considered relevant in terms of occupational health implications.

References

1) Navah U, Froom P, Kristal-Boneh E, Moschovitch B, Ribak J (1996) Relationship of blood lead levels to blood pressure in battery workers. Archives of Environmental Health **51**, 324–8.
2) Weiss ST, Munoz A, Stein A, Sparrow D, Speizer FE (1988) The relationship of blood lead to systolic blood pressure in a longitudinal study of policeman. Environ Health Perspect **78**, 53–6.
3) Chu NF, Liou SH,Wu TN, Chang PY (1999) Reappraisal of the relation between blood lead concentration and blood pressure among general population in Taiwan Occup Environ Med **56**, 30–3.
4) Wu TN, Shen CY, Ko KN, Guu CF, Gau HJ, Lai JS, Chen CJ, Chang PY (1996) Occupational lead exposure and blood pressure. Int J Epidemiol **25**, 791–6.
5) Parkinson DK, Hodgson MJ, Bromet EJ, Dew MA, Connell MM (1987) Occupational lead exposure and blood pressure. Br J Ind Med **44**, 744–8.
6) American Conference of Governmental Industrial Hygienist (ACGIH) (2001) Threshold limit values for chemical substances and physical agents and biological exposure indices. ACGIH, Cincinnati.
7) Dingwall-Fordyce I, Lane RE (1963). A follow-up study of lead workers. Br J Ind Med **20**, 313–5.
8) Apostoli P, Corulli A, Metra M, Dei Cas L (2004) Piombo e cardiopatie. Med Lav **95**, 124–32.
9) Schuhmacher M, Bosque MA, Domingo JL, Corbella J (1994) Effect of cronic lead cadmium exposure on blood pressure in occupationally exposed workers. Biological Trace Elem Res **41**, 269–78.
10) Hertz-Picciotto I (1993) Review of the relation between blood lead and blood pressure. Epidemiol Rev **15**, 352–73.
11) Dos Santos AC, Colacioppo S, Dal Bo CMR, dos Santos NAG (1994) Occupational Exposure to lead, kidney, function tests, and blood pressure. Am J Ind Med **26**, 635–43.
12) Maheswaran R, Gill JS, Beevers DG (1993) Blood pressure and industrial lead exposure Am J Epidemiol **137**, 645–53.
13) Lai J-S, Wu TN, Liou SH, Shen CY, Gun CF, Ko KN, Ch HY, Chang PY (1997) A study of the relationship between ambient lead and blood lead among lead battery workers. In Arch Occup Environ Health **69**,

295–300.
14) Goyer RA (1993) Lead toxicity: current concerns. Environ Health Perspect **100**, 177–87.
15) Telisman S, Jurasovic J, Pizent A, Cvitkovic P (2001) Blood pressure in relation to biomarkers of lead, cadmium, copper, zinc, and selenium in men without occupational exposure to metals. Environ Res **87**, 57–68.
16) Vupputuri S, He J, Muntner P, Bazzano LA, Whelton PK, Batuman V (2003) Blood lead level is associated with elevated blood pressure in blacks. Hypert **41**, 463–8.
17) Nomiyama K, Nomiyama H, Liu SJ, Tao YX, Nomiyama T, Omae K (2002) Lead induced increase of blood pressure in female lead workers. Occup Environ Med **59**, 734–9.
18) Gonick HC, Behari JR (2002) Is lead exposure the principal cause of essential hypertension? Medical Hypotheses **59**, 239–46.