AUDIOLOGICAL EVALUATION IN CHILDREN WITH CUMULATIVE LOW-LEVEL OF LEAD EXPOSURE

Avaliação audiológica em crianças com baixo nível de exposição cumulativa ao chumbo

Kátia de Freitas Alvarenga[1], Daniela de Oliveira Manoel[2], Fernanda Zucki[3], Lilian Cássia Bórnia Jacob-Corteletti[4], Andrea Cintra Lopes[5], Mariza Ribeiro Feniman[6]

ABSTRACT

Purpose: to verify the occurrence of sensorineural hearing loss in children with low level of cumulative lead exposure. **Methods:** 156 lead-poisoned children, 94 males and 62 females, ranging in age from 18 months old to 14 years and 5 months old were subjected to analysis of longitudinal lead level in blood as well as pure tone audiometry and transient evoked otoacoustic emissions. **Results:** the population studied had a mean estimated blood lead level of 12,2±5,7μg/dL (range between 2,4 and 33μg/dL); all children had a normal response in pure tone audiometry at 20 dBHL in the frequencies tested, 0.5, 1, 2 and 4 kHz, in both ears; the transient evoked otoacoustic emissions were presented for all frequencies bilaterally in 79 children surveyed. **Conclusion:** there has been no hearing loss in children with a history of low cumulative lead exposure, as there was no injury of cochlear outer hair cells, even if subclinical.

KEYWORDS: Lead; Hearing Loss; Hair Cells, Auditory, Outer

INTRODUCTION

Lead, one of the most common environment contaminants, is a well known neurotoxic agent, which vast range of associated effects and the millions of people affected around the world, regardless of the level of development of the nations, transform it into a public healthcare problem[1].

The environmental exposure to this metal has become a worrisome issue, as the results of the studies developed in this area showed neurophysiologic and neurocognitive alterations on children and adults, even in low contamination levels[2].

In this regard, the *Center for Disease Control*[3] described adverse effects that blood lead levels considered low (10mg/dL) may cause. Since then, the normative regulations referring to lead environmental control were reviewed, and lead level in blood commended to determine an intervention was reduced from 25 mg/dL to 10 mg/dL[3,4].

Research has pointed out that lead levels in the blood between 10 and 20 mg/dL are not considered safe, as there is the possibility of occurrence of central nervous system dysfunction, especially in children, causing alterations in reasoning, concentration, and learning abilities; attention and vigil deficits; cognitive losses; psychomotor function, short term memory, and visuospatial abilities alterations; language dysfunction; and also headaches,

(1) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

(2) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

(3) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

(4) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

(5) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

(6) Department of Audiology and Speech-Language Therapy of the Bauru School of Dentistry/University of São Paulo - FOB/USP, Bauru, São Paulo, Brazil.

Financial aid: scholarships for scientific initiation – PIBIC - CNPq
Conflict of interest: non-existent

seizures, IQ decrease, hearing loss, aggressive behavior, and mental retardation[5-7].

However, cognition, attention and behavior dysfunctions have been verified on children whose blood lead level are found in levels as low as 3 to 5mg/dL. This demonstrates that these levels can be considered inducers of behavioral alterations, being, in this aspect, also harmful to health[8,9].

Considering specifically the auditory system, literature presents clinical and experimental studies with contradictory results. So far, there is no consensus regarding the effect of lead in the auditory system, and about possible structures that could be altered by poisoning, regardless of the concentration rate of this substance in blood.

Therefore, the occurrence of hearing loss as a consequence of contamination by this metal has been questioned. Studies aimed at the action of lead in the auditory system began in the 70's. Figure 1 shows a compilation of the studies presented in the field literature, which performed an auditory assessment of children and adults through behavioral methods. Another important aspect to be emphasized about this compilation is that only two studies demonstrated the absence of cochlear lesion[10,11].

Author	Sample	Evaluation	Results
Repko and Corum (1979)	Workers with blood lead level > 70 µg/dl	Behavioral (tonal threshold audiometry)	Hearing thresholds correlated with the lead blood level.
Schwartz and Otto (1987)	4519 children	Behavioral (tonal threshold audiometry)	Thresholds changed at 0,5, 1, 2 and 4 kHz related to lead exposure
Schwartz and Otto (1991)	3545 children and teenagers evaluated during the *Hispanic Health and Nutrition Examination Survey* (HHANES)	Behavioral (tonal threshold audiometry)	Thresholds increase at frequencies 0,5, 1, 2 and 4 kHz with significant correlation with blood lead level. The pathologic nature of the contamination was not clear.
Forst *et al.* (1997)	183 workers with blood lead level between 1-18µg/dl	Behavioral (tonal threshold audiometry)	Thresholds increase at frequency 4 kHz. The level of exposure to noise was not considered.
Farahat *et al.* (1997)	90 workers, 45 exposed to Pb (36,94±4,36 µg/dl) and 45 workers without exposure (11,51±1,22µg/dl)	Behavioral (tonal threshold audiometry)	Auditory threshold increase at frequencies 1 and 8 kHz, with significant difference in the control group, with association with blood lead level at frequency 8 kHz.
Trong-Neng *et al.* (2000)	220 workers exposed to Pb and noise	Behavioral (tonal threshold audiometry)	There was no correlation between the auditory threshold, and the blood lead level and noise. The variability of the auditory threshold was explained by the long term exposure to lead index.
Hwang *et al.* (2009)	412 workers exposed to chemical agents and noise	Behavioral (tonal threshold audiometry)	Significant association found between low lead levels and induced hearing loss by noise in different frequencies. There is higher impact on high frequencies, especially 6000 Hz. Exposure to lead may contribute to hearing loss.

Figure 1 – Effects of lead on the auditory system of adults and children

Due to the lack of consensus in the literature in terms of the action of lead on the auditory system, the objective of this study is to verify the occurrence of sensorineural hearing loss in children with cumulative low-level lead exposure.

METHODS

Subjects and locations

The sample consisted of 156 children poisoned by lead, 94 males and 62 females, aged from 18 months to 14 years and 5 months (6a8m±3a2m). These children were residents of a battery factory neighborhood in the city of Bauru, state of São Paulo. In 2002, it caused an environmental accident, contaminating the soil and rivers of the region with lead.

Plumbism monitoring

Plumbism monitoring was performed longitudinally through periodic blood collection, where all the children had a minimum of two and a maximum of four collections. The sample collection was under the responsibility of the Municipal Health Department and Regional Health Division (DIR) of Bauru/SP, and the analyses were under the responsibility of the Adolfo Lutz/SP Laboratory. The analytical technique to measure the blood lead level was the Atomic Absorption Spectrometry with a Graphite Furnace.

Audiological Evaluation

Initially, the children had their hearing verified using tonal threshold audiometry (TTA) in the frequencies of 0,5; 1; 2 and 4 kHz. The presence of response on the 20 dBNA intensity, level that determines regular social hearing, was checked. To this end, the pure tone was presented with intensities of 40 and 20 dB. In case a response is not obtained in 20 dB, a research would be done on the hearing threshold. The TTA was done in an acoustic booth, using a Madsen audiometer (model MD622), with standard TDH-39 earphones fitted with the MX-41 cushion, calibrated to the ISO 8253/ IEC 645/ ISO 389 standards.

In children under the age of 2 and ½ years, with the objective of evaluating the cochlea, the functionality of outer hair cells was studied, using evoked otoacoustic emissions through transient stimulus research, at a frequency range between 1 to 5 kHz, using Otodynamics Ltda ILO92 Research OAE System. The presence of otoacoustic emissions was considered when the reproducibility presented a value ≥ 50%, and a relationship signal/noise ≥ 3 dB. A click-type stimulus was applied, non-linear, with intensity at about 80 dB. The probe stability was always superior to 80% and calibration was done on a daily basis.

The present study was undertaken at the Speech-Language Pathology and Audiology Clinic of the Bauru School of Dentistry and Audiological Research Center of the Hospital for Rehabilitation of Craniofacial Anomalies, both belonging to the University of São Paulo. It was approved by the Research Ethics Committee of the Bauru School of Dentistry through process number 133/2003.

Next, the descriptive statistics analysis done will be presented (mean, standard deviation, median, minimum and maximum), regarding plumbism, estimated plumbism considering males and females, as well as the data obtained from monitoring the hearing system evaluation using tonal threshold audiometry and evoked otoacoustic emissions through transient stimulus.

RESULTS

Table 1 presents the descriptive statistics analysis (mean, standard deviation, median, minimum and maximum) considering the date of collection of each plumbism; the plumbism values obtained and the date of the audiological assessment, considering all the 156 children evaluated.

Tonal threshold audiometry was conducted in 125 children (80%). Normal response at 20 dBNA was found in all of them, for the frequencies of 0,5; 1; 2 e 4 kHz, for both ears. In the same way, the evoked otoacoustic emissions through transient stimulus were present in 31 children (20%), with amplitude >3dB and reproducibility >75% in the frequency bands from 1 to 5 kHz.

Considering the fact that there is no clarity about the cumulative effect of lead on the auditory system, that is, its long term influence, the authors decided to calculate the value of estimated plumbism at the date of the audiological evaluation. To do so, the date on which the first collection was done in the population was considered as the reference. Also on table 1, it is possible to observe that the estimated plumbism was calculated for 130 children. 26 children were excluded from the total, due to the fact that their audiological evaluation took place later than date of last collection, thus not allowing the proposed calculation. The estimated plumbism value was 12,2±5,7mg/dL

Table 1 – Descriptive statistics analysis (mean, standard deviation, median, minimum and maximum) considering the date of collection of each plumbism; the plumbism values obtained, estimated plumbism and the date of the hearing assessment, considering males and females

Gender	Variables	N	Mean	Standard Deviation	Median	Minimum	Maximum
Female	D1 (months)	62	4,2	1,2	4,2	1,2	8,7
	D2	60	7,1	2,0	6,8	3,7	13,5
	D3	57	23,5	3,6	22,4	10,5	32,9
	D4	46	32,6	1,4	32,1	31,0	35,5
	P1	62	16,5	11,0	14,0	10,0	90,0
	P2	60	14,8	10,7	12,5	4,9	81,6
	P3	57	9,3	9,1	7,4	2,0	68,2
	P4	46	7,5	3,9	6,3	0,0	18,1
	Estimated plumbism	50	11,2	4,6	9,6	2,4	23,0
	Evaluation Date (months)	62	15,1	9,2	11,3	4,1	41,2
Male	D1 (months)	94	4,0	1,0	4,2	1,3	7,9
	D2	93	6,9	2,4	6,4	3,1	19,1
	D3	87	23,4	2,9	22,0	12,6	32,2
	D4	65	33,2	1,8	33,1	27,5	36,0
	P1	94	17,1	6,7	15,1	10,0	44,2
	P2	93	14,5	6,2	13,0	4,9	33,0
	P3	87	9,0	4,8	7,8	0,0	26,5
	P4	65	8,3	4,8	7,3	2,1	27,1
	Estimated plumbism	80	12,8	6,2	10,9	4,4	33,0
	Evaluation Date (months)	94	15,1	9,9	11,3	4,1	41,2
Total	D1	156	4,1	1,1	4,2	1,2	8,7
	D2	153	6,9	2,2	6,6	3,1	19,1
	D3	144	23,5	3,2	22,0	10,5	32,9
	D4	111	33,0	1,6	32,9	27,5	36,0
	P1	156	16,9	8,6	14,6	10,0	90,0
	P2	153	14,6	8,2	12,6	4,9	81,6
	P3	144	9,1	6,8	7,6	0,0	68,2
	P4	111	8,0	4,5	6,7	0,0	27,1
	Estimated plumbism	130	12,2	5,7	10,2	2,4	33,0
	Evaluation Date (months)	156	15,1	9,6	11,3	4,1	41,2

DISCUSSION

The concern with the effect of lead on health has allowed the realization of several experimental and clinical studies with industry workers, adults and children with a history of contamination by this metal, even at levels close to 10mg/dL, previously believed to be safe [3].

Regarding the auditory system, in fact, there is still no clarity about the toxic effect of lead. In a careful analysis of the methodology used in the various studies reviewed here, some points seem to suggest a certain discrepancy of the findings, which will be discussed below.

Initially, it appears that there is no consensus as to the index to be used to determine the degree of contamination of the various populations which

were studied; in other words, what would be the lead level to be taken into account in the analyses: the blood lead level at the time of the evaluation, the cumulative level, or another proposal for calculation?

Considering the studies that used the blood lead levels at the time of the evaluation, there was no agreement as to whether there is significant association with the parameters used on the evaluation of the auditory function. Some studies have shown that the increase in the auditory threshold was correlated with the levels of lead in blood[12,13-15] while others did not confirm this finding[16,17].

Only a single study considered the cumulative lead level, given by the index calculation of the long term exposure to the metal, similar to that proposed in this study. As a result, the authors found no correlation with the auditory thresholds observed in workers exposed to lead and noise[12].

In the present work, two to four collections in the children were done for Plumbism control. The values obtained were between 16,9±8,6mg/dL (range between 10-90mg/dL); 14,6±8,2mg/dL (range between 4,9-81,6mg/dL); 9,1± 6,8mg/dL (range between 0-68,2mg/dL); 8,0±4,5mg/dL (range between 0- 27,1mg/dlL (table 1).

It was possible to verify, therefore, that there was a decrease on the lead blood level, and in the last two collections, the mean value was already below 10mg/dL, considered as the limit for definition for intervention. This fact is justified by the measures assumed by the municipal government and the company responsible for the ecological accident near the community of the area around the factory, such as: drug treatment of the child when necessary; asphalt in the houses and streets; orientation of the population for the non-consumption of food produced in the region, awareness regarding care for children, among others.

It is important to emphasize that, even though the present study obtained a rigid monitoring of the blood lead level, it was not possible to carry out the audiological assessment in the same week of the blood collection for all the individuals. Thus, there was a difference of 15,1±9,6 months between the blood collection and audiological evaluation. For this reason, the estimated Plumbism was calculated. This fact raises difficulties on the comparative analysis between the studies, since there is no direction on the lead parameter to be used. Therefore, in this study, the authors opted for using the estimated Plumbism value, because it considers the variable time of exposure and, consequently, the cumulative effect of lead in the body. As a result, the mean value of 12,2±5,7mg/dL was obtained (range between 2,4-33mg/dL).

In the tonal audiometry threshold, response to 20dBNA, the minimum intensity studied, was found in all the children. Considering that the children presented, at some point, blood lead level > 10 mg/dL, with maximum value of 90 mg/dL in the first collection, even though the estimated plumbism value was considered low (12,2±5,7mg/dL, range between 2,4-33mg/dL), the occurrence of sensorioneural hearing loss could be assumed if the lead really had ototoxic effect.

Nevertheless, all the children assessed by tonal threshold audiometry presented normal response, demonstrating that, regardless of the lead level found, hearing loss was not verified, finding that supports some studies in the literature[10,18].

It is important to critically analyze the studies that found an increase of the hearing threshold with significant correlation with the blood lead level, as it is possible to verify some methodological fragilities that are noteworthy[12,13,19-21,].

In the studies involving exposure to lead and workers, it is observed that control groups are not adopted in their methodologies, nor are presented information about concomitant exposure to noise and its intensity, aspects which are considerably relevant to the true understanding of the effects of lead on the hearing function. This argumentation is based on a study[11] in which a control group with equivalence on the factors age and level of exposure to noise is used. It found hearing alterations, however there was no difference in the amplitude of the evoked otoacoustic emissions, a product of the distortion between the lead-exposed group associated to noise and the group exposed solely to noise

With reference to research done with children, various authors have discussed small changes on the thresholds found on intensities £10dBNA, that is, hearing thresholds that do not clinically represent hearing loss19,20. On the other hand, this finding allows questioning whether this threshold variation would not be reflecting initial alterations on the auditory system, as for example on the outer hair cells, first structure which is usually injured on ototoxicity. In this study, the children subjected to evoked otoacoustic emissions through transient stimulus research presented normal result, bilaterally, demonstrating that there was no of outer hair cells in the cochlea, even sub-clinical. Considering the sensitivity of the procedure to detect this type of alteration, it is possible to assume that the lead did not cause cochlear alteration on the structure that was specifically analyzed, finding that corroborates with what is described in the literature[10,11].

CONCLUSION

No sensorineural hearing loss was verified in children with a history of cumulative low-level lead exposure. Also, no injury of cochlear outer hair cells was found, not even subclinical ones.

ACKNOWLEDGEMENTS

National Council for Scientific and Technological Development – CNPq.

RESUMO

Objetivo: verificar a ocorrência de perda auditiva sensorioneural em crianças com baixo nível de exposição cumulativa ao chumbo. **Métodos:** 156 crianças intoxicadas por chumbo, 94 do sexo masculino e 62 do sexo feminino, na faixa etária entre 18 meses a 14 anos e 5 meses, foram submetidas a análise longitudinal do nível de Plumbemia em sangue, bem como audiometria tonal liminar e emissões otoacústicas evocadas por estímulo transiente. **Resultados:** a população pesquisada apresentou um valor médio de Plumbemia estimada de 12,2±5,7μg/dL (faixa entre 2,4-33μg/dL); todas as crianças apresentaram resposta normal na audiometria tonal liminar em 20 dBNA nas frequências testadas, 0,5; 1; 2 e 4 kHz, para ambas as orelhas; as emissões otoacústicas evocadas por estímulo transiente estiveram presentes para todas as frequências bilateralmente, nas 79 crianças pesquisadas. **Conclusão:** não foi constatada perda auditiva sensorioneural em crianças com histórico de baixo nível de exposição cumulativa por chumbo, assim como não foi encontrada lesão de células ciliadas externas na cóclea, mesmo que subclínicas.

DESCRITORES: Chumbo; Perda Auditiva; Células Ciliadas Auditivas Externas

REFERENCES

1. Olympio KPK, Oliveira PV, Naozuka J, Cardoso MRA, Gunther WMR, Bechara EJH. Surface dental enamel lead levels and antisocial behavior in Brazilian adolescents. The Toxicologist (Supplement to Toxicological Sciences). 2009;108(1):76-7.
2. Dascanio D, Valle TGM. A associação entre variáveis sócio-demográficas e plumbemia em crianças. Paidéia. 2008;18(41):541-53.
3. CDC. Preventing lead poisoning in young children. Atlanta: US Department of Health and Human Services, Public Health Service, 1991.
4. OMS - Human exposure to lead. In. Human Exposure Assessurent Series, WHO, 1992.
5. Mostafa GA, El-Shahawi HH, Mokhtar A. Blood lead levels in Egyptian children from high and low lead-polluted areas: impact on cognitive function. Acta Neurol Scand. 2009;120:30-7.
6. Min MO, Singer LT, Kirchner HL, Minnes S, Short E, Hussain Z. et al. Cognitive development and low-level lead exposure in poly-drug exposed children. Neurotoxicology and Teratology. 2009;31:225-31.
7. Bellinger D. Very low lead exposures and children's neurodevelopment. Curr Opin Pediatr. 2008;20:172-7.
8. Chiodo LM, Jacobson SW, Jacobson JL. Neurodevelopmental effects of postnatal lead exposure at very low levels. Neurotoxicol. 2004;26:359-71.
9. Chiodo LM, Covington C, Sokol RJ, Hannigan JH, Jannise J, Ager J, Greennwald M, Delaney-Black V. Blood lead levels and specific attention effects in young children. Neurotoxicol Teratol. 2007;29:538-46.
10. Buchanan LH, Counter SA, Ortega F, Goran L. Distortion product oto-acoustic emissions in Andean children and adults with chronic lead intoxication. Acta Otolaryngol (Stockh). 1999;119:652-8.
11. Alvarenga KF, Jacob LCB, Martins CHF, Costa Filho AO, Coube CZV, Marques JM. Emissões otoacústicas - produto de distorção em indivíduos expostos ao chumbo e ao ruído. Rev Bras Otorrinolaringol. 2003;69(5):681-9.
12. Farahat TM, Abdel-Rasoul GM, El-Assy AR, Kandil SH, Kabil MK. Hearing thresholds of workers in a printing facility. Environ Res.1997;73:189-92.
13. Hwang YH, Chiang HY, Yen-Jean MC, Wang JD. The association between low levels of lead in blood and occupational noise-induced hearing loss in steel workers. Science of the Total Environment 408. 2009:43–9.

14. Counter SA, Buchanan LH. Neuro-ototoxicity in andean adults with chronic lead and noise exposure. J Occup Environ Med. 2002;44(1):30-8.
15. Bernard SM. Should the Center for Disease Control and Prevention's childhood lead poisoning intervention level be lowered? Am J Public Health. 2003; 93:1253-60.
16. Zou C, Zhao Z, Tang L, Chen Z, Du L. The effect of lead on brainstem auditory evoked potentials in children. Chin Med J (England) 2003;116(4):565-8.
17. Hirata M, Kosaka H. Effects of lead exposure on neurophysiological parameters. Environ Res. 1993;63:60-9.
18. Trong-Neng W, Chen-Yang S, Jim-Shoung L, Chain-Fun G, Kquei-Nu K, Hsueh-Yun C, et al. Effects of lead and noise exposure on hearing ability. Arch Env Health. 2000;55(2):109-18.
19. Schwartz J, Otto D. Blood lead, hearing thresholds, and neurobehabioral development in children and youth. Arch Environ Health. 1987;42(3):153-60.
20. Schwartz J, Otto D. Lead and minor hearing impairment. Arch Environ Health. 1991;46(5):300-5.
21. Forst LS, Freels S, Persky V. Occupational lead exposure and hearing loss. J Occup Environm Med. 1997;39(7):658-60.

Received on: October 18, 2011
Accepted on: February 05, 2012

Mailing address:
Kátia de Freitas Alvarenga
Faculdade de Odontologia de Bauru
Departamento de Fonoaudiologia (in care of
Professora Doutora Kátia de Freitas Alvarenga)
Alameda Doutor Otávio Pinheiro Brizola, Nº 9-75 -
Vila Universitária
Bauru - SP
CEP: 17043-101
E-mail: katialv@fob.usp.br