Effects of blood lead and cadmium levels on the functioning of children with behaviour disorders in the family environment

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Abstract

Introduction and objective: The developing brain of a child is extremely prone to damage resulting from exposure to harmful environmental factors, e.g. heavy metals. Intoxication of children's organisms with lead and cadmium affects their intellectual development. Even a relatively small amount of this metal in children's blood can lead to developmental dysfunctions. The aim of this study was to analyse the correlation between blood lead and cadmium levels in children with behaviour disorders and their functioning in the home. Material and methods: This survey-based study was conducted among 78 families with children diagnosed as having behaviour disorders. It was performed using the ADHD-Rating Scale-IV. To determine lead and cadmium levels the laboratory procedure was based on Stoppler and Brandt’s method. Results: The mean blood lead level was 19.71 µg/l and the mean blood cadmium level was 0.215µg/l. Higher blood lead levels in children correlates positively with incidences of hyperactive and impulsive behaviour in the home, as assessed by parents (p=0.048). Statistically significant effects of cadmium on children's behaviour were not noticed. Conclusions: The effect of lead on the developing organism of a child has such behavioural consequences as attention disorders, hyperactivity and impulsive behaviour which, in turn, may interfere with children's functioning in the home. A negative effect of cadmium on the functioning of children with behaviour disorders in the home was not proved.

Key words
lead, cadmium, child behaviour disorders

INTRODUCTION

Developmental disorders are a consequence of interaction between genetic, chemical and social factors. Genetic factors aside, the environment is more and more often regarded as potentially detrimental to children's health and contributing to such present-day problems as obesity, asthma and neoplasms, as well as behavioural and learning disorders. Exposure to chemical toxic substances should receive particular attention since it can be avoided. The developing brain of a child is extremely prone to damage resulting from lengthy exposure to harmful environmental factors [1]. The effects of lead on a child’s development can be observed as early as in the prenatal period. Research conducted among pregnant women showed that higher lead levels in women’s blood in the first and second trimester are main contributors to the risk of premature birth [2].

The latest research on children demonstrated that their blood lead levels were continuously decreasing. This is most probably the effect of imposing a ban on using this metal in petrol, paints for places of residence, and soldered parts of dishes and pipes delivering water. In 1991-1994, the National Health and Nutrition Examination Surveys (NHANES) carried out research on children aged 1-5 years, which proved that 4.4% of them had lead concentrations higher or equal to 100 µg/l, with the geometric mean being equal to 27 µg/l. More recent data, obtained in the years 1999-2002, showed that lead concentrations above 100 µg/l were noted in 1.6% of 1-5-year-old children, and the average concentration in the analysed population was 19 µg/l [3]. Nevertheless, approximately 310,000 children in the USA from the age of 1-5 have lead levels exceeding 100 µg/l [4].

The most recent outcomes suggest that intoxication of children’s organisms with lead affects their intellectual development, and not only when it occurs in high doses. Even a relatively small amount of this metal in children's blood can lead to developmental dysfunctions. Numerous studies conducted recently proved that exposure to lead in the early period of life, resulting in blood lead concentration even below 20 µg/l, may cause a considerable decrease in the intelligence quotient (IQ). Analysis of data shows that there is no safe lead level in blood, i.e. the one which would not have an effect on the neurobehavioural functioning of a child [5]. Research on children’s non-verbal intelligence suggests that there is a correlation between blood lead levels and lower IQ scores [6].

In the general population, the main sources of exposure to cadmium are cigarettes, food (mainly crustaceans, giblets,
The study was conducted with the consent of the Bioethical Commission of the Pomeranian Medical University in Szczecin (Permit No. BN-001/113/08, dated 24 November 2008). The study involved 78 children – 16 girls and 62 boys. The basic inclusion criterion was a diagnosis of behaviour disorders such as hyperactivity, impulsiveness and attention deficit disorder, diagnosed by a psychologist or school educationalist. The parents gave their written consent to children's participation in the study; they were informed about its anonymous character and the possibility of resigning at any moment without the necessity of giving reasons. The mean age of the children was 8 years. Age groups were created so that the appropriate balance between them was maintained – the youngest respondents, aged between 2 and 5, constituted 35.6% of all children, those aged between 5 and 10-31.5%, and the oldest, aged between 10 and 18, were 32.9%.

This survey-based study was performed using the standardised and valid ADHD-Rating Scale-IV, which is a reliable and easy-to-administer instrument for diagnosing attention deficit disorder and behavioural problems in children [15]. Each version includes descriptions of 18 behaviours, resulting in behaviour disorders [12]. This element has the most direct influence on brain metabolism, hindering many enzymes containing sulphhydryl groups. As a consequence, lengthy exposure to cadmium negatively affects levels of norepinephrine, serotonin and acetylcholine [13]. It was also observed in humans that early childhood, which is the time of dynamic brain development, can be a critical stage because of particular susceptibility to a neurotoxic effect of cadmium [14].

The aim of this study was to analyse the correlation between blood lead and cadmium levels in children with developmental disorders and their functioning at home.

MATERIALS AND METHODS

The study was performed using the selected modules of STATISTICA 7.1. All data transformations and preliminary calculations were carried out with Microsoft Excel 2007. Statistical analysis was performed using the selected modules of STATISTICA 7.1. Some data were subjected to the non-parametric Mann-Whitney test to assess statistically significant differences between the assessment of children's behaviour according to the questionnaire and children's lead (Pb) and cadmium (Cd) levels. The Tables include Pearson's linear correlation coefficients (r) and the test probability or p-value calculated for these coefficients. The accepted significance level was equal to 0.05.

The children included in the study were characterised by the proportion. Pb and Cd levels were determined using median, lower and upper quartiles, arithmetic mean and standard deviation. The Mann-Whitney test was used to assess statistically significant differences between the assessment of children's behaviour according to the questionnaire and children's blood lead levels, classifying them for one of two groups:

- group 1 – with lower lead levels – children with lead levels up to 19.9 µg/l;
- group 2 – with higher lead levels – children with lead levels of 20 µg/l or more.

All data transformations and preliminary calculations were carried out with Microsoft Excel 2007. Statistical analysis was performed using the selected modules of STATISTICA 7.1.
RESULTS

The lowest blood lead level in the group examined was 6 µg/l and the highest 101 µg/l. The mean level of this element was 19.71 µg/l. Lead concentration in particular patients differed from the mean value by +/− 13.59 µg/l, on average.

The lowest cadmium level noted in the children was 0.05 µg/l, and the highest – 2.91 µg/l. The mean level of this element was 0.22 µg/l +/− 0.34 µg/l (Tab. 1).

Table 1. Basic descriptive statistics of lead and cadmium levels in children’s full blood (µg/l)

<table>
<thead>
<tr>
<th>Heavy metal levels for N=73</th>
<th>Min.-Max.</th>
<th>Median</th>
<th>Q1-Q3</th>
<th>X±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb (µg/l)</td>
<td>6-101</td>
<td>16</td>
<td>12-22</td>
<td>19.71±13.59</td>
</tr>
<tr>
<td>Cd (µg/l)</td>
<td>0.05-2.91</td>
<td>0.16</td>
<td>0.12-0.22</td>
<td>0.22±0.34</td>
</tr>
</tbody>
</table>

The children’s behaviour at home were assessed with the ADHD-Rating Scale-IV. The questionnaire evaluated 2 aspects of a child’s behaviour: 1) attention deficit disorder and 2) hyperactivity and impulsiveness.

We analysed the correlation between blood lead and cadmium levels and the frequency of undesirable behaviour making children’s normal functioning at home difficult. To evaluate the intensity of behaviour suggesting attention disorders (Part I) and hyperactivity and impulsiveness (Part II), the parents responded to each item on the 4 point Likert scale in ‘the home questionnaire’ (Parent ADHD Rating Scale-IV). The obvious but slight correlation between lead levels and hyperactivity and impulsiveness results (p < 0.05) in ‘the home questionnaire’ was noticed. This permits the assumption that higher lead levels correlate with a lower assessment of children’s behaviour (with the prevalence of hyperactivity and impulsiveness) (Tab. 2).

Table 2. Correlation between results of ‘home questionnaire’ and children’s blood lead and cadmium levels

<table>
<thead>
<tr>
<th>Pb (µg/l)</th>
<th>Cd (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention deficit disorder</td>
<td>0.2292</td>
</tr>
<tr>
<td>Hyperactivity and impulsiveness</td>
<td>0.2369</td>
</tr>
</tbody>
</table>

r – Pearson’s Linear Correlation Coefficient
p – significance level

Figure 1 is a graphic illustration of the correlation between blood lead levels and the intensification of their hyperactive and impulsive behaviour at home.

Figure 2 illustrates the comparison between the escalation of attention deficit disorder symptoms at home in both groups of children.

Figure 3 is a graphic illustration of the correlation between the children’s blood lead levels and the escalation of hyperactivity and impulsive behaviour.
During the last century, the progress of industrialization and urbanization resulted in economic growth and better health of people in many regions of the world. Thanks to wider access to safe drinking water, improvements in food nutrition, vaccinations and waste utilization, former infectious diseases in children were brought under control. The infant mortality rate was also noticeably reduced.

American researchers discovered a significant correlation between increased blood lead levels and the incidence of ADHD in 4,704 children [27]. Analysis of hair lead levels in ADHD children also showed that the concentration of this metal was considerably higher than in the control group [28, 29].

The research on 150 American children proved that the presence of lead in their blood considerably contributed to a higher incidence of hyperactive and impulsive behaviour. However, such a correlation was not found with reference to attention deficit disorder, compared to the control group [30]. A similar correlation was reported in this study. According to the parents, the degree of hyperactivity and impulsiveness was considerably higher in the children who had elevated blood lead levels.

Data analysis performed within the National Health and Nutrition Examination Survey (NHANES III) demonstrated that the elevated blood lead levels significantly correlated with the incidence of ADHD. Children with lead levels higher than 20 µg/l were at 4.1 times greater risk of developing symptoms associated with psychomotor hyperactivity than individuals with lower levels of this metal [31]. In the presented study, blood lead levels exceeding 20 µg/l were found in 32.9% of children, while levels higher or equal to 10 µg/l were noted in 94.5% of the participants (the mean lead level in this group was 19.7 µg/l). In 2007, Surkan et al. published an analysis of differences in intelligence levels, school achievements, attention levels and working memory between children allocated to one of three categories depending on their blood lead levels: I – lead levels between 10 and 20 µg/l, II – 30-40 µg/l and III – 50-100 µg/l. It was found that the children in group III had numerous deficits in areas such as intelligence, visual and spatial abilities, and school achievements. Also comparison of results obtained from the children in groups I and II proved some differences suggesting that lead concentrations between 30-40 µg/l were less safe for the normal development of a child than the level of this metal equal to 10-20 µg/l [32]. In the presented study, the children were divided into 2 groups: 1) individuals with blood lead levels below 20 µg/l; 2) those with the levels equal to and higher than 20 µg/l. Some differences between these groups were noticed, especially in the assessment of hyperactivity, impulsive behaviour and attention deficit disorder in the home, which were significantly more intensive in the group with higher blood lead levels.

Recently, research has been conducted in Szczecin and its environs on a group of 141 healthy children aged 5-18 years. The aim was to assess lead levels in the children's serum, erythrocytes and hair. The mean lead concentration in erythrocytes was 2.78 µg/dl [33]. Other studies performed on 174 healthy children living in this area proved that the mean lead concentration was 0.73 µg/dl in serum, 2.41 µg/dl in erythrocytes and 1.6 µg/g in hair (dry mass) [34]. The comparison of our results with those mentioned above is not possible since we used different methodology, based on the analysis of heavy metal levels in full blood collected from ill children.

Cadmium is a heavy metal having a toxic and carcinogenic effect on the human organism [35]. Numerous epidemiological studies conducted in the 1970s and 1980s provided evidence for the profound effect of this metal on children's behaviour and neurological development [36]. Research on children whose development was slower compared to their peers revealed that cadmium levels in their hair were considerably
higher [37]. Other authors have noted that the presence of this metal correlated positively with learning difficulties and dyslexia in children [38]. The cohort study carried out by R. Thatcher et al. demonstrated that cadmium affects children’s intelligence level (IQ score) [39]. Apart from the correlation between IQ and cadmium levels, other researchers noticed that this metal had an effect on children’s visual, locomotive and cognitive abilities [40]. The results reported by R. Pihl and M. Parkes show that the presence of cadmium, cobalt, manganese, chromium or lithium in blood results in a 98% certainty that a child is going to have learning problems [41]. Research conducted among 149 children aged 5-16 years demonstrated that the presence of cadmium considerably affected test results measuring their intelligence, physical fitness and academic achievement [42].

The results of research conducted in a similar area and a similar, in terms of age, group of healthy children demonstrated that the average cadmium level in erythrocytes was 0.311 µg/dl [33]. Other comparable studies that have been carried out in the surroundings of Szczecin showed that the mean cadmium level in serum of healthy children was 0.12 µg/dl, in erythrocytes 0.21 µg/dl, and in hair 0.1 µg/g (dry mass) [34]. The direct comparison of our results with those obtained by other authors is not possible since we used different methodology based on the analysis of this metal content in full blood. We determined levels of heavy metals in full blood using a method recommended by the accredited laboratories of the Institute of Industrial Medicine and Community Health in Sosnowiec.

**CONCLUSION**

The effect of lead on the developing organism of a child has such behavioural consequences as attention deficit disorder, hyperactivity and impulsiveness which, in turn, may result in functional problems in the home.

Negative effect of cadmium on the functioning of children with behaviour disorders in the home was not proved.

**REFERENCES**


**Annals of Agricultural and Environmental Medicine 2012, Vol 19, No 2**

Małgorzata Szkup-Jabłońska, Beata Karakiewicz, Elżbieta Grochans, Anna Jurczak, Grażyna Nowak-Starz, Iwona Rotter, Adam Prokopowicz. Effects of blood lead...