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Blood levels of heavy metals and selected trace elements in adolescents and impact on their health

[1]Dr Nimrat Sandhu, Ms Ramaiah Medical College, Bangalore

[2]Dr Chandrika Rao, Ms Ramaiah Medical College, Bangalore

Corresponding Author: Dr Nimrat Sandhu, Ms Ramaiah Medical College, Bangalore

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Abstract

Justification: Heavy metals exert detrimental effects on body. There is no concrete study of Heavy metals in India, hence may go unnoticed and not evaluated. We studied ten heavy metals and trace elements -Lead, Aluminium, Iron, Mercury, Copper, Cadmium, Aluminium, Arsenic, Nickel and Tin. This study adds value to the knowledge of a paediatrician as this subject has not been explored.

Process

Study design: Cross Sectional study.

Participants: Ethical clearance taken, Convenience Sampling done, conducted on 100 adolescents. This study was done over a period of two years (2017-2019).

Intervention

1. Questionnaire: containing questions on

- Socio demographic details

- signs, symptoms of poisonings

2 .General Physical examination: (vitals and anthropometry)

3. CNS Examination

4. Blood and urine test. 5 ml of blood sample analysed in Ramaiah Drug Testing laboratory. Using ICP – OES machine (Inductive Coupled Plasma Optical Emission Spectrophotometer, Model Number- Icap7200 Duo,): quantifies the levels in PPB i.e Parts Per billion.

Objectives

1. To quantify heavy metal exposure through blood in adolescents and define spectrum
2. To compare exposure in urban and rural adolescents.

Recommendations: Regular follow up helps to monitor profound effects of environmental exposure and adequate growth of the adolescent. Paediatricians should be aware of the effects of heavy metals and toxic elements to implement it in their practice. There should be policies and guidelines to diagnose, treat, prevent and monitor heavy metal exposure in adolescents in India. Establishing National registries can be initiated and require additional resources and collaboration.

Keywords: Heavy metal exposure, Adolescent Health, Impact on health , Heavy metal toxicity

Introduction

Adolescence is a critical and complex phase in human development characterized by major biological, psychological and social changes. It is greatly influenced by onset, timing, tempo, genetic factors as well as by general health and nutritional, environmental, and socioeconomic factors[1] . They are more prone to the effects of heavy metals due to their behavioral features, high absorption rate of metals (lead) from gastrointestinal system and immature detoxification systems[2]. Exposure to heavy metals occurs through the ingestion, inhalation, and handling of contaminants in chemical products, industrial paints, building materials, fertilizers, nasal sprays, silver dental fillings, fish containing high mercury concentrations, and mercury-containing preservatives in vaccines. Exposure to heavy metals can alter genes and increase disease susceptibility, cause congenital and neurological defects, developmental delays, behavioral abnormalities, and learning disabilities.Among heavy metals, lead, mercury, and cadmium were ranked as the second, third, and seventh most hazardous substances. It is important to understand the spectrum of the disorders in adolescents which may be attributed to heavy metals exposure so that we can have protective regulations in place. Hence it is necessary to study the effects of heavy metals on adolescent health in India[3-4].

Methods

This was a cross sectional study conducted for 2 years in a tertiary hospital in Bangalore. 100 adolescents in the age group of 10-16 years were enrolled in the study. Adolescents with earlier known poisoning either occupational or consumption, chronic illness, known psychiatric disturbances, congenital visual deficits or with congenital deafness were excluded. Ethical approval was taken from the Ethics committee in M S Ramaiah Medical College, Bangalore, dated 01.09. 2017, letter number- (SS-1/EC/052/2017) .Consent was taken from parents and assent was taken from adolescents above the age of 12 years. Socio demographic characteristics such as - Address (if near any factory), Lifestyle habits, Type of water, Health status, Drug history, Occupation, Hobbies, Recent history of travel, Signs and symptoms of various heavy metal poisonings, Conduct problems such as temper tantrums, Hyperactivity were collected in a questionnaire filled by parents and adolescents .

General Physical examination was performed. A Detailed Central Nervous System examination was done. 5 ml of blood sample and urine samples were collected and sent to the Ramaiah Drug Testing laboratory (using ICP-OES machine Inductive Coupled Plasma Optical Emission Spectrophotometer,) for quantification of heavy metals (of Heavy metals -Copper, Cadmium, Cobalt, Arsenic, Nickel, Mercury, Chromium, Lead, Mercury, Selenium and Tin) in a random sequence. Parents and adolescents were given anticipatory guidance about the effect of high levels of heavy metals on adolescents and prevention.

Sample size was based on a study carried out by Isa et al[5]., on heavy metals among female adolescents attending secondary schools in Kano , which revealed the SD from mean values after calculating the urinary and blood values of Copper, Chromium and Arsenic is 0.7. Based on this sample size was calculated as 95 adolescents should be included using 5% alpha error , 10% beta error with 90% statistical power , Chi-square/ Fisher Exact test has been used to find the significance of study parameters on categorical scale between two or

more groups, Non-parametric setting for Qualitative data analysis.

Results

Of the 100 adolescents enrolled (57-males, 43-females), 54% belong to early adolescent age group, 61% belonged to an urban background. Of these 63.9% had higher levels of heavy metals with environmental exposures like pollution and parental exposures to paints, glass and fertilizers. The heavy metals detected in blood were :- Mercury in 4% cases, (9.3% Females (p, 0.031), Aluminum 93% (87.7% males, Females: 100% (p-0.019*) and Iron in 82.5% males and 97.7% females (p-0.016*) (shown in table-1). Urine examination revealed higher concentrations of Aluminum in 9.1% females and 1 male (2.4%) (p 0.40). Arsenic in 2 females (2%), (p 0.544), Nickel in 1 female (3%) (p 0.3) and Tin in 1 female (3%) (p 0.3). (Shown in table 1)

On Screening, clinical symptoms of toxicity were : headaches 17% tremors and numbness in 2%, Clumsiness (14%), dermatitis (81%), eczema (5%), metallic taste (12%), loose teeth (6%), irritability (9%). Environmental risk factors were parents worked in agricultural lands using fertilizers 11%, drinking kaveri water (31%) and filters (59%) which were an important risk factor. Another demographical factor which had a significant impact was the source of water, as 59 adolescents (59%) had water filters and 31 (31%) sourced their water through Kaveri. Aluminum levels were in toxic range in 93% adolescents, (87% males , 100% females). Clinical symptoms of toxicity- metallic taste 75% (p 0.036), ADHD in 84% adolescents. Iron was toxic in 89% adolescents (p 0.016). Clinical symptoms were food insensitivities 89%, metallic taste 75%. Mercury toxic in 4% (p 0.031). Symptoms of toxicity : 1% weakness, 1% anemia, 1% rhinitis (p 0.57). 78% adolescents had lead toxicity (p 0.47), symptoms :- numbness 1%, generalized weakness 9%. Dermatological manifestations due to source of exposure (smoke, paints) were - red blotches 1%, itchy scars 4%. Tin toxicity in 14% (7% males, 21% females. Clinical symptoms seen:- 21% tremors (p 0.042), Cold peripheries 20% (p 0.042) , rhinitis 21% (p 0.195) and anemia in 21% (p 0.044). Chromium toxicity in 56% of adolescents. Clinical signs – dermatitis (81%) and skin eczemas (88%) were seen with chromium toxicity . Copper toxicity seen in 52% of adolescents. Signs of toxicity seen were :- allergies 33%, rhinitis 27% cases (p 0.03*), perspiration 33% cases. Neurological manifestations such as headache in 66% cases and ADHD in 66.7% cases. Nickel toxic in 46% of adolescents (27% males, 19% were females). Clinical manifestations seen were :- rhinitis (40%,) ,sinusitis (46%), arthritis (46%). Cadmium toxicity levels in 11% adolescents (5% males 6% females). Clinically symptoms of Cadmium toxicity seen were :- ADHD (11%), weakness (11%) and significant tachycardia (11% p 0.023). Arsenic was seen in 2% of adolescents, equally seen in both genders (1%). Clinical symptoms of toxicity:- allergies in (2% .p 0.051) and manifestations such as eczema(2%) and dermatitis (2%). Children who used Kaveri water had higher levels of Arsenic in the blood than compared to those who used filter water. Urinary levels of Nickels were significant in 3% (table-1)

Discussion

In our study 63.9% of adolescents had toxic levels of heavy metals. Heavy metal poisoning is the accumulation of heavy metals in toxic amounts in the body[5]. Heavy metals detected were – Lead, Cadmium, Mercury , Arsenic , Chromium, Copper, Nickel , Iron

and Tin and trace elements detected wasManganese . Source of water is an important concern of for heavy metal contamination, as ground water is usually contaminated with high concentrations of copper and arsenic. In our study 59% adolescents used filter water (aqua guard) , 31% used Kaveri water, dental amalgams were used by 4% , vapor fumes due to industrial exposure. A similar study done on Yamuna river in India recently revealed that the highest levels of Iron, Manganese, Zinc , Copper and Nickel[6]. The highest level of organ toxicity was seen in Liver, Kidney and Muscles. Low dose exposure is a hidden threat and chronicity has been linked to carcinogenic activity in our body. Arsenic, Cadmium and Chromium are the most carcinogenic metals[7].Symptoms and signs vary depending upon the amount accumulated. It should be noted that in our study that higher proportion of early adolescents were affected owing to immature detoxifying systems and depressed immunity status along with nutritional compromises. Exposure from the environment can occur in two ways- presence in the environment (air, water and soil) or by transformation in their structure which causes significant toxicity for eg Mercury[7]. Manganese forms a vapor which diffuses through blood and enters the lungs. This highlights the immature detoxification systems in adolescents[9]. In our study 1% had weakness with elevated mercury levels (p 0.348) . Roberto et al., found that exposure to mercury causes damage to occipital cortex and cerebellum, hence leading to symptoms of tremors with visual defects, ataxia and emotional lability[9]. Arsenic in our study was toxic in 2% of the adolescents, especially in adolescents drinking Kaveririver water. Overexposure to arsenic may cause encephalopathy, peripheral neuropathy, demyelination, seizures. 2% of our cases had numbness associated with toxic levels of arsenic (p 0.505). Frequent headache with severe symptoms was seen in 87% (p 0.88), myalgias in 77% adolescents. Studies state that lead has innumerable effects on CNS system including neurotransmitter storage and release and altering neurotransmitter receptors[10]. Hypertension is a casual effect and a clear dose response observation has been demonstrated by Abhayankar et al., our study also showed adolescents having hypertension due to heavy metal toxicity[11].One important target of leads disruptive influences is the glutamate receptor increasing apoptosis. This could also lead to effects such as numbness, disturbed gait etc. Lead is distributed by our RBCs which then gets deposited as phosphate in teeth , bones and hair. It also causes disruption of cellular membrane causing anemia. 66% of the adolescents in our study had anemia. Cadmium was in toxic range 11% of the adolescents. Cadmium toxicity has non specific symptoms such as nausea , vomiting and headache. Acute high doses toxicity leads to Itai-Itai disease manifestations include osteomalacia, waddling gait , leg pains. Cadmium binds to albumin and distributed by blood cells to kidneys and cause kidney injury. Robin et al., studied Itai itai exposure due to cadmium and also found children with Cadmium toxicity had significant tachycardia, in our study 11% (p 0.023) had significant tachycardia[12]. Aluminium is the most abundant metal on earth with main exposure being through inhalation. In our study 93% adolescents had toxic. 6 % had chronic headaches, 75% had metallic taste. Aluminium cans, containers, cooking utensils and Ayurvedic medications are indispensable source of aluminium. It causes hyper alimentation i.e vomiting, diuresis, diarrhoea, chronic headaches etc. Another important source of Aluminum is Al-phos which is used as a fertilizer for rice and wheat

paddy. As studied by Awasthi et al., rice in a north eastern area of India had higher level of MDA[13].

Chromium is the seventh most abundant metal in the world. In our study 56% adolescents had toxic levels of chromium in the blood. The most common source being soil pollution. Withmodern agriculture there is continuous release of Cr into the environment bymeans of Cr residues, Cr dust and Cr waste water irrigation, resulting in soil pollution. Most common symptoms seen aredryness, erythema, fissuring ,papules and respiratory manifestations such as chronic asthma , bronchitis . In our study dermatitis and skin eczemas, seen in 81% and 88% of adolescents. Tchounwou et al[14]., studied that when broken skin comes in contact with any type of chromium compounds, a deeply penetrating hole will be formed. Exposure to chromium compounds can result in the formation of ulcers.

Copper is essential for maintaining the strength of the skin, blood vessels, epithelial andconnective tissue throughout the body. It plays a role as an antioxidant and a pro-oxidant. 52% ofadolescents in our study were found to have toxic levels of copper, out of which 30% were malesand 22% were females. Most common sources are cookware, preservatives, electric wires andwater ingestion. Sharma et al[15]., studied the effects of copper toxicity , stated that breakdown of the liver cells releases a very large amount of copper into the circulation, damaging red blood cells and causing anemia. Pallor, seen in 74% of the children could be attributed to the effects of Copper metal toxicity. Ashish et al[16]., studied copper toxicity profile in adults and found these symptoms to be seenmaximum- Metallic taste in mouth, salivation,burning pain stomach, nausea, vomiting, cramps of legs or spasm . In our study metallic taste was seen in 6% of cases (p 1.0), other Gastrointestinal symptoms were not significant in our study. Flu like reaction called metal-fume disease may be seen due to copper toxicity, in our study allergies were seen in 33% cases (p 0.216) and rhinitis due to elevatedcopper levels was seen in 27% cases (p 0.03*) Perspiration , in our study was seen in 33% cases(p 0.6).In our study ADHD was seen in 66% cases (p 0.47), headache was seen in 66% cases (p0.37). Iron was seen in toxic levels in 89% adolescents. 89% had food insentivities[17], metallic taste in 75% . Most common symptoms are metallic taste, vomiting, constipation or diarrhea with dehydration. All the adolescents were on weekly iron programme. Nickel was seen toxic in 46% of adolescents out of which 27% were males and 16% werefemales. Chang Yu et al[18]., studied effects on Nickel toxicity and tocopherol depletion. Hestudied that nickel toxicity causes decreased lipid peroxidation and increase in hydroxyl radicalproduction. Clinically these effects attribute to unstable RBCs, diabetes, renal diseases, seizures,skin rashes. In our study anaemia was seen in 9%. Manifestation of anaemia in the form of irritability was seen in 2% of children with toxic levels of Nickel . Neurological symptoms like weakness was seen in 46% of cases with highest association with Nickel (p 0.007). Releaseof hydroxyl radicals cause skin irritation in the form of acne, dermatitis. In our study itching wasseen in 46% of patients who had higher levels on nickel (p 0.20). Matrazek et al[19]., studied the dual nature of nickel both as an essential element and a toxic element and a source of allergies in children. They revealed that susceptible children demonstrated allergic rhinitis, frequent sinopulmonary infections due to nickel toxicity. In our study 40% had rhinitis (p 1.00) and 46% had sinusitis (p 0.36).

Our study shows 79% adolescents with significant tin levels. 21% had tremors. The most common source in adolescents is run lacquered tin cans with food of a low pH for example fruits and pickled vegetables. Paul et al., studied that organic compounds of tin such as triethylin causes toxicity[20]. Overexposure to tin mainly damages the Central nervous system and causes psychomotor disturbances like tremors , hallucinations, numbness and cold peripheries, psychosis and convulsions. This has been demonstrated due to intramyelin edema due to triethylin[21].

Limitations of our study were that the correlation of the water and soil samples in adolescents who had high levels of toxic elements could not be studied. Longitudinal follow up and a larger sample size could be considered in further studies. No programme has yet been initiated for the awareness or the monitoring of environmental heavy metals and its impact on adolescent health.

Table 1: Blood (B) and Urine Levels (U) of Toxic Metals according to age :

Heavy Metal and Toxic Range	Early Adolescence (n=55)	Mid Adolescence (n=41)	Late Adolescence (n=4)	Males (n-57)	Females (n-43)	Total (n-100)	P Value
1. Mercury -B >2 ug/l	5.5%	2.4%	0	0%	9.3%	4%	0.031*
-U	0	0	0	0%	0%	0%	0.458 1.00
2. Arsenic -B >6 ug/L	3.6%	0%	0%	1%	2.3%	3.6%	1.00 0.262
-U	3.6%	0%	0%	0%	0%	3.6%	0.544
3. Lead -B >20ug/L	74.5%	82.9%	75%	75.4%	81.4%	78%	0.477 0.431
-U	0	0	0			0%	1.00
4. Cadmium -B >0.50 ug/l -U	9.1%	12.2%	12.5%	10.5%	11.6%	11%	0.862
	0	0	0			0	0.775 1.00
5. Aluminium -B >100	89.1%	97.6%	100%	87.7%	100%	93%	0.019*
	5 (9.1%)	1 (2.4%)	0			6%	1.00 0.405

ug/l	-U							
6. Chromium	-B	50.9%	61%	75%	54.4%	81.1%	56%	0.708
	>0.80 ug/l -U	0	0	0			0	0.557 1.00
7. Copper	-B	50.9%	51.2%	75%	52.6%	51.2%	52%	0.884
	>1200 ug/l -U	0	0	0			0	0.912 1.00
8. Iron	-B	87.3%	90.2%	100%	82.5%	97.7%	89%	0.016*
	>300 ug/l -U	0	0	0			0	0.455 1.00
9. Nickel	-B	47.3%	43.9%	50%	47.4%	44.4%	46%	0.752 0.555
	>3 ug/l -U	5.5%	0	0			3%	0.345
10. Tin	-B	20%	22%	25%	24.6%	16.3%	21 %	0.314
	>30 ug/l -U	5.5%	0	0			3 %	0.044* 0.345

Table 2: Demographic characteristics

	Rural (N=39)	Urban (N=61)
Gender: Males Females	 38 % 38%	 62% 62%
Fertilizer exposure	56%	44%
Silver fillings and Dental amalgams	40%	60%
Water Source BBMP	 30%	 70%

Kaveri water	80%	20%
Industrial Exposure	24%	76%

Conclusion

Higher level of toxic heavy metals found in blood and urine of adolescents. Higher toxicity was seen in Urban background and in the age group of Early adolescence. Mercury, Copper, Iron, Aluminium and Arsenic were present in higher numbers.Regular follow up helps to monitorprofound effects of environmental exposure and adequate growth of the adolescent. Pediatricians should be aware of the effects of heavy metals and toxic elements to implement it in their practice. There should be policies and guidelines to diagnose, treat, prevent and monitor heavy metal exposure in adolescents in India. Establishing National registries can be initiated and require additional resources and collaboration.

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