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Research Article

A biomonitoring investigation with ICP-OES to determine bioaccumulation of lead in the serum of hypertensive patients and healthy individuals in Karbala, Iraq

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Abstract

In recent year, the use of methods to investigate the correlation between trace elements and pathologies has increased in prevalence. The samples of serum from 201 people in Karbala, Iraq were collected. The group included healthy individuals and those with hypertension. Their ages ranged from 16 to 75 years. The lead levels were quantified using inductively coupled plasma optical emission spectrometry (ICP-OES). The relationship between blood lead levels and various factors, including health, gender, and smoking, was examined and discussed using the F-test and a two-tailed t-test. The lead concentration (Pb) in blood serum of people with hypertension (11.123 ± 16.898)µg/g was significantly higher than that in healthy people (1.662 ± 0.442) µg/mL, with p=0.01. Although the difference in lead (Pb) concentration between males and females was not statistically significant (p=0.059), the average Pb concentration in male serum (7.306 ± 12.069) µg/mL was higher than in female serum (4.422 ± 12.300) µg/mL. In contrast, the difference in lead concentrations between smokers (5.28 ± 9.76) µg/mL and non-smokers (6.65 ± 14.64) µg/mL was not statistically significant, with ρ=0.231. In summary, a study of 201 people in Karbala, Iraq, showed that lead (Pb) levels in serum were significantly lower in healthy individuals compared to those with high blood pressure. Also, males had higher lead levels than females. However, smoking did not seem to have a significant effect.

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Introduction

The utilization of human tissues or fluids, such as fingernails, scalp hair, blood serum, whole blood, saliva, and urine, for assessing trace element levels in the human body has been extensively documented[1-5]. Assessing trace element levels in the human body offers numerous benefits, including identifying potential sources of ambient chemical exposure [6], analysing relationships among chemical substances, body burden, dietary practices, and occupational exposure [7], and assessing temporal trends associated with chemical fluctuations, such as analysing the effects of prohibitions or limitations on particular poisons or pollutants [8]. Numerous studies have examined the correlation between elemental concentrations in the human body and associated disorders [9-12]. Despite being present or utilised in minimal quantities, these components can profoundly affect critical physiological processes in the human body. Hypertension is a condition for which numerous investigations indicate a possible association between trace element concentrations and blood pressure [13-16]. Hypertension is a predominant cardiovascular disease affecting over a billion individuals globally and resulting in millions of fatalities each year[17]. This chronic sickness impacts various biological systems and can lead to permanent organ damage, such as left ventricular hypertrophy, nephropathy, microalbuminuria, atherosclerosis, and renal failure. Elevated pressure during childhood is significantly correlated with a heightened probability of having hypertension in later life[18]. Epidemiological studies have identified links between elevated blood pressure and several factors, including age, gender, ethnicity, geographic location, level of industrialisation, lifestyle choices, dietary habits, and professional settings [19-22]. Blood pressure is recorded using two measurements: diastolic blood pressure, which is measured during the heart's resting phase between beats, and systolic blood pressure, measured during the heart's contraction. Normal blood pressure values are defined as systolic <120 mmHg and diastolic <80 mmHg. A person is diagnosed with hypertension when their systolic blood pressure exceeds 140 mmHg or their diastolic blood pressure reaches 90 mmHg [23-24]. Trace elements significantly regulate blood pressure by affecting vascular function and hormonal equilibrium and mitigating oxidative stress. They are necessary in minute quantities, although imbalances (deficiencies or surpluses) significantly affect cardiovascular health.

Maintaining a proper balance of vital trace elements is critical for overall health. Despite their tiny levels, these micronutrients are essential for enzyme activity, metabolic control, and cell integrity. Their role in metalloenzymes facilitates crucial biological processes, including respiration, growth, digestion, muscle contraction, redox reactions, and intracellular transport [25-26]. Elements are classified as essential, non-essential, or hazardous based on their physiological function and probable health effects. An element is considered essential if it is present in living organisms, participates actively in biological processes, and is necessary in the human diet to sustain normal physiological functions[27-28]. A shortage of essential nutrients can delay growth and impair metabolic processes [29]. Lead (Pb), mercury (Hg), and cadmium (Cd) are harmful even in trace doses because they accumulate in the body and disrupt cellular processes [30-32]. The harmful impacts of trace elements depend on their concentration, chemical composition, route of exposure (e.g., ingestion or inhalation), and exposure duration [33]. Long-term exposure is frequently associated with nephrotoxicity, an increased risk of cancer, and nervous system disorders. Despite ongoing studies, there is still insufficient epidemiological data associating trace element imbalance with diseases such as cancer, heart disease, and autoimmune problems. Many investigations have focused on occupational inhalation rather than dietary sources[26, 34]. Lead is ubiquitous in our environment. Nevertheless, as indicated in the study [35], no physiological function inside biological systems has been identified thus far. Lead directly interferes with some enzyme functions, deactivates sulfhydryl antioxidant reserves, competitively reduces the absorption of certain trace elements, and enhances arterial stiffness. Lead is a hazardous environmental contaminant with considerable toxicity impacting multiple tissues and organs of organisms [36]. It can interfere with essential physiological functions by replacing zinc and calcium in proteins. The principal effects of lead exposure encompass cardiovascular, pulmonary, and neurological disorders[33]. These have been associated with several diseases and frequently involve the induction of disruptions in immunological regulation, including oxidative and inflammatory processes [30]. A prior study elucidated the influence of Pb on cardiovascular disease. Moreover, elevated concentrations of Pb in the human body result in detrimental effects on vitamin D metabolism[37]. Numerous studies have investigated the relationship between lead levels in the body and high blood pressure, which is the subject of our research[16,38-39]. In this work, the determination of lead in the serum of hypertensive patients and healthy individuals in Karbala, Iraq was investigated with ICP-OES and discus the results.

Materials and method

Apparatus

Lead concentrations in serum samples were measured using the Shimadzu ICPE-9000 using to measured the concentration of Pb. For this instrument, the standard operating parameters were RF power (1.2 KW), plasma gas flow (10 L/min), auxiliary gas flow (0.6 L/min), and nebulizer gas flow (0.6 L/min).

Sample collection and preparation

The biological fluid of blood serum samples were obtained from Iraqi citizens residing in Karbala, Iraq. In a 15 ml polypropylene tube with a screw cap (VWR Laboratories), 100 µl of blood serum, 200 µl of roughly 65% nitric acid (HNO_3), and 100 µl of hydrogen peroxide (H_2O_2) were used to digest the samples [40]. The mixture was then vortexed for a short time. The tubes were heated to 60˚C for 90 minutes. Following incubation, 2100 µl of deionized water (18 MΩ cm-1) was added to cool the samples. Samples were prepared for measurement following centrifugation (3 minutes at 2500 rpm) and vortexing. For quality control purposes, ten milliliters of a "pooled" serum sample were also taken from six people sharing a family home [40].

Analysis of statistics

The analysis of the data used descriptive statistics like the arithmetic mean, standard deviation (SD), range, and 95% confidence interval to look at the serum concentration levels that were found. The F-test and a two-tailed t-test were utilised to evaluate the significance of the differences in serum lead levels among healthy individuals, smokers, non-smokers, and both genders.

Result and discussion

Elemental concentrations in human biological specimens vary by country, reflecting geographic differences, nutritional state, and analytical method. Thus, determining reference ranges for trace elements in human fluids and tissues is difficult due to these factors, which limit the interpretation of the findings. The results can be used to evaluate the potential correlation between serum levels and human health status.

Table1displays the primary descriptive statistics for serum elemental levels, encompassing the arithmetic mean, standard deviation (SD), range, median, 95% confidence interval for the mean, and sample size. It additionally juxtaposes these levels with those documented in the literature.

Table 1: The mean, standard deviation (Sd), range, median, and 95% confidence interval of lead (µg/g) in serum (n=201).

Variables	Concentration (µg/g)	Literature range(µg/g)
Mean ± SD	5.913±12.232	42.6-1.8 [15,41]
Range	96.500−0.096	
Median	1.728	
Confidence interval 95%	4.093−7.733	

This study's range comparison with current research indicates that age, gender, smoking habits, lifestyle, and environmental exposure may affect serum lead concentrations. An F-test and a two-tailed t-test were conducted to determine the significance of variations in serum lead levels among healthy individuals, smokers, non-smokers, males, and women, as depicted in Table 2.

Table 2: Lead levels in serum samples for different groups (healthy and sick), (men and women), and (smokers and non-smokers).

Factor	Concentration Mean ± SD		Levene's test for quality variances F-test			T-test of the quality of means, two-tailed t-test		
Health status	Healthy	Hypertension		*F*	Sig.	*t*	*df*	Sig.
	1.662 ± 0.442	11.123 ± 16.898	Equal variances assumed	158.264	<0.001	5.511	174	<0.001
Gender	Male	Female						
	7.306 ± 12.069	4.422 ± 12.300	Equal variances assumed	6.422	0.012	1.569	174	0.059
Smoking activity	Smoker	Nonsmoker						
	5.28 ± 9.76	6.65 ± 14.64	Equal variances assumed	2.301	0.131	-0.737	174	0.231

Table 2 indicates a highly statistically significant difference in mean lead concentration between the healthy group and the hypertensive patients. The mean lead concentration in the hypertensive patients was significantly higher compared to the healthy group. This finding confirms the well-established link between chronic lead exposure and the development of cardiovascular disease. Lead is an environmental toxin that accumulates in the body (especially in bones) and is slowly released into the bloodstream, leading to hypertension[16]. The relation between males and females with lead concentration showed that the mean lead concentration was higher in males than in females, but the difference was not statistically significant. Statistical conclusion: The null hypothesis (no significant difference) cannot be definitively rejected, but the value is very close to statistical significance. Epidemiological studies generally indicate elevated lead levels in males relative to females, although this finding is not significant in the current sample. This finding is traditionally attributed to increased occupational exposure to lead in predominantly male industries (such as welding, mining, and auto repair shops) or to biological factors such as hormonal and physiological differences in the storage and excretion of lead in the body [42]. The analysis did not show a statistically significant difference in mean lead concentration between smokers and non-smokers ($p = 0.231$). Smoking was not a decisive and independent factor in determining serum lead levels in this sample. This result suggests that non-smoking environmental and dietary sources of exposure (such as water pollution, dust, and old paint) are the most dominant factors in determining total serum lead concentration [43].

Accuracy and precision

The precision and accuracy of the ICP-OES instrument were validated through the computation of the relative standard deviation (%RSD) and percentage recoveries (%R) based on ten replicate measurements of a "pooled" serum sample and certified reference materials (CRMs). Overall, satisfactory accuracy levels were achieved for most analytes, with an ideal value of 5.889 % RSD, as illustrated in Table 3. The measured CRM values for lead analysis via ICP-OES were closely aligned with the certified values. The analytical recovery value for lead, as indicated in Table 1, is 94.601 %. The limit of detection (LOD) for lead under examination was within the anticipated range for ICP-OES (4.838 µg/mL).

Table 3: The population data of precision and accuracy for lead level in serum in Karbala

Pb n=10	**Precision Mean ± SD (RSD)**	**Accuracy**			**Detection limit**
		Measured value Mean ± SD	**Certified value Mean ± SD**	**Percentage recovery (%R)**	
	3.073 ± 0.181 (5.889)	18.116 ± 0.397	19.150 ± 0.200	94.601	4.838

Conclusion

A substantial positive association ($P < 0.001$) existed between elevated blood lead levels and increased blood pressure. Given that lead levels in patients were noticeably greater than in healthy people, this indicates that long-term exposure to lead may be a decisive pathogenic factor causing hypertension. The study found no statistically significant variation in serum lead levels based on smoking status ($\rho = 0.231$) or gender ($P = 0.059$). This suggests that, in comparison to the substantial impact of health status, the contributions of smoking and sex to lead levels in this sample were negligible or statistically insignificant. The study's findings align with the idea that lead poisoning plays a substantial role in the pathophysiology of hypertension.

Ethics information

The Ethics Committee of University of Kerbala sanctioned this study (Official Letter No: 193, dated September 22, 2025). Before signing the consent form, all participants received a comprehensive description of the study protocols. Furthermore, each participant completed study questionnaires, supplying personal information and data regarding their health, diet, smoking habits, and lifestyle at the time of sample collection.

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