

Original Research Article

The Impact of Chronic Smoking on Blood and Hair Cadmium Levels among Saudi Citizens in Hail

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Abstract: The increased incidence of idiopathic cardiovascular disorders in the modern society has highlighted on the putative role of metals deposition in human body with the development of chronic disorders in urban area. In this study was carried out to assess the influence of smoking on cadmium deposition in acute (blood) and chronic (hair) storage sites. 200 healthy Saudi citizens in Hail district, 90 nonsmokers and 110 smokers were enrolled voluntarily in this study, 400 biological samples (hair and blood) were obtained from 200 volunteer; 102 male and 98 female with age ranged between 18 and 65 years with a median of 35 years. All biological samples were analyzed for cadmium levels using inductively coupled plasma-atomic emission spectroscopy. In results the mean H-Cd and B-Cd concentration for study population was 0.417 µg/g and 0.292 µg/L, respectively. Cadmium levels were significantly higher in males than females ($P < 0.05$); mean H- Cd and B- Cd concentrations were 0.485 µg/g, 0.464 µg/L for male and 0.289 µg/g, 0.295 µg/L for female, respectively. An exponential increase in cadmium levels in hair and blood with smoking was demonstrated ($P < 0.05$), additionally, a significant correlation was shown for smoking duration and levels of H-Cd and B-Cd ($r = 0.289$, $P < 0.05$) ($r = 0.303$, $P < 0.05$), respectively. There was a threefold increase in levels of H-Cd and B-Cd for smokers group of more than 10 years in comparison with nonsmokers group.

Keywords: Cadmium, Smoking, Hail, Hair, Blood, ICP-AES.

INTRODUCTION

Heavy metals are contributed in the pathogenesis of different disorders in human body, not only through an essential role in disrupting homeostasis of biochemical reactions, but also, by their dissemination and storage in different tissues [1]. The concentration of trace metals varies from tissue to tissue throughout the body; for example metals concentration is higher in liver than blood and other tissues [2]. Environmental factors like temperature, pH, water hardness, and organic matter can influence the toxicity of metals in biological systems [3]. Exposure to metals can occur through variety of routes; metals may be inhaled as dust of fume or smoking, or even ingested involuntarily through food and drink [4]. Once a metal is absorbed, it distributes in tissues and organs, later on, excretion typically occurs primarily through kidneys and digestive tract, some metals tend to persist in some storage sites, like hair, liver, bones and kidneys, for years or decades [5].

Cadmium induces deleterious side effects in the human body such as renal dysfunction, vascular disorders and interstitial cell tumors in the testes in chronic metals exposure [6, 7]. Exposure to cadmium

would lead to an increase in blood pressure; prevalence of hypertension, and cardiovascular disease [8]. Chronic exposure to airborne cadmium results in a number of toxic effects; the two main symptoms are lung emphysema and proteinurea [9]. Epidemiological studies carried out in Japan indicated that the incidence of proteinuria in the urine of contaminated population is significantly higher [10].

Cigarette smoking is basically one of the major causes for the progressive increase in mortality rate worldwide. Smoking is an exogenous source of metals contamination in human body; smoking may increase reactive oxygen species and the depletion of redox scavengers in peripheral blood [11]. A single cigarette contains 1.0–4.5 µg Cd [10], and at least one tenth of the metal content of a cigarette is inhaled [12-14].

An epidemiological study for blood cadmium concentration in non-occupationally exposed workers in England showed significantly higher levels in B-Cd of smoker in comparison with nonsmokers of the same age group [15, 16]. In addition, cadmium concentration is found to be higher in the blood and scalp hair of lung cancer patients at different stages [17].

In this study, our main goal is to explore the influence of smoking duration on cadmium deposition in both tissues of blood (as acute exposure indicator) and hair (as chronic exposure indicator) among Saudi citizens in Hail.

MATERIAL AND METHODS

Study population

The study was conducted on a group of 200 volunteers were cooperatively involved, 102 males and 98 females aged between 18 and 65 years old. The study population was divided into three subgroups according to their smoking habits and duration; non smokers, smokers for more than 1 and less than 10 years and smokers for more than 10 years. Smokers were consuming less than 20 cigarettes per day. Sampling process took place at King Khalid Hospital, Hail, KSA, two biological samples (hair and blood) were obtained from each volunteer. The study has been approved by the College of Medicine, University of Hail. This study is conducted on the behalf of community awareness program against smoking habit

Sample collection

Samples were collected by healthcare professionals at the Khalid Hospital, Hail, and KSA following a standard protocol [18]. After collection of hair from scalp position (approximately 0.1-0.3 g) in polyethylene cups with lids (Greiner, Germany), the hair was washed two times with metals free detergent followed by ultrapure water to remove contaminations of metals on the outer hair cuticle. Blood samples were obtained from volunteers in 5.00 ml plain polypropylene tubes and labeled. Samples were stored at -20 °C until analysis.

Samples digestion

Sample preparation was carried out according to friel and Ngyuen, 1986 guidelines [19].

Cadmium determination

Hair and blood digested samples were analyzed using inductively coupled plasma-atomic emission spectroscope (PerkinElmer optima 2000) (Department of Health Sciences, University of Hail, Hail, Saudi Arabia). All samples were analyzed in triplicates; the mean level was adopted for results. The sample digests were diluted (100-fold) with 0.2% (v/v) HNO₃ solution before injection into the ICP-AES. Sample solutions were measured in triplicate. For results with RSD \geq 10%, an additional two injections were performed. Calibration standards were also

prepared by diluting a commercial multi-element standard solution (PerkinElmer Pure; Part No. N9300244) with 0.2% (v/v) HNO₃ solution.

Analytical quality control

The validity and accuracy of the methodology was checked using certified reference materials and using conventional wet acid digestion method on the same certified reference materials (CRMs). The recovery of all studied elements was found to be in the range of 97.5-99.7% of certified reference values of CRMs

Statistical evaluation

The data was expressed as M \pm SD and analyzed using the SPSS computer software (Statistical Package for the Social Sciences, version 19.0, SPSS Inc., Chicago, IL, USA). Statistical analysis was done using of variance (ANOVA), independent t-test analysis and Duncan's method. Correlation between cadmium levels in hair, blood sex and duration of smoking was determined by Spearman's correlation. P<0.05 was considered significant.

RESULTS

Cadmium levels according to duration of smoking

Over ninety percent of the study population had B-Cd levels less than 0.4 μ g/L with a mean of 0.292 μ g/L and a median of 0.152 μ g/L. The H-Cd levels were ranged from (0.04 to 1.73) μ g/g with a mean of 0.417 μ g/g and a median of 0.27 μ g/g, cadmium concentration in scalp hair and blood was illustrated in Table I, Fig 1 and 2. There was a significant correlation between levels of H-Cd and B-Cd ($r=0.48$ $p < 0.05$).

In our study, the levels of H-Cd and B-Cd were 0.253 μ g/g, 0.193 μ g/L for nonsmokers and 0.552 μ g/g, 0.406 μ g/L for smokers respectively. There was a statistically significant difference for the influence of smoking on cadmium deposition in different tissues ($p < 0.05$). The study population was divided into three subgroups according to their smoking duration; nonsmokers, smokers for more than 1 and less than 10 years, smokers for more than 10 years. Mean H-Cd and B-Cd for 90 nonsmokers was 0.253 μ g/g and 0.193 μ g/L, respectively (Table I, Fig 3). Whereas, mean concentration of H-Cd and B-Cd for 69 smokers for more than 1 and less than 10 years was 0.487 μ g/g and 0.35 μ g/L, respectively (Table I, Fig 3). For the last smoking group of more than 10 years, the mean concentration of H-Cd and B-Cd for 41 cases was 0.66 μ g/g and 0.502 μ g/L, respectively (Table I, Fig 3) .

Table I: Mean cadmium concentration of hair and blood samples

	N	Mean Hair Cadmium ±SD (µg/g)	Mean Blood Cadmium ± SD (µg/L)
Non smoker	90	0.253 ± 0.085 ^a	0.193 ± 0.091 ^a
Smoking for 1-10 years	69	0.487 ± 0.14 ^a	0.35 ± 0.133 ^a
Smoking > 10 years	41	0.66 ± 0.18 ^b	0.502 ± 0.16 ^b
p Value		< 0.05	< 0.05
Non smoker	90	0.253 ± 0.085	0.193 ± 0.091
Smokers	110	0.552 ± 0.16	0.406 ± 0.146
p Value		< 0.05	< 0.05
Sex			
Male	102	0.485 ± 0.17	0.464 ± 0.15
Female	98	0.289 ± 0.135	0.295 ± 0.091
P- value		< 0.05	< 0.05
All volunteers	200	0.417 ± 0.18	0.292 ± 0.13

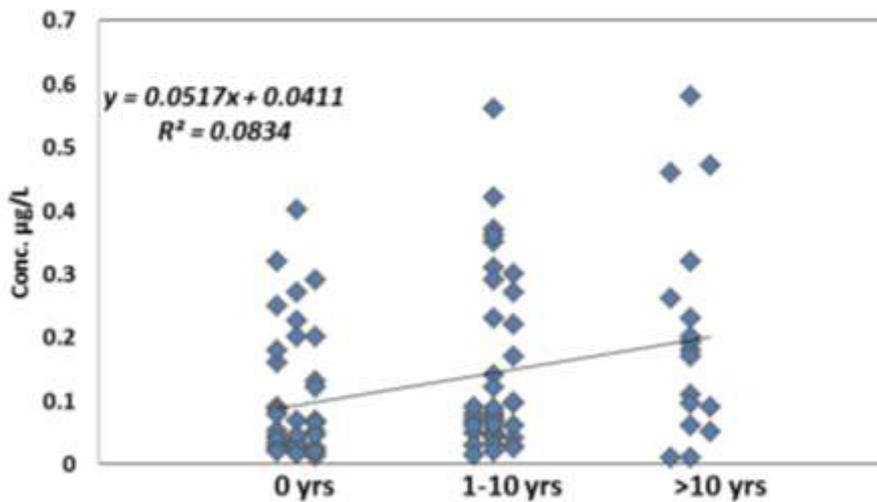


Fig-1: Cadmium concentration in blood according to duration of smoking. There was almost two fold increase in cadmium levels in blood within ten years of smoking.

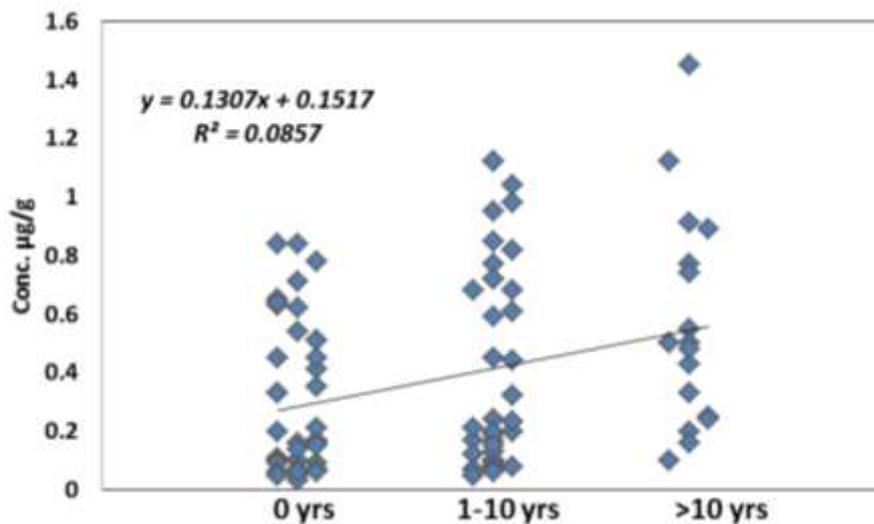


Fig-2: Cadmium concentration in scalp hair according to duration of smoking. There was an increase in cadmium levels in hair with the duration of smoking there was almost two fold increase in the concentration within ten years.

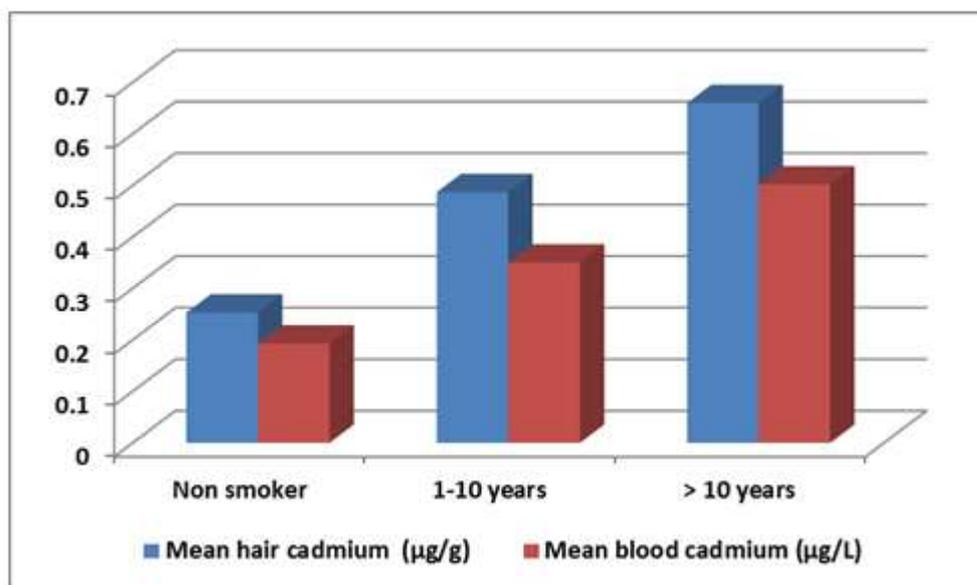


Fig-3: Mean cadmium concentration in hair and blood samples in different duration smoking groups. There was a significant correlation between both levels of B-Cd and H-Cd ($P>0.05$) and the levels of cadmium in relation with smoking duration as there was an ascending in cadmium levels with duration of smoking

Cadmium levels in females and males.

There was 98 female and 102 male; mean concentration of H-Cd and B-Cd for females was 0.289 µg/g and 0.295 µg/L, respectively (Table I, Figure 4).

Whereas, mean concentration of H-Cd and B-Cd for males was 0.485 µg/g and 0.464 µg/L, respectively, (Table I, Figure 4).

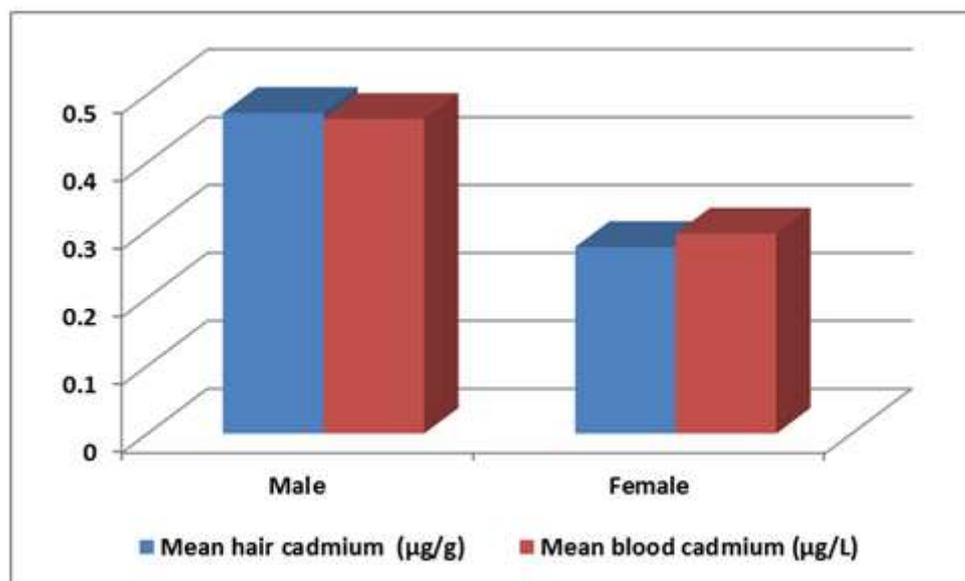


Fig- 4: Mean cadmium concentration in hair and blood samples in males and females. Levels of B-Cd and H-Cd were higher in males than females; there was almost two fold increase.

DISCUSSION

Metals analysis in biological systems is recommended method for examination of acute and chronic exposure to contaminants in the environment [19]. Cadmium finds its way to the human body through air, food and smoking. Deposition of cadmium in

different organ systems causes versatile disorders as hypertension and even cancer [20].

Levels of both H-Cd and B-Cd were significantly higher levels in smokers than nonsmokers group; there was an increase of 56% and 59% in levels of cadmium respectively. A comparative study for the

influence of smoking on blood cadmium concentration in Korea demonstrated levels of 0.8 µg/l for smokers. Whereas, in a non-occupationally exposed population, the reference ranges for blood cadmium was < 0.65 µg/L for non-smokers [21]. A comparative studies for blood cadmium concentration were conducted in Boston and London citizens showed cadmium levels of 0.73 µg/L and 0.5 µg/L, respectively [30, 31]. According to cadmium exposure standards, the recommended blood level of cadmium in the general population (≥1 year of age) is 0.315 µg/L [32]. A descriptive study was conducted in Amman to measure trace metals in the blood of Jordanian smokers population demonstrated a level of 0.313 µg/L for cadmium [29].

The major sources for cadmium contamination for the study population is cigarettes and shisha smoking as tobacco leaves naturally accumulate and concentrate relatively high levels of cadmium, and therefore smoking of tobacco is considered to be an important source for air cadmium uptake, additionally, it has been reported that one cigarette contains about 0.5-2 µg/g and that about 10% of the cadmium content is inhaled when the cigarette is smoked [22]. Naturally daily excretion amounts of cadmium for normal adult has been considered to be 0.002 mg in urine, other amounts of cadmium are eliminated through hair, nails, and sweat. For those who are occupationally exposed to cadmium, levels in the urine can be a few hundred times this value. Studies indicate that the excretion of cadmium occurs in three stages and that the half-life for the slow component of excretion is approximately 20 to 30 years [23].

The cadmium concentration was increasing in blood and hair with duration of smoking, this result demonstrate a significant statistical relation ($r=0.289$, $p<0.05$, $r=0.303$ $p<0.05$) respectively. Interestingly, levels of H-Cd and B-Cd have increased in a ratio of 48%, 45% respectively, for smokers of 1 and less than 10 years in comparison with nonsmokers group. On the other hand, there was an increase in levels of H-Cd and B-Cd in a ratio of 26%, 30% respectively for smokers of more than 10 years in comparison with smokers of 1 and less than 10 years group. Whereas, there was a threefold increase in levels of H-Cd and B-Cd respectively, for smokers of more than 10 years in comparison with nonsmokers group. Kumosani *et al.*; 2008 showed higher cadmium levels in smokers compared with nonsmokers living in Jeddah, KSA [34] Omu *et al.*; 1998 showed levels of 0.8 µg/L in the blood of smokers when compared with 0.51 µg/L for the nonsmokers in Kuwait [25]. While literature reviewing, Alomary *et al.*; found that there is increase in blood and hair cadmium concentration with age [24]. Several studies suggest that accumulation of cadmium in the human body is a function of exposure for

contaminants, smoking age and food habits [25]. Within minutes of cadmium exposure, the metal is present in the plasma of the blood, from which it is readily taken up by the liver and kidneys twenty-four hours after exposure, most of the cadmium is distributed in blood cells, and carried by metallo thionein into liver, kidneys, duodenum, hair and urine of human body [26]. The analysis of the data about metals distribution in different chronic disorders showed there is a decrease in blood and serum concentrations of nontoxic metals as selenium combined with an increase in toxic metals concentrations as cadmium in case of cigarette smokers and development of CVD [27]. In addition, levels of cadmium and lead had a statistically significant correlation with cause of death for heart-related disease vs. non-heart-related disease, although the cause of death was more significantly associated with age, the association of cadmium and lead persisted after statistical for the effect of age [28]. The results of current study are going in a parallel with toxicokinetics of cadmium distribution in the body, as the distribution is influenced by exposure amount and duration. All of our findings support the hypothesis of indirect role of metals toxicity through deleterious deposition in the different tissues causes chronic disorders such as hypertension through destroying the different cellular tissues.

Taha *et al.*; 2014 showed cadmium levels in urbans of Al-Madinah is 0.5 µg/l whereas, the cadmium levels rural of Al-Madinah is 0.3 µg/l [39]. García-Esquinas *et al.*; 2013 showed different levels in the blood of cadmium in Spain 0.27 µg/L in newborns; 0.53 µg/L in pregnant women; and 0.49 µg/L in men [40].

In our study population, cadmium concentrations demonstrated low level of contamination in city of Hail. Basically these figures discern a healthy atmosphere in Hail; also it could be explained due to rural nature of the region and lacking of mining or manufacturing activities. Nevertheless, toxicokinetics of cadmium demonstrate high levels of cadmium deposition in tissues after age of 50, in our study showed higher levels in cadmium levels in elderly aged above 50 in comparison with young ages [29]. A positive correlation has been shown between H-Cd and B-Cd for our study population ($r=0.48$ $p<0.05$), even though there is a conflict point about using values of different organ systems to monitor the acute and chronic exposure, but literally in this study we show that there is a significant correlation in this age group as the deposition of cadmium has increased in both hair and blood.

Smoking has affected levels of cadmium in both hair and blood ($r=0.345$, $P<0.05$) ($r=0.367$, $P<0.05$), respectively, there was an increase in cadmium levels in smokers in comparison with nonsmokers at the

same age group. In the human body age, sex, occupation, and smoking are causing gradual changes of cadmium homeostasis during different life stages [30]. Whereas, the overall cadmium image in the acute (blood) and chronic state (hair) were significantly dependent to each other in a manner of concentration dependent shifting among storage sites.

Cadmium levels were higher in hair and blood of males than females; there was a significant correlation between cadmium levels in male and female for H-Cd and B-Cd ($r=0.267$ $P < 0.05$, $r=0.241$ $P < 0.05$). According to the toxicokinetics of cadmium; the differences can arise from the average daily number of cigarettes smoked by males was higher than females as the mean was 15 and 9, respectively. In addition to that, environmental and physiological differences between males and females as BMI, blood volume and menstrual cycle play another factor for these differences. Baecklund *et al.*; demonstrated a higher cadmium levels in males than females in Sweden [31]. Al-Saleh *et al.*; 2006 showed mean blood cadmium concentrations were higher in hypertensive women 0.874 ± 0.995 $\mu\text{g/L}$ and 0.785 ± 0.665 $\mu\text{g/L}$ in controls with 3.934 times were more likely to be hypertensive than those with blood cadmium levels < 0.627 $\mu\text{g/L}$ [36]. Abed, KF 2007 showed low cadmium level in the hair of females' 0.04 ± 0.01 $\mu\text{g/g}$ [37].

These levels of cadmium could not cause deleterious pathological disorders on the short term; nevertheless, the clinical manifestations may develop after 10 or 20 years of smoking. In the other hand, other source for cadmium contamination for our study population is food as rice and fish beside to the leakage of cadmium from old water pipes in the municipal drinking water system itself especially there is no factories or industries dealing with cadmium in Hail [32].

CONCLUSION AND RECOMMENDATIONS

From our data, clearly, we found that cadmium deposition in soft and hard tissues in human beings has showed a dramatic increase in relation with both smoking and duration of smoking. It could be concluded that, despite the low cadmium concentration in hair and blood of university students there should be enforcement for smoking prohibition law in Saudi Arabia as the levels of cadmium were increasing with duration of smoking.

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