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Original Article

Cadmium Concentration in Cigarette Brands, Tobacco Leaves, and Smokers' Blood Samples

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Abstract

Background and Aim: The present study sought to determine cadmium (Cd) concentration in three different types of tobacco leaves, cigarette smokers' blood, and certain cigarette brands that are both imported from abroad and produced in Iran.

Materials and Methods: The participants consisted of male volunteers of 40-65 years old whose blood samples were collected and categorized into four distinct groups of cigarette smokers (N=40) based on the number of cigarettes every participant would smoke per day. Serum concentrations of heavy metal were determined using graphite furnace atomic absorption (GFAA). Moreover, graphite furnace atomic absorption spectroscopy technique was used to determine all of the samples examined in this research.

Results: Mean concentrations of Cd in imported cigarettes brands and cigarettes produced in Iran were 1.89±o.12 µg/g (dry weight) and 1.44±0.8 µg/g (dry weight) respectively. Average levels of Cd in smokers' blood with 10, 20, 30, and 40 cigarettes per day were 1.31±0.14, 2.42±0.17, 3.18±0.21, and 4.38±0.18 µg per liter respectively. The mean concentrations of Cd in Hakan, Kasham and Borazjan tobacco were 2.18 ± 0.12, 2.43±0.9, and 2.89±017µ/g (dry weight) respectively.

Conclusion: The data presented in this study did not indicate any significant difference between the cigarette brands produced in Iran, while Rothman cigarette brand had the highest Cd concentrations among the imported cigarettes. The blood Cd concentration in smokers that depends on the number of cigarette smoked per day was about four times higher than non-smokers.

Keywords: Tobacco smoke pollution, Cadmium, Smoking

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Introduction

Metals are crucial to many physiological processes in the human body, but they could be at one harmful to human health in concentrations that are not physiologically favorable. Heavy metals, weather in

metallic or ionic form, are detrimental environmental pollutants (1). Significant favorable and unfavorable roles of trace heavy metal ions in human health have been identified (2). Lead, chromium, cadmium, copper, zinc, arsenic, and mercury are highly toxic even in the trace level. They might damage or decrease mental and central nervous functions, and influence blood composition, lungs, kidneys, liver, and other vital organs (3, 4). Long-term exposure to heavy metals could induce cancer, neurological degenerative conditions, and in some cases might lead to death (5).

Smoking could be regarded as a primary source of exposure to heavy metals (6). Tobacco is the main ingredient of cigarette which is wrapped in papers containing additives and encompassing heavy metals such as lead, mercury, and cadmium (7). Cadmium (Cd) is added to cigarette papers to keep the paper from going out once it is lit (8). According to Mussalo-Rauhamaa *et. al*., (9) the average contents in cigarette tobacco sampled from Finland were 1.7 for Cd and 2.4 µg Lead (Pb). Average Cd levels in cigarettes range from 1-3 mg/kg (10, 11). There is approximately 2 µg of Cd in a cigarette, of which nearly 10 % is transferred to cigarette smokers (12). A single pack of cigarettes contains 19-20 filtered cigarettes (depending on the country) that could deposit 2–4 µg into the smokers' lungs (13, 14).

Tobacco plants are capable of taking up Cd and Pb from soil and concentrate them in leaves. Hence, tobacco and cigarettes could hold these metals in roughly high amounts (15, 16). Nonetheless, no obligation has been set to control the potential contamination of tobacco or cigarettes with toxic heavy metals to date. Likewise, there is not sufficient information concerning the contents in the different brands of cigarette that are currently produced.

The present study was designed to (i) determine the levels of Cd in distinct brands of cigarettes sold in Iran, (ii) to determine the distinctions between the levels of Cd in Iranian cigarettes and that of imported cigarettes sold in Iran, (iii) to determine the levels of Cd in the Iranian tobacco, and finally (iv) to determine the levels of Cd in the blood samples of smokers.

Materials and Methods

Materials

Hakan, Kashan and Borazjan tobacco leaves, and also eight different importated cigarette brands were purchased from the center of products distribution, the Iranian Tobacco Company, Isfahan, Iran. The homogenized mixture of each cigarette was prepared through removing the papers and filters of twenty cigarettes. To reach a statistically significant state, the cigarettes were obtained randomly from eight different batches (four cigarettes from every pack of distinct batch number).

Preparation of Samples

Preparation of samples was carried out using the modified Campbell and Plank method (17). The samples were dried in oven at 80°C overnight through a cooling step in a desiccator. A mass of 3.4 ± 0.001 g of the dried tobacco was placed in a beaker. 10 ml of concentrated nitric acid (HNO_3) and 4 ml of concentrated hydrochloric acid (HCl) were added to every sample. The beakers were covered and boiled to reach the final volume of 6 ml. Finally, the mixtures were filtered and diluted to 25 ml with deionized water.

Blood samples were obtained from 40 cigarette smoking volunteers aged between 40 and 65 years old. The period of smoking ranged from 2 to 25 years.

Cadmium Assessment

Fasting venous blood samples were collected from all the participants in the morning and placed into sterile tubes that were untreated with heparin, EDTA, citrate, and so forth. The blood serum was separated following two hours standing and centrifugation at 3500 rpm for 10 minutes. The serum samples were then placed in closed plastic laboratory vessels and finally stored at −80 °C until the time of cadmium analysis.

Prior to the commencement of the analysis, all glassware were soaked in (1+1) HNO_3 overnight. Subsequently, they were rinsed with tap water and then with deionized water. Standard working solutions were prepared through the serial dilution of 16 mL of either 1000 mg/L standard stock solution of Cd. The solution was prepared based on reference (Ivanenko *et al*., 2012), and then was stored at 4 °C (18).

Cd levels in serum were identified through the utilization of a Perkin-Elmer model 3030 atomic

absorption spectrometer with graphite 19 furance HGA-600 and Zeeman background correction (19). Heavy metal (cd) single-element hollow 20 cathode lamps of Cd were operated. The matrix modifier used for heavy metals was 0.2% HNO3, 0.5% Triton X-100, and 0.2% ammonium phosphate (20). A questionnaire was filled by every subject regarding his/her smoking habit.

Statistical Analysis

Data have been indicated as mean±sd. Independent two-sample t-test was used for comparing the differences between Cd concentrations of Iranian and foreign cigarettes. One-way analysis of variance (ANOVA) was used for comparing the distinctions between brands' names or the differences between individuals with different numbers of smoked cigarettes (per day). Statistical analysis was carried out using SPSS15 (SPSS Inc., Chicago, USA). The results were considered statistically significant at $p<0.05$.

Results and Discussion

The weight of the cigarette tobacco following the removal of the papers and filters varied depending on several factors, including the length of the cigarette and other determinants. The average weight of the cigarettes without the filter and paper ranged from 1.43 to 1.62 µg per gram. The average concentration of the eight cigarettes brand produced in Iran was 1.57 µg /g (dry weight) (Chart 1).

The provided chart 2 shows Cd concentrations in some popular foreign cigarette brands in Iran. As the graph shows, Rothmans brand had more Cd concentration than other brands. The Cd concentration rate for every brands, i.e. Marlboro, Modern and Zest, ranged from 1.97±0.9 to 2.43±0.14.

The bar of Chart 3 compares Cd concentrations in three types of tobacco leaves commonly used in Iran. Borazjan tobacco leaves had the highest Cd concentration.

By looking at Table 1, it could be observed that generally there was a significant Cd concentration between Iranian cigarette brands vs. popular foreign cigarette brands.

The present study indicated that average blood Cd concentrations in smokers' blood with 10, 20, 30, and 40 cigarettes per day were 1.31±0.14, 2.42± .17, 3.18±0.21, and 4.3 8±0.18 µg per liter, respectively. These results have been presented in Table 2.

One of the highly significant findings of the present study is that popular foreign cigarette brands were characterized by higher rates of Cd concentration compared to Iranian cigarette brands. It was also revealed that Borazjan tobacco leaves had the highest Cd concentration compared to the two other brands of tobacco leaves. The second major finding was that the average blood Cd concentration in smokers' blood could rise via the increasing consumption (use) of cigarette.

Most of the results of this research are consistent with

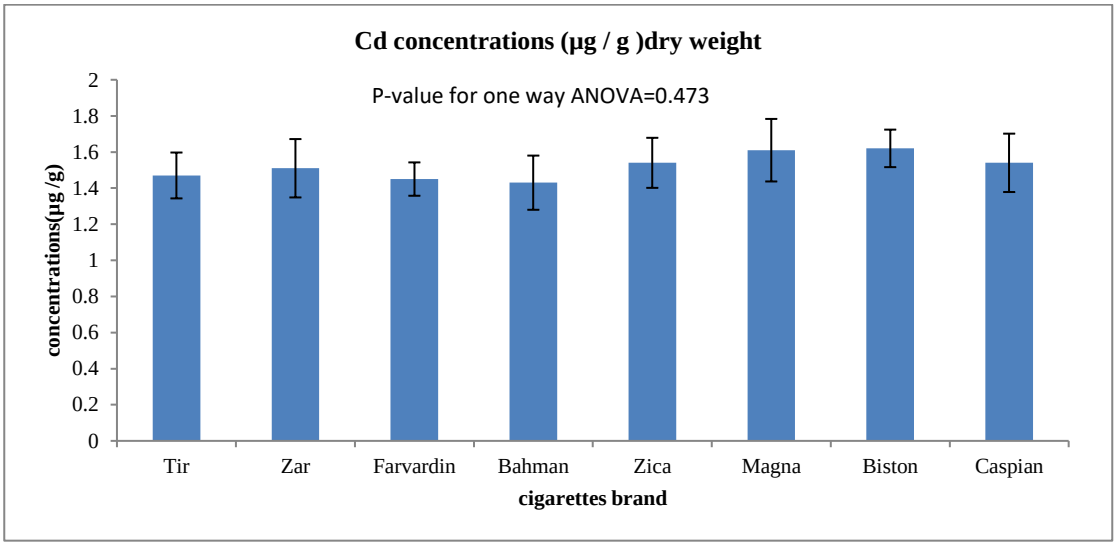

Chart 1. Cd concentrations in some popular Iranian cigarette brands.

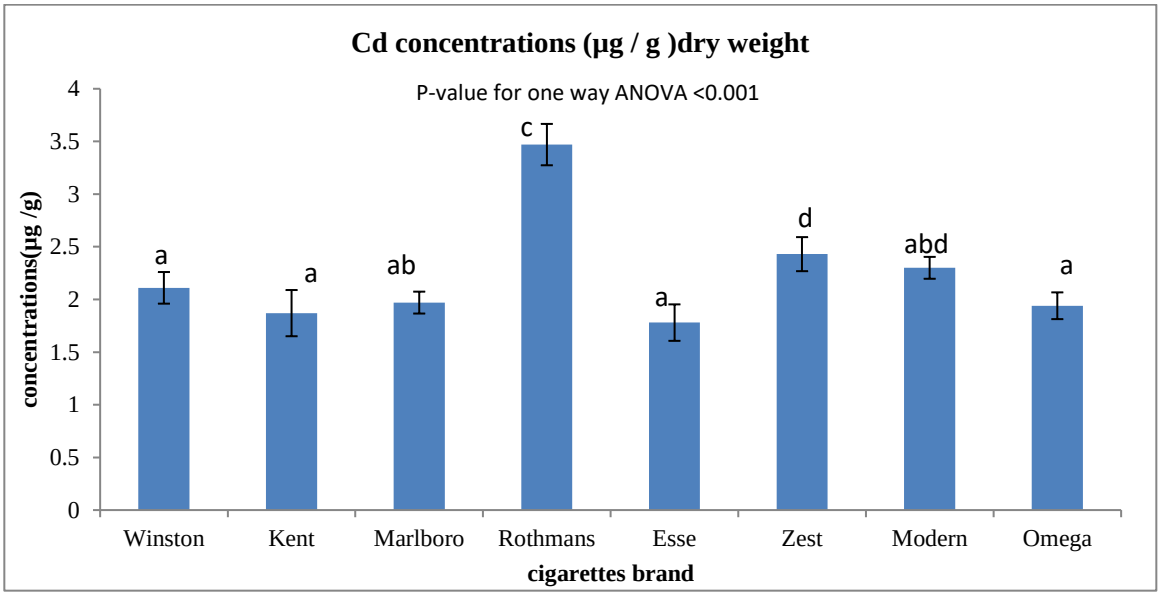

Chart 2. Cd concentrations in some popular foreign cigarette brands in Iran (Columns with different letters have statistically significant difference).

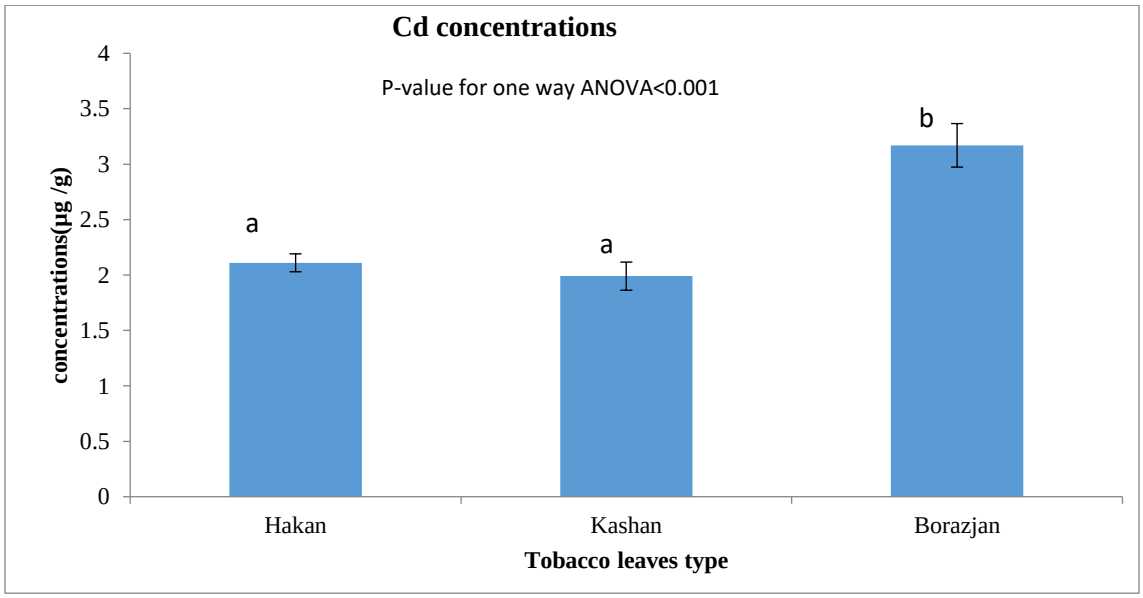

Chart 3. Cd concentrations in three type of tobacco leaves commonly used in Iran (Columns with different letters have statistically significant difference).

the literature results. A study in 2017 indicated that the levels of Cd, Pb, Cu and Zn in cigarettes sold in Ethiopia could be compared very well with the same levels in cigarettes from other parts of the world (8). Another study has addressed and indicated the toxic metal concentrations (As, Cd, Cr, Ni, and Pb) in cigarettes obtained from U.S. (21). Sebiawu *et. al.* analyzed the heavy metals content of tobacco for different metals including Pb, as well as for the cigarettes sold in a city in Ghana (Municipality of Upper West Region) (22). A study has reported the levels of Cd and Pb found in popular cigarette brands that are sold and/or produced in Saudi Arabia (23). The data obtained in this section was in a good agreement with the mentioned references.

Imported cigarettes indicated higher Cd contents compared to Ethiopian cigarette brands. The main source of trace metals in tobacco leaves and cigarettes is probably the extensive use of chemical fertilizers (24). According to the results proposed by Nnorom *et.*

Table 1: The Comparison of Cd concentrations of popular Iranian cigarette brands vs. popular foreign cigarette brands.

nationality	Cd concentrations(µg /g)dry weight	Cd concentrations (µg /cigarette)
Iranian	1.52 ± 0.12	1.45 ± 0.06
foreign	2.23 ± 0.35	1.58 ± 0.22
p-value	**<0.001**	0.133

Table 2: Average levels of Cd in smokers' blood with 10, 20, 30, and 40 cigarettes per day (n=40).

Number of cigarettes (per day)	Cd Concentration	Age(year)
0	1.07± 0.11[a]	51.96 ±17.88
10	1.31± 0.14[b]	42.15±12.43
20	2.42±0.17[c]	48.15±10.09
30	3.18±0.21[d]	53.69 ±13.58
40	4.38±0.18[e]	62.00±21.01
p-value	<0.001	0.081

al., the mean metal contents of cigarettes remarkably varied. They stated that the location of production had a key role in the variation. Nevertheless, there is no convincing evidence to confirm that the distinctions are rooted in the place of production or the extent of industrial development of the area. Nnorom *et. al*. have exhibited that certain species of plants could accumulate high concentrations of some metals, particularly Cd, in their leaf tissues rather than in their roots (7). Certain operations, including processing, packaging, and other technological procedures, including the utilization of additives that are supposed to bring raw items to the consumer, could remarkably increase heavy metal contents in cigarette tobacco (24).

The available literature data indicate that there is a wide range of values of Cd concentration in tobacco and their contents. Cd contents in cigarettes that are manufactured in distinct countries worldwide range from 0.21 to 2.79 µg per cigarette, whereas the concentration in tobacco rages from 0.5 to 5 µg /g, or even higher, as it has already been reported (9, 25, 26).

The Cd blood concentrations increased in accordance with the elevation in the number of cigarettes smoked per day and smoking indices in all age groups.

40-60% of cadmium inhaled during smoking (27) could straightly enter the blood of smokers (28). To a greater degree, smoking more than 20 cigarettes a day could raise Cd contents in the human body by 10 folds (27), and consequently induce distinct damages in the body organs. For residents of non-Cd-polluted areas, the average daily Cd uptake associated with food and water usually reaches 0.6–1.3 µg and 0.04 µg from the air (World Health Organization) (29). Moreover, Cd uptake from tobacco smoke might be more than that of other sources.

Conclusion

The measurements and calculations carried out during this research exhibited that the evaluation of the risk of health damage induced by the exposure to Cd requires the consideration of smoking habit. Furthermore, it is necessary to check both tobacco contamination and concentrations of these metals in the smokers' blood samples. Apparently, the unpolluted area residents are not exposed to the risk of heavy metal exposure, while habitual smoking might be a potential source of long-term exposure to heavy metals (particularly Cd). Likewise, residents of regions that are unpolluted with regard to Cd might be exposed to increased risk of health damage caused by these toxic metals when they are close to cigarette smokers. The level of blood Cd concentration in cigarette smokers that depends on the number of cigarettes smoked per day is about four times higher than non-smokers.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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