Biological Trace Element Research (2020) 194:105–114
https://doi.org/10.1007/s12011-019-01769-5

The Interaction Between Concentration of Heavy Metal-Trace Elements and Non-Smoking Status of Adolescents in Sinop (Turkey)

Huriye Demet Cabar[1] · Melek Ersoy Karaçuha[2] · Muhitdin Yilmaz[3]

Received: 24 April 2019 / Accepted: 30 May 2019 / Published online: 13 June 2019

Abstract
This study was experimentally conducted between 2017 and 2018 in order to determine the interactions of heavy metals and non-smoking status of adolescents in Sinop Province (Turkey). In this regard, the students of Sarı Saltuk Anatolian High School students in Sinop Province were examined. The research data was obtained using a questionnaire, including questions about sociodemographic characteristics and smoking status of the adolescences. Afterwards, 0.5 g of hair samples from 40 female students who accepted to participate to the research was collected and analyzed by inductively coupled plasma mass spectrometry (ICP-MSMS), and the obtained data were evaluated using SPSS (version 22.0) statistical program. At the end of the study, the Mg, Cr, Co, and Zn elements of the non-smoking girls were found to be slightly higher than the normal range of hair, and the high concentration of Cd element was related to the contamination by passive smoking. Besides, it was determined that the elements which showed the highest positive correlation in hair samples taken from the children of smokers were Ca/Cd, Al/Fe, Mg/Cr, Na/Fe, Al/Cd, and Al/Na, respectively. As the nursing approach, it is thought that trainings aiming to prevent smoking and quitting smoking are extremely important.

Keywords Heavy metals · Adolescent · Smoking · Nursing approach · Sinop

Introduction

The greatest effects of heavy metals on human health are seen in childhood in the age of growth and development. Smoking, one of the factors causing heavy metal accumulation in the body, poses a great threat for adolescents with growth age [1].

The effects of smoking on health are the result of the interaction of various forms of toxic components in the human body and cigarette smoke. While individuals who use active cigarettes breathe the main cigarette smoke, non-smokers are exposed to second-hand and third-hand smoke. These environments are considered to be the largest source of environmental tobacco smoke (ETS) and are considered to be the main source of the gaseous and particulate toxic chemical species of indoor environments [2, 3]. This side cigarette smoke, which is inhaled by non-smokers, usually involves relatively high concentrations of many harmful substances, including heavy metals [4], and is great damage for babies and toddlers who eat, eat with their hands, and are cared for by a cigarette user with toxins on their skin and/or clothing [5, 6].

Most of the elements in the cigarette smoke are exposed by the burning of tobacco leaves and water pipes and these elements can be deposited in the tobacco plant by either atmospheric dusts [7, 8] or the pesticides accumulated by the tobacco [9, 10] or in the soil [11–13]. However, when the plants grow in environments characterized by high concentrations of heavy metals, heavy metals and other elements in tobacco can be further increased [14, 15]. In addition to the toxic elements that can be taken from the smoke during smoking, various organic carcinogenic substances can be taken into the lungs and some metals such as cadmium (Cd), nickel (Ni), and lead (Pb) could easily be dispersed in the body with blood flow and accumulate in certain organs such as kidney and liver [16].

✉ Muhitdin Yilmaz
muhittinylmaz@gmail.com

Huriye Demet Cabar
gonener@hotmail.com

Melek Ersoy Karaçuha
melekersoy57@hotmail.com

1 School of Health, Department of Nursing, Sinop University, 57000 Sinop, Turkey

2 School of Health, Department of Occupational Health and Safety, Sinop University, 57000 Sinop, Turkey

3 Vocational High School of Health Services, Department of Environmental Health, Sinop University, 57000 Sinop, Turkey

The effects of environmental pollution on human health could be analyzed using some biological materials such as teeth, hair, and nails, and it is possible to monitor changes in the body. Hair and nails are biomaterials of fibrous protein structure consisting of keratin [17, 18], and human hair is a long-term growth material with a large number of trace elements accumulated in the hair, which can provide useful data for a long time in determining the health status of an individual [19, 20]. On the other hand, the concentration of these elements could be used to investigate dietary exposure to chemical pollutants, especially to toxic metals, including the effects of smoking and drug use by an individual or population [21]. For this reason, hair and nails are considered as valuable textures for the research of people's exposure to environmental pollution.

In recent years, it has been observed that the hair of the children is particularly prominent as a biomarker used in the monitoring of exposure to heavy metals [22–26]. In the analysis of addictive substances, the most important reason for studying with hair samples is that it is possible to obtain information about the use of chronic substance in the distant past which cannot be detected by blood and urine samples [27, 28]. The reason for this is the long-term accumulation of inorganic components in hair samples and the higher concentrations of the elements than in biological fluids [10, 29]. Considering the researches on this subject, it is thought that the high affinity of hair tissue to metals is mainly due to the presence of cysteine, which constitutes approximately 14% of the human hair structure [27]. As a matter of fact, many metals interacting with hair tissue, sulfur atoms in cystine, or sulfur groups in other amino acids [30] and metals such as mercury can also be attached to the hydrophobic nucleus of the hair structure melanin polymer [31]. However, metals circulate in the hair during the hair formation in hair follicles [32], endogenously by absorption of metals secreted by oil and sweat glands, semi-oiled, and by contacting the hair with endogenous and polluted ambient air, soil and dust, and cosmetic [33].

In this study, it is aimed to explain the relationship between smoking status and heavy metal levels of smoking in Sarı Saltuk Anatolian High School students living in Sinop Province, to determine the relationship between smoking status and the interaction of the mentioned elements and nursing approach in adolescent children.

Material and Methods

The aim of this study is to determine the relationship between smoking status and heavy metal interaction and nursing approach in adolescents in Sinop Province. The required permission was obtained from the Ethics Committee of Sinop University and the Provincial Directorate of National Education for the research. The population of the study was comprised of the students of Sarı Saltuk Anatolian High School in Sinop. The study was selected from among the students who were studying in the boarding school, who stated that they did not smoke, were less affected by outdoor pollution by staying away from extracurricular activities, and were only at the end of the week, during holidays, and when they were on leave. According to the research, female students were preferred to have a longer hair compared with male students and to obtain the amount of hair to be used for analysis. The amount of heavy metal and trace elements in the hair and the amount of heavy metal and trace elements were analyzed with the 40 female students who fulfilled the conditions mentioned and accepted to participate in the research. In order to determine the sample of the study, female students who did not have any mental or chronic disease/syndrome, who did not use any drugs, and who did not have any mental or chronic disease/syndrome, were selected as case selection criteria.

Of the hair samples, 0.5% were collected from 40 female students between ages 13 and 18 in the Sarı Saltuk Anatolian High School. In order not to affect the result of the analysis, care was taken not to stain the hair while collecting the hair sample. Forty students were evaluated within the scope of sociodemographic and other questionnaire questions. The hair samples were taken with high-purity 3 mL HNO_3 and 9 mL HCl and in high-pressure Teflon containers at a temperature of 200 °C for half an hour. The samples were then transferred to 50-mL falcon tubes. The resulting filtrate was dissolved in 50 mL of pure water and dissolved. Cd, Pb, Ni, Cu, and Fe heavy metals of the samples were measured in ICP-MSMS at Sinop University (SÜBİTAM). Also, the quantitation of the analytes was performed by using the calibration curve method for each analyte. The calibration curves were prepared from the standard solutions of the analytes. The least correlation coefficients were obtained as 0.9934. The limits of detection (LOD = 3 s) and limits of quantification (LOQ = 10s) for fifteen metals were also calculated and values of R, LOQ, and LOD of analytes were given in Table 1.

Statistical Analysis

Statistical analyses were performed using SPSS (version 22.0) program. The socio-demographic characteristics of student were done by using descriptive statistical methods (percentage up, mean). Besides, the correlation of elements was determined by the Spearman correlation (2-tailed) analysis.

Results

A total of 40 students participated in the study. Table 2 presents socio-demographic characteristics and smoking status of all students. Once the socio-demographic data of the subjects were evaluated, 60% of their families were found to smoke

Table 1 Parameters of metric for ICP-MSMS

Elements	Linear range (μg/kg)	Regression	R	LOD (μg/kg)	LOQ (μg/kg)
Na	0–100	$y = 30{,}101.1175x + 431{,}823.1256$	0.9995	0.4166	1.3887
Mg	0–100	$y = 18{,}106.6085x + 1570.3856$	0.9997	0.3917	1.3057
Al	0–100	$y = 24.6019x + 24.4808$	0.9998	1.0150	3.3833
Ca	0–100	$y = 58.6526x + 10{,}130.8304$	0.9934	19.9500	66.5000
Cr	0–100	$y = 2374.2833x - 28.2171$	1.0000	0.0193	0.0643
Mn	0–100	$y = 732.5724x + 63.1845$	1.0000	0.0946	0.3153
Fe	0–100	$y = 1648.9975x + 3859.5245$	0.9977	0.1767	0.5890
Co	0–100	$y = 4729.5479x - 65.8590$	1.0000	0.0073	0.0243
Ni	0–100	$y = 1422.0971x + 269.3346$	1.0000	0.0366	0.1220
Cu	0–100	$y = 4051.6775x + 400.0200$	1.0000	0.0678	0.2260
Zn	0–100	$y = 404.2578x + 398.1919$	1.0000	0.5051	1.6837
As	0–100	$y = 282.9334x + 10.9904$	1.0000	0.0367	0.1223
Se	0–100	$y = 414.7518x + 289.5721$	1.0000	0.0835	0.2783
Cd	0–100	$y = 5918.4731x - 336.7565$	1.0000	0.0023	0.0077
Pb	0–100	$y = 17{,}297.5112x + 64{,}049.8253$	1.0000	0.0655	0.2183

R correlation coefficient, *LOD* limit of detection, *LOQ* limit of quantification

and 40% were non-smokers (Table 2). The mean values of the data obtained from the analysis of the hair samples taken from the subjects (μg kg^{-1}) are given in Table 3.

As a result of the analysis of the hair samples taken from the students, Na (sodium) value is 189,244.64 ± 29,922.21 μg kg^{-1} (min. 20,100.62, max. 85,4407.22); Mg (magnesium) value is 356,244.73 ± 56,327.24 mg kg^{-1} (min. 73,076.59, max. 2,124,364.96); Ca (calcium) value is 6,635,802.86 ± 1,049,212.56 μg kg^{-1} (min. 1,882,126.67, max. 20,352,833.51); Mn (manganese) value is 1481.29 ± 234.21 μg kg^{-1} (min. 124.87, max. 10,140.57); Fe (iron) value is 19,203.18 ± 3036.29 μg kg^{-1} (min. 8410.46, max. 40,528.07); the value of Se (selenium) was 594.80 ± 94.05 μg kg^{-1} (min. 215.33, max. 1275.09); Zn (zinc) value is 625,721.49 ± 98,935.26 μg kg^{-1} (min. 140,951.77, max. 3,197,924.85); and Al (aluminum) value was determined as 13,913.38 ± 10,636.3 μg kg^{-1} (min. 4507.67, max.58,204.80).

Based on the heavy metal analysis of hair samples taken from the students, As (arsenic) value is found to be 31.26 ± 10.67 μg kg^{-1} (min. 8.28, max. 59.95), Cd (cadmium) value is 161.68 ± 458.21 μg kg^{-1} (min. 14.21, max. 2929.55), and Pb (lead) value was detected as 1379.75 ± 775.20 μg kg^{-1} (min. 417.41, max. 3837.42). The value of the As (arsenic) is 31.26 ± 10.67 μg kg^{-1} (min. 8.28, max. 59.95), Cd (cadmium) value is 161.68 ± 458.21 μg kg^{-1} (min. 14.21, max. 2929.55), the lead (Pb) value was determined as 1379.75 ± 775.20 μg kg^{-1} (min. 417.41, max. 3837.42), Cr (chromium) value is 210.63 ± 202.98 μg kg^{-1} (min. 57.07, max. 1084.24), Co (cobalt) value is 559.21 ± 1518.83 μg kg^{-1} (min. 14.38, max. 7264.96), the value of the nickel (Ni) 1749.50 ± 932.94 μg kg^{-1} (min. 381.78, max. 4298.27), and Cu (copper) was obtained as 17,450.42 ± 21,575.00 μg kg^{-1} (min. 2645.75, max. 138246.03).

The findings of 40 female students obtained from the study and reported that they do not smoke are re-evaluated according to their smoking habits and the findings obtained from the hair analysis are given in Table 4.

As a result of the analysis, the results of the hair analysis of the students who had smokers in their families are as follows: Cd (198.43 μg kg^{-1}), Pb (1582.89 μg kg^{-1}), Ni (1842.19 μg kg^{-1}), Co (765.38 μg kg^{-1}), As (31.73 μg kg^{-1}), Al (14,676.76 μg kg^{-1}), Zn (680,692.08 μg kg^{-1}), Na (228,978.70 μg kg^{-1}), Se (622.69 μg kg^{-1}), and Fe (19,262.30 μg.kg^{-1}). The mean values of Cr (211.63 μg kg^{-1}) and Ca (7,417,706.80 μg kg^{-1}) were found to be in the family of non-smoker students (106.54 μg kg^{-1}; 1054.72 μg kg^{-1}; 1610.47 μg kg^{-1}; 249.97 μg kg^{-1}; 30.54 μg kg^{-1}; 12,768.30 μg kg^{-1}; 543,265.61 μg kg^{-1}; 129,643.56 μg kg^{-1}; 552.98 μg kg^{-1}; 19,114.49 μg kg^{-1}; 209.13 μg kg^{-1}; 5,462,946.94 μg kg^{-1}, respectively) in the case of non-smoking students in their families, but according to the results of the hair analysis of Cu (18,149.68 μg kg^{-1}), Mg (423,931.20 μg kg^{-1}), and Mn (2429.83 μg kg^{-1}) element values compared with the other group (16,984.24 μg kg^{-1}; 311,120.42 μg kg^{-1}; 848.92 μg kg^{-1}, respectively) are determined to a higher rate of hair (Table 4).

The correlation coefficient matrix of the relationship between the element concentrations obtained from the hair samples of the students who smoke in their families is given in

Table 2 Distribution of socio-demographic and smoking status of students ($n = 40$)

Properties		n	%
What is your mother's education?	Elementary education graduate	23	57.5
	Secondary education graduate	13	32.5
	Higher education graduate	4	10.0
What is your father's education?	Elementary education graduate	16	40.0
	Secondary education graduate	15	37.5
	Higher education graduate	9	22.5
What is your average monthly income?	Below 1500	8	20.0
	1500–2500	20	50.0
	2500–3500	7	17.5
	3500 3500 and above	5	12.5
What is your monthly allowance?	100 or less	11	27.5
	Between 100 and 200	16	40.0
	Between 200 and 300	9	22.5
	300 and above	4	10.0
Are there any smokers in your family?	Yes	24	60.0
	No	16	40.0
What is your approach to smoking?	Never drink	32	80.0
	Sometimes drinkable	8	20.0
Did you get any information about the harms of smoking?	Yes	40	100
	No	0	0
If yes, where did you get the information?	Nurse	17	42.5
	Television	1	2.5
	Teacher	11	27.5
	Doctor	2	5.0
	Other	9	22.5
What do you think is the impact of smoking on human health?	Whole body/organs	38	95.0
	Some organs	1	2.5
	Other	1	2.5

Table 5. When the correlation between the essential and toxic element levels obtained from the hair samples taken from the children of the smoker families was examined, it was determined that the elements showing the correlation between the levels of essential and toxic elements were Ca/Cd ($R^2 = 0.86$, $p < 0.01$), Al/Fe ($R^2 = 0.86$, $p < 0.01$), Mg/Cr ($R^2 = 0.85$, $p < 0.01$), Na/Fe ($R^2 = 0.82$, $p < 0.01$), Al/Cd ($R^2 = 0.77$, $p < 0.01$), and Al/Na ($R^2 = 0.74$, $p < 0.01$), and Al/Mg, Al/Ca, Mn/Na, Fe/Mg, Ni/Al, Ni/Ca, Cu/Na, Zn/Cr, Mg/Ca, Mg/Cd, Fe/Cd, Cd/Ni, Pb/Na, Al/Pb, and Fe/Pb (Table 5). However, Se and Co elements were not significantly correlated with other elements.

The correlation coefficient matrix of the relationship between element concentrations obtained from hair samples of non-smoker students in their families is given in Table 6.

According to Table 6, the correlation between the concentrations of the elements determined in the hair of 16 female students who stated that they had not smoked and that they had not smoked before were examined: Fe/Al ($R^2 = 0.81$, $p < 0.01$), Mn/Ca and Mg/Ca ($R^2 = 0.80$, $p < 0.01$), Cd/Se ($R^2 = 0.70$, $p < 0.01$), Se/Pb ($R^2 = 0.62$, $p < 0.01$), As/Co ($R^2 = 0.54$, $p < 0.05$), and As/Se ($R^2 = 0.53$, $p < 0.05$), and no significant correlation was found between the other elements.

Discussion

For humans, hair is one of the storage sites of living organisms, such as fat tissue, which can provide information on the accumulation of toxic and other substances in the body, and can only be reliably stored and analyzed by hair mineral analysis and can show the accumulated amount of toxin [34]. Another feature of the hair is that these substances do not vary daily and that the results of hair analysis are not subject to multiple changes such as blood counts or blood/urine tests [34]. The fact that the essential elements obtained from hair analyzes are more or less, for example, Fe, Ca, and Zn element concentrations, shows that there are serious problems in the physiological structure of human beings [30, 35], including the effects of smoking or drug use of an individual or population. It can also be used to investigate exposure to chemical

Table 3 Results obtained from the study of the female students' hair analysis of the metals in the study (μg kg^{-1}) (*Na* sodium, *Mg* magnesium, *Ca* calcium, *Mn* manganese, *Fe* iron, *Se* selenium, *Zn* zinc, *Al* alumina, *Cu* copper, *As* arsenic, *Cd* cadmium, *Pb* lead, *Cr* chrome, *Co* cobalt, *Ni* nickel) (n = 40)

Participant (K)	Na	Mg	Ca	Mn	Fe	Se	Zn	Al
K1	91,864.87	437,032.18	4,941,733.54	537.40	18,382.34	413.25	521,124.98	6920.00
K2	90,036.97	260,317.85	6,012,996.44	450.73	18,717.30	512.74	434,557.66	13,977.58
K3	100,911.94	231,573.83	6,704,164.63	769.36	18,493.79	582.50	1,040,334.73	16,834.11
K4	79,990.06	267,964.08	6,661,800.82	556.17	12,291.34	642.65	819,738.15	7304.94
K5	47,934.08	198,234.81	5,367,552.27	1118.91	11,796.73	843.91	449,729.11	8725.88
K6	332,753.51	222,415.39	6,917,172.30	2363.02	16,941.78	542.20	1,605,235.12	7119.27
K7	854,407.22	296,699.45	6,656,207.70	2110.44	27,105.36	685.69	464,670.20	21,132.42
K8	802,304.65	433,419.82	6,725,229.41	995.35	40,528.07	573.36	516,527.74	39,646.17
K9	205,584.69	99,902.77	2,835,346.85	1374.74	10,711.38	340.26	193,443.14	7435.40
K10	606,488.88	675,851.21	20,352,833.51	1359.18	40,495.53	249.77	158,686.21	58,204.80
K11	133,251.79	751,565.01	8,260,698.25	519.54	21,615.90	916.34	3,197,924.85	12,964.29
K12	178,002.38	255,334.12	4,837,049.82	1021.07	19,714.92	600.02	378,834.45	16,119.80
K13	524,929.94	541,319.27	5,788,697.89	2545.15	34,464.16	728.20	464,998.93	26,692.69
K14	88,463.84	240,166.85	6,144,452.93	217.65	9497.45	649.46	347,503.07	6036.14
K15	177,296.60	235,780.89	5,765,176.56	481.63	15,675.39	675.28	1,066,065.13	15,537.63
K16	294,957.41	276,468.06	9,036,324.59	758.20	20,621.25	529.32	140,951.77	19,374.27
K17	35,254.16	252,811.33	8,525,351.24	470.96	14,750.69	608.13	735,532.51	9068.00
K18	134,988.43	267,912.28	9,247,386.18	537.34	14,411.30	643.31	954,860.85	12,542.17
K19	36,491.41	222,552.82	9,251,174.44	280.05	11,274.27	455.56	178,430.88	8911.81
K20	167,989.25	261,205.30	7,937,453.91	520.68	14,248.53	511.49	541,742.41	7197.03
K21	73,826.86	345,095.76	8,653,445.27	322.92	12,529.35	816.58	360,728.54	9991.88
K22	123,127.83	239,124.81	7,394,684.59	385.34	21,324.53	789.67	1,272,539.38	6975.64
K23	65,841.40	185,922.80	5,525,375.03	124.87	9671.87	910.38	313,815.77	4507.67
K24	248,790.64	268,219.36	8,482,654.99	553.48	27,031.93	724.38	178,634.38	9022.59
K25	305,078.91	404,924.46	6,951,779.04	706.39	12,953.95	418.88	657,943.37	10,468.28
K26	69,025.71	395,976.78	1,882,126.67	327.96	14,207.69	486.85	183,420.02	8258.15
K27	124,156.28	392,350.39	6,851,525.75	409.43	12,411.22	485.89	458,044.39	8192.09
K28	81,801.76	226,617.90	6,255,973.17	1058.21	33,123.18	1275.09	767,636.14	28,764.68
K29	144,524.75	185,767.58	3,244,899.81	444.21	25,717.01	581.28	880,314.27	9161.81
K30	102,134.39	1,082,110.46	6,160,851.60	7080.39	18,981.87	579.70	340,442.16	8354.43
K31	404,036.36	2,124,364.96	11,438,699.30	10,140.57	26,302.63	491.19	442,616.78	21,571.21
K32	186,308.27	430,517.46	4,848,726.39	832.83	24,619.07	532.33	438,281.04	14,483.27
K33	139,725.11	310,210.06	2,040,814.16	659.75	15,890.48	631.27	630,242.45	6094.32
K34	76,251.17	188,793.86	5,293,745.00	480.82	17,932.27	719.34	504,338.49	15,648.97
K35	68,692.42	249,695.00	8,569,403.63	5420.40	19,896.14	572.82	895,133.06	15,225,98
K36	59,432.05	344,402.08	9,096,757.18	8301.61	11,874.80	622.61	233,523.13	7808,72
K37	246,270.03	124,272.06	3,658,665.22	1708.00	32,138.03	356.69	164,851.00	31,137.22
K38	24,779.02	139,379.45	4,122,692.15	212.17	10,938.87	433.11	1,124,794.04	7925.83
K39	21,980.08	73,076.59	3,475,490.88	440.97	8410.46	215.33	292,085.68	6458.03
K40	20,100.62	110,440.04	3,515,001.09	653.58	20,434.22	445.25	678,583,80	4739.88
Mean	189,244.64	356,244.73	6,635,802.86	1481.29	19,203.18	594.80	625,721.49	13,913.38

Table 3 (continued)

Participant (K)	Cu	As	Cd	Pb	Cr	Co	Ni
K1	6027.55	47.06	48.93	1274.87	162.23	28.95	1444.42
K2	15,100.09	31.93	42.08	975.02	131.97	145.93	790.45
K3	16,160.90	30.71	97.55	1854.76	160.24	90.11	2456.54
K4	2645.75	30.12	49.05	1264.66	142.72	42.14	1629.69
K5	18,973.21	39.68	40.73	964.82	118.15	1492.39	1686.45
K6	8448.58	35.08	99.71	1673.14	131.69	123.77	2005.87
K7	43,711.01	39.03	124.01	2380.82	226.59	63.96	3035.85
KH	28,696.13	44.53	77.00	2037.40	252.25	87.37	1403.16
K9	9195.34	11.05	89.93	1138.52	112.64	54.21	762.67
K10	23,643.19	29.87	2929.55	3460.82	413.94	285.48	4298.27
K11	10,387.78	36.32	387.03	1383.55	917.29	113.50	2191.99
K12	10,928.85	35.74	92.72	874.89	206.43	6403.53	3437.54
K13	16,115.97	40.78	143.72	3091.60	435.69	156.93	1588.49
K14	19,250.87	35.76	41.38	1217.83	168.11	43.77	906.19
K15	16,209.97	25.24	71.69	3837.42	198.43	56.11	1881.24
K16	27,440.87	25.57	54.68	1048.24	277.37	257.86	1227.61
K17	6863.31	31.08	51.17	1192.69	97.42	71.93	1570.63
K18	4019.60	26.06	56.76	1861.51	108.62	1084.71	3404.55
K19	14,610.10	29.38	39.35	843.54	123.84	48.27	2841.23
K20	8058.09	26.85	33.76	835.75	160.54	7264.96	1065.14
K21	24,308.80	24.96	60.62	1419.21	110.84	346.07	944.18
K22	36,469.94	24.93	55.43	1884.14	164.58	52.82	1784.27
K23	26,456.82	29.65	41.11	954.04	75.66	23.66	1474.35
K24	13,899.05	30.25	34.47	520.15	181.80	30.61	381.78
K25	8522.96	31.78	315.72	1029.77	136.15	51.89	1416.05
K26	13,772.37	42.82	32.29	584.86	170.79	28.26	1057.87
K27	3057.98	30.87	51.14	1496.08	111.79	72.83	3109.22
K28	15,886.62	39.80	461.75	2329.77	376.45	113.82	2069.67
K29	12,281.95	42.18	54.95	704.33	1084.24	438.58	721.02
K30	9999.88	32.85	73.02	417.41	111.83	129.16	1923.15
K31	11,262.83	28.66	105.97	1097.49	215.97	138.89	1265.07
K32	10,911.63	34.66	91.08	787.63	209.85	42.98	1134.15
K33	138,246.03	47.95	92.47	1397.34	126.58	33.45	558.92
K34	18,497.09	59.95	66.22	1416.49	150.05	2057.51	1289.89
K35	8002.35	27,18	105,60	787,92	119,51	82,85	2011,83
K36	15,177.94	23,45	78,58	605,47	104,59	629,45	2050,24
K37	10,486.41	15.93	41.37	770.77	198.47	35.48	598.78
K38	3544.37	8.28	103.04	1397.90	57.07	21.91	3076.64
K39	8027.24	10.81	14.21	–	74.09	108.02	540.78
K40	2717.25	11.42	17.30	997.53	98.67	14.38	2944.20
Mean	17,450.42	31.26	161.68	1379.75	210.63	559.21	1749.50

contaminants, particularly toxic metals [21]. In a study, Ghoochani et al. [36] examined the relationship between diet and cadmium in non-smoking adults in Tehran, and no correlation was found between acute and chronic. However, they found that low serum ferritin increased blood cadmium levels.

In heavy metal analyzes performed in hair samples, the contents of the trace metal may generally increase due to the consumption of contaminated water and nutrients, and other non-smokers have shown that the concentration of metal is less than metal concentration [37], approximately 4-fold in terms of level of non-smokers and 2.5-fold in Pb-level care. It has been reported 3 times higher [38]. At the same time, the gender factor was the most important variable affecting the Cd, Zn, and Pb content in the hair [39] and the Ca/Mg and Zn/Cu ratios were significantly correlated with age, race, sex, and smoking habits [40]. However, when the metal concentrations obtained from the 40 female students who were not smoking were compared with the normal reference range values in the hair [5] (Table 7), it was determined that the Mg, Cr, Co, and Zn element concentrations were slightly higher than the normal range. It is thought that more than half of the students included in the average were contaminated by passive smoking of Cd members due to smoking.

Table 4 Average, maximum, and minimum element values ($\mu g\ kg^{-1}$) and distribution of their families according to their smoking habits (n = 40)

Element	Cigarette smoking students in the family			Non-smoking students in the family		
	N	Mean	Min–max	*N*	Mean	Min–max
Na	24	228,978.70	35,254.16–854,407.22	16	129,643.56	20,100.62–404,036.36
Mg	24	311,120.42	99,902.77–751,565.01	16	423,931.20	212.17–10,140.57
Al	24	14,676.76	4507.67–58,204.80	16	12,768.30	4739.88–31,137.22
Cr	24	211.63	75.66–917.29	16	209.13	57.07–1084.24
Mn	24	848.92	124.87–2545.15	16	2429.83	212.17–10,140.57
Fe	24	19,262.30	9497.45–40,528.07	16	19,114.49	8410.46–33,123.18
Co	24	765.38	23.66–7264.96	16	249.97	14.38–2057.51
Ni	24	1842.19	381.78–4298.27	16	1610.47	540.78–3109.22
Cu	24	16,984.24	2645.75–43,711.01	16	18,149.68	2717.25–138,246.03
Zn	24	680,692.08	140,951.77–3,197,924.85	16	543,265.61	164,851.00–1,124,794.04
As	24	31.73	11.05–47.06	16	30.54	8.28–59.95
Se	24	622.69	249.77–916.34	16	552.98	215.33–1275.09
Cd	24	198.43	33.76–2929.55	16	106.54	14.21–461.75
Pb	24	1582.89	520.15–3837.42	16	1054.72	417.41–2329.77
Ca	24	7,417,706.80	2,835,346.85–20,352,833.51	16	5,462,946.94	1,882,126.67–11,438,699.30

In addition to toxic elements that can be removed from smoke during smoking, passive smoking plays an important role in the exposure of children to toxic heavy metals [41]. Inhalation of cadmium-containing tobacco smoke is a predominant source of cadmium exposure [42], and children are more susceptible to the effects of toxic elements such as Pb than adults, especially [41].

Studies showed that the levels of Cu, Cd, and Pb were significantly higher in the smokers' hair [20, 43] and increased Cd and Pb levels in the hair due to increased number of smokers in the home [43, 44]. Similar to Serdar et al. (2012)'s study of 1–6-year-old children, parents of children who smoke are smokers; Cd, Pb, Cr, Sb, Fe, and Al concentrations of the parents of smokers are significantly higher than

Table 5 The relationship between essential and toxic element concentrations obtained from hair samples of students who smoke in their families is shown in the Pearson correlation sig. (2-tailed) coefficient matrix (*Na* sodium, *Mg* magnesium, *Ca* calcium, *Mn* manganese, *Fe* iron, *Se* selenium, *Zn* zinc, *Al* aluminum, *As* arsenic, *Cd* cadmium, *Pb* lead, *Cr* chrome, *Co* cobalt, *Ni* nickel; n = 24)

	Mg	Al	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Cd	Pb
Na	0.387	0.737**	0.261	0.275	0.674**	0.820**	− 0.099	0.283	0.529**	− 0.136	0.334	− 0.206	0.363	0.532**
Mg		0.615**	0.527**	0.852**	0.188	0.658**	− 0.118	0.318	0.039	0.404	0.433*	0.012	0.583**	0.414*
Al			0.659**	0.386	0.382	0.857**	− 0.082	0.502*	0.338	− 0.159	0.220	− 0.383	0.773**	0.635**
Ca				0.281	− 0.012	0.461*	− 0.073	0.522**	0.139	− 0.049	− 0.085	− 0.320	0.859**	0.342
Cr					0.186	0.470*	− 0.072	0.225	0.031	0.631**	0.257	0.193	0.355	0.280
Mn						0.479*	− 0.034	0.252	0.137	0.000	0.263	− 0.178	0.192	0.425*
Fe							− 0.111	0.289	0.375	− 0.028	0.407*	− 0.196	0.534**	0.529**
Co								0.143	− 0.239	− 0.107	− 0.019	− 0.088	− 0.065	− 0.267
Ni									0.081	0.137	0.124	− 0.213	0.561**	0.440*
Cu										− 0.202	0.086	0.244	0.132	0.277
Zn											0.116	0.402	− 0.071	0.128
As												0.163	− 0.028	0.075
Se													− 0.432*	− 0.107
Cd														0.487*

*Correlation is important at 0.05 (2-tailed)

**Correlation is important at the level of 0.01 (2-tailed)

Table 6 The relationship between trace element concentrations obtained from hair samples belonging to those students whose families are not smokers, the Pearson correlation sig. (2-tailed) coefficient matrix (*Na* sodium, *Mg* magnesium, *Ca* calcium, *Mn* manganese, *Fe* iron, *Se* selenium, *Zn* zinc, *Al* aluminum, *As* arsenic, *Cd* cadmium, *Pb* lead, *Cr* chrome, *Co* cobalt, *Ni* nickel; $n = 16$)

	Mg	Al	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Cd	Pb
Na	0.339	0.453	0.433	0.141	0.339	0.397	−0.151	−0.367	0.039	−0.179	0.129	−0.132	0.211	−0.083
Mg		0.154	0.791**	−0.146	1.000**	0.117	−0.006	0.061	−0.115	−0.246	−0.114	0.037	−0.048	−0.358
Al			0.278	0.127	0.154	0.811**	0.048	−0.220	−0.163	−0.108	0.081	0.414	0.449	0.334
Ca				−0.163	0.791**	0.095	0.090	0.296	−0.325	−0.008	−0.070	0.169	0.280	0.027
Cr					−0.146	0.467	0.086	−0.319	−0.049	0.288	0.324	0.256	0.094	−0.043
Mn						0.117	−0.006	0.061	−0.115	−0.246	−0.114	0.037	−0.048	−0.358
Fe							−0.054	−0.219	−0.067	0.038	0.174	0.481	0.329	0.180
Co								−0.114	−0.027	−0.071	0.544*	0.241	−0.109	0.101
Ni									−0.388	0.402	−0.356	0.150	0.115	0.315
Cu										0.037	0.415	0.168	0.005	0.196
Zn											−0.045	0.263	0.344	0.423
As												0.533*	0.206	0.186
Se													0.701**	0.617*
Cd														0.635

**Correlation is important at the level of 0.01 (2-tailed)

*Correlation is important at 0.05 (2-tailed)

the non-smokers; also, with the frequency of smoking at home, a positive correlation was found between Cd, Cu, Ni, and Sb levels, and this correlation between smoking the status of family members and the toxic trace element levels in hair was more significant with Pb and Cd levels [45]. In fact, in this study carried out on the adolescents in Sinop Province, similar to their families, in those students whose families are cigarette users, in the results of the hair analysis of Cd, Pb, Ni, Co, As, Al, Zn, Na, Se, Fe, Cr, and Ca in terms of the average values of elements, it was found that the students were higher than the average of hair analysis (Table 4).

Table 7 The mean values of the elements detected in the hair of non-smoking girls (mg kg^{-1}) compared with the normal element concentration in human hair ($n = 40$)

	Average concentration of students' hair (mg kg^{-1})	Normal concentration in human hair (mg kg^{-1})
Na	189.24	50–1000*
Mg	356.24	60–160*
Al	14	< 50.0*
Cr	0.21	0.10–1.50*
Mn	1.48	0.2–2.00*
Fe	19.2	5.0–30*
Co	0.6	0.01–0.20*
Cu	17.45	10–100*
Zn	625	160–240*
As	0.03	< 1.00*
Se	0.6	0.40–2.00*
Cd	0.16	< 0.10*
Pb	1.38	< 2.00*
Ca	6636	200–2800*

*Reference range from Serdar et al. 2012 [5]

The assessment of the toxic effects of lead and cadmium in individuals with contaminated environments is mainly based on the concentrations of toxic metals in the hair. Mehra and Thakur [46] analyzed the hair of men working in a workplace where recycling metals were processed, and it showed the strongest positive correlation ($p < 0.05$) Mn/Cd, Mn/Pb, Mn/Fe, Cd/Pb, Cd/Fe, and Pb/Fe metals according to the Pearson correlation analysis.

As a result of this research conducted with the adolescents of Sinop Province, the elements showed significant and highest positive correlation in the hair samples taken from the children of the smoker families between Ca/Cd, Al/Fe, Mg/Cr, Na/Fe, Al/Cd, and Al/Na, respectively, and Al/Mg, Al/Ca, Mn/Na, Fe/Mg, Ni/Al, Ni/Ca, Cu/Na, Zn/Cr, Mg/Ca, Mg/Cd, Fe/Cd, Cd/Ni, Pb/Na, Al/Pb, and Fe/Pb (Table 5), sand this study was similar to the results of Mehra and Thakur [46].

Health education is one of the most important roles and responsibilities of the nurse [47]. Health education for adolescents is one of the most important roles and responsibilities of pediatric nursing [48]. Adolescent is a very long period of development between childhood and adulthood. Especially during these periods, adolescents experiencing pubertal changes, be in physical, emotional, and social changes, have an active role in their lives and also try to transition to adult personality by breaking off from childhood personality [49].

In these processes, adolescents may also face smoking as a risky behavior. For this reason, nurses may carry out studies to prevent smoking. Panels, conferences, studies based on schools, and systematic education planning with parents on this issue may be among the studies that prevent smoking. In addition, studies to quit smoking for smoking adolescents may be given weight. These studies may include giving information about the health hazards of smoking, what can be done for smoking cessation, and training to encourage parents to quit if they are smokers [49].

Conclusions

As a result of the research, it was determined that cadmium, cobalt, zinc, and chromium, especially heavy metals, in the hair analysis of smoking adolescents in their families were slightly higher than the required reference range values of healthy individuals. As seen in the research findings, adolescents without active smoking are also unaware of exposure to passive cigarette smoke. This situation is a problem that threatens public health and adolescent/child health. Therefore, one of the most important ways to overcome this problem is to give effective education. This training, which should be given by health professionals, should include the harms of active and passive smoking. In addition, in these trainings, it is revealed that heavy metal and toxic elements in the air with the smoke in the indoor environment have the possibility of settling all usage goods and environment in high concentration and consequently cause negative effect on the health of adolescents by passive smoking.

Acknowledgments We would like to thank Sinop Provincial Directorate of National Education and the valuable managers, teachers, and students of Sarı Saltuk Anatolian High School for their support in the realization of this study.

Funding Information This study was supported by the Scientific Research Projects Coordination Unit of Sinop University. Project Number: SYO-1901-17-24.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Cabar HD, Oruç S, Gümüş E (2017) Heavy metal exposure in children. Acta Scientiae et Intellectus (ASI) 3(6):147–153 ISSN 2410-9738,2519-1896
2. Rodgman A, Perfetti TA (2009) The chemical components of tobacco and tobacco smoke. CRC Press, Taylor & Francis Group, Boca Raton
3. Sleiman M, Logue JM, Luo W, Pankow JF, Gundel LA, Destaillats H (2014) Inhalable constituents of thirdhand tobacco smoke: chemical characterization and health impact considerations. Environ Sci Technol 48:13,093–13,101
4. Chiba M, Masironi R (1992) Toxic and trace elements in tobacco and tobacco smoking. Bull World Health Organ 70:262–269
5. Ferrante G, Simoni M, Cibella F et al (2013) Thirdhand smoke exposure and health hazards in children. Monaldi Arch Chest Dis 79:38–43
6. Matt GE, Quintana PJ, Destaillats H et al (2011) Thirdhand tobacco smoke: emerging evidence and arguments for a multidisciplinary research agenda. Environ Health Perspect 119(9):1218–1226
7. Geiss O, Kotzias D (2007) Tobacco, cigarettes and cigarette smoke. An overview. European Commission, Directorate-General, Joint Research Centre, Institute for Health and Consumer Protection, pp. 27–29.
8. Rostami R, Zarei A, Saranjam B, Ghaffari HR, Hazrati S, Poureshg Y, Fazlzadeh M (2019) Exposure and risk assessment of PAHs in indoor air of waterpipe cafés in Ardebil, Iran. Build Environ 155: 47–57
9. Martinez T, Lartigue J, Zarazua G, Avila-Perez P, Navarrete M, Tejeda S (2008) Application of the total reflection X-ray fluorescence technique to trace elements determination in tobacco. Spectrochim Acta B 63(12):1469–1472
10. Kaya-Akyüzlü D, Kayaaltı Z (2015) Blood, hair, urine and breath samples for the analysis of drugs of abuse. Marmara Pharm J 19: 232–237
11. Pappas RS, Polzin GM, Watson CH, Ashley DL (2007) Cadmium, lead, and thallium in smoke particulate from counterfeit cigarettes compared to authentic US brands. Food Chem Toxicol 45:202–209
12. Verma S, Yadav S, Singh I (2010) Trace metal concentration in different Indian tobacco products and related health implications. Food Chem Toxicol 48:2291–2297
13. Lugon-Moulin N, Zhang M, Gadani F et al (2004) Critical review of the science and options for reducing cadmium in tobacco (*Nicotiana tabacum* L.) and other plants. Adv Agron:111–180
14. Sebiawu GE, Mensah NJ, Ayiah-Mensah F (2014) Analysis of heavy metals content of tobacco and cigarettes sold in Wa municipality of upper West region. Chem Process Eng Res 25:24–34
15. Xiao T, Guha J, Boyle D, Liu CQ, Chen J (2004) Environmental concerns related to high thallium levels in soils and thallium uptake by plants in southwest Guizhou China. Sci Total Environ 318:223–244
16. Afridi HI, Kazi TG, Brabazon D, Naher S (2012) Interaction between zinc, cadmium, and lead in scalp hair samples of Pakistani and Irish smokers rheumatoid arthritis subjects in relation to controls. Biol Trace Elem Res 148(2):139–147
17. Dongarrá G, Lombardo M, Tamburo E, Varrica D, Cibella F, Cuttitta G (2011) Concentration and reference interval of trace elements in human hair from students living in Palermo, Sicily (Italy). Environ Toxicol Pharmacol 32:27–34
18. Gault AG, Rowland AL, Charnock JM et al (2008) Arsenic in hair and nails of individuals exposed to arsenic-rich groundwater in Kandal province, Cambodia. Sci Total Environ 393:168–176
19. Wang T, Fu J, Wang Y, Liao C, Tao Y, Jiang G (2009) Use of scalp hair as indicator of human exposure to heavy metals in an electronic waste recycling area. Environ Pollut 157(8-9):2445–2451
20. Sukumar A, Subramanian R (2007) Relative element levels in the paired samples of scalp hair and fingernails of patients from New Delhi. Sci Total Environ 372:474–479
21. Esteban M, Castano A (2009) Non-invasive matrices in human biomonitoring: a review. Environ Int 35:438–449
22. Barlow PJ, Sidani SA, Lyons M (1985) Trace elements in hair in the UK Results and interpretation in the preconception situation. Sci Total Environ 42:121–131

23. Wilhelm M, Lombeck I, Nesorge FK (1994) Cadmium, copper, lead and zinc concentrations in hair and toenail of young children and family members: a follow-up study. Sci Total Environ 35:174–185
24. Srogi K (2004) Heavy metals in human hair samples from Silesia Province: the influence of sex, age and smoking habit. Probl. Forensic Sci LX: 7–27.
25. Srogi K (2006) Hair analysis for monitoring environmental pollution and the resulting human exposure to trace metals: an overview. Environ Risque Santé 5:391–405
26. Partsinevelou AS, Evrenoglou L (2016) Heavy metal contamination in surface water and impacts in public health. The case of Kifissos River, Athens, Greece. International Journal of Energy and Environment (IJEE) 10:213–216
27. Pragst F, Balikova MA (2006) State of the art in hair analysis for the detection of drug and alcohol abuse. Clin Chim Acta 70:17–49
28. Chojnacka K, Mikulewicz M (2012) Hair mineral analysis in the assessment of human exposure to metals, Handbook of hair in health and disease, 279, 292.
29. Teresa M, Vasconcelos SD, Tavares HMF (1997) Trace element concentrations in blood and hair of young apprentices of a technical-professional school. Sci Total Environ 205:189–199
30. Katz SA, Chatt A (1998) Hair analysis in the biomedical and environmental sciences. VCH Publishers, New York
31. Kronstrand R, Förstberg-Peterson S, Kagedal B, Ahlner J, Larson G (1999) Codeine concentration in hair after oral administration is dependent on melanin content. Clin Chem 45:1485–1494
32. Clarkson TW (1983) Mercury. Annu Rev Public Health 4:375–380
33. Herber RFM, Wibowo AAE, Das HA, Egger RJ, van Deyck W, Zielhuis RL (1983) Trace element levels in hair of eight-year-old children. Int Arch Occup Environ Health 53:127–137
34. Chojnacka K, Gorecka H, Chojnacki A, Gorecki H (2005) Inter–element interactions in human hair. Environ Toxicol Pharmacol 20: 368–374
35. Dombovári J, Papp L, Uzonyi I, Borbély-Kiss I, Elekes Z, Varga Z, Mátyus J, Kakuk G (1999) Study of cross - sectional and longitudinal distribution of some major and minor elements in the hair samples of haemodialysed patients with micro - PIXE. J Anal At Spectrom 14:553–557
36. Ghoochani M, Dehghani MH, Rastkari N, Nodehi RN, Yunesian M, Mesdaghinia A, Houshiarrad A, Saraei M (2018) Association among sources exposure of cadmium in the adult non-smoking general population of Tehran. Biol Trace Elem Res. https://doi.org/10.1007/s12011-018-1590-9
37. Raposo JC, Navarro P, Sarmiento A, Arribas E, Irazola M, Alonso RM (2014) Analytical proposal for trace element determination in human hair, application to the Biscay province population, northern Spain. Microchem J 116:125–134
38. Varhan Oral E (2016) Determination of the trace element levels in hair of smokers and non-smokers by ICP-MS. JOTCSA 3(3):367–380
39. Baran A, Wieczorek J (2013) Concentrations of heavy metals in hair as indicators of environmental pollution, E3S Web of Conferences, 1, 21005.
40. Fakayode SO, Owen SK, Pollard DA, Yakubu M (2013) Use of flame atomic absorption spectroscopy and multivariate analysis for the determination of trace elements in human scalp. Am J Anal Chem 4:348–359
41. Mannino DM, Albalak R, Grosse S, Repace J (2003) Second-hand smoke exposure and blood lead levels in US children. Epidemiology 14:719–727
42. Jarup L, Berglund M, Elinder CG, Nordberg G, Vahter M (1998) Health effects of cadmium exposure-a review of the literature and a risk estimate. Scand J Work Environ Health 24, Suppl:1:1–1:151
43. Özden TA, Gökçay G, Ertem HV et al (2007) Elevated hair levels of cadmium and lead in school children exposed to smoking and in highways near schools. Clin Biochem 40:52–56
44. Özden TA, Kılıc A, Vehid HE, Toparlak D, Gokcay G, Saner G (2004) Blood lead levels in school children. Indoor Built Environ 13:149–154
45. Serdar MA, Akin BS, Razi C, Akin O, Tokgoz S, Kenar L, Aykut O (2012) The correlation between smoking status of family members and concentrations of toxic trace elements in the hair of children. Biol Trace Elem Res 148(1):11–17
46. Mehra R, Thakur AS (2012) Relationship between lead, cadmium, zinc, manganese and iron in hair of environmentally exposed subjects. Arab J Chem 9:1214–1217
47. Birol L (2013) Nursing period-systematic approach in nursing care, Berke Ofset Printing, 10th Edition.
48. Conk Z, Başbakkal Z, Yardımcı F (2018) An overview of child health. In: Conk Z, Başbakkal Z, Bal Yılmaz H, Bolışık B (eds) Pediatric Nursing, 2nd edition. Academician Bookstore, Ankara, pp 1–52
49. Arıkan D, Çelebioğlu A, Güdücü Tüfekçi F (2018) Growth and development in childhood periods. In: Conk Z, Başbakkal Z, Bal Yılamz H, Bolışık B (eds) Pediatric Nursing, 2nd edition. Academician Bookstore, Ankara, pp 53–99 ISBN: 978-605-81550-2-2