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Original Research

Blood Levels of Lead, Cadmium, and Mercury in Healthy Women in their 50s in an Urban Area of Poland: A Pilot Study

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Abstract

In 2009 we investigated exposure to lead, cadmium, and mercury in 80 women aged 50-59 in an urban area of Poland. Blood levels of lead, cadmium, and total mercury were used as biomarkers. The participants completed an extended questionnaire to identify potential sociodemographic, lifestyle, and nutritional correlates for the concentration of metals in the blood. The geometric means in the study population were: 21.5 µg/l (95% CI 20-23) for blood lead, 0.67 µg/l (95% CI 0.56-0.79) for blood cadmium, and 0.75 µg/l (95% CI 0.64-0.87) for total mercury in the blood. Regression analyses revealed that the increased lead levels in the blood were significantly associated with BMI values under 25 kg/m^2, being postmenopausal, smoking habits, the use of heating sources other than electricity or centrally heated buildings, and frequent or constant trucks passing through a residential area. The levels of cadmium in the blood were significantly higher in subjects who smoked cigarettes and decreased as education increased. Fish consumption and the number of teeth containing amalgam were the only factors that were significantly associated with blood mercury levels.

Keywords: lead, cadmium, mercury, blood, exposure, women

Introduction

Lead, cadmium, and mercury are well-known toxic metals that are widespread in the environment. These metals occur as a result of both natural processes and human activities. They can cause a wide spectrum of multisystemic adverse health effects ranging from subclinical changes in function to serious intoxication. In the last decade, a number of new studies have led to increased awareness of the health risks associated with environmental exposure to lead, cadmium, and mercury, even at low levels of exposure. Exposure assessments have typically focused on children and women of childbearing age because developing children and fetuses are especially sensitive to environmental poisons. Women who are nearing menopause may be another segment of the population that is very sensitive to environmental pollutants, including toxic metals, because menopause is one of the periods during a women's life where she is at an increased risk for adverse health effects caused by these metals [1]. Postmenopausal quality of life is of great concern, as demographic trends in Polish society indicate an increasing proportion of women at the peri- and post-menopausal stages of life [2].

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Exposure to lead remains a significant public health concern, despite decreased emission and environmental exposure [3]. Even at low doses lead is known to be toxic to the nervous system and can decrease renal function [4, 5]. Lead exposure is a risk factor for the development of cardiovascular diseases and is known to increase blood pressure and homocysteine level in plasma [6-8]. Lead accumulates in the bone and is mobilized during increased bone turnover, which tends to occur in the first few years after the onset of menopause. Increased bone turnover leads to increased blood lead concentrations in women, which were found to be the highest at 50-55 years of age [9].

Cadmium exposure can cause several health outcomes, primarily kidney and bone damage. Because cadmium accumulates in the renal cortex, one of the first signs of its adverse effects is renal tubular dysfunction, which may be induced at relatively low exposure levels [10]. Itai-itai disease is a well described example of the toxic effects on bone caused by high and prolonged exposure to cadmium. The disease – a combination of osteoporosis, osteomalacia, and renal damage – was first reported in the late 1940s in Japan, and almost exclusively affected multiparous women who were close to menopause [9]. Some studies have shown that even low-level environmental cadmium exposure promotes osteoporosis, especially in postmenopausal women [11, 12]. There is evidence that cadmium is a potent metallohormone that mimics the effects of estrogen by interacting with estrogen receptor, and may be a risk factor for the development of breast and endometrial cancers [13]. Recent studies have demonstrated that pancreatic damage and macular degeneration may also result from cadmium exposure [14, 15]. In the general population, the highest body burden of cadmium has been observed in cigarette smokers. Aside from smoking, food, especially cereal, certain types of vegetables, offal and shellfish, is usually the most important source of environmental exposure to cadmium. In women, maximal cadmium retention is observed in the 50s, after which point it begins to decrease due to aging of the kidney.

Exposure to mercury remains the focus of much attention and is a cause for concern. No metal better illustrates the diversity of effects that can be caused by chemical species than mercury [16, 17]. Organomercurial compounds tend to be more toxic than inorganic mercury salts and elemental mercury vapor [18]. Highly toxic methylmercury has the ability of bioaccumulate and biomagnify, particularly in the tissues of fish and marine mammals. For this reason, fish food that has been contaminated with methylmercury is usually the predominant source of environmental exposure to mercury. The major source of elemental mercury in the general population is dental amalgam fillings, from which mercury is released by vaporization. Inorganic mercury ions are very poorly absorbed from the gastrointestinal track and, therefore, have only a minor contribution to total mercury exposure in the general population. Mercury is a well-documented nephrotoxic and neurotoxic agent, with high affinity for the cerebral cortex and cerebellum. Possible cardiovascular effects, such as an increased incidence of myocardial infarction after exposure to methylmercury, also have been reported, but the pathogenic mechanism underlying this toxic action remains unclear [19]. Also, there are indications of effects of methylmercury on increased blood pressure, which was found even in a population that was exposed to low methylmercury levels [20]. The immune system of mammals also appears to be affected by methylmercury, as previously observed in adult mice [21]. The data collected from people who were poisoned in Iraq after eating wheat grain treated with methylmercury suggested that women were more susceptible than men to the toxic effects of methylmercury at adulthood [22].

Human biomonitoring is an important tool that can be used to assess the exposure of a population or an individual to toxic environmental compounds. Lead, cadmium, and mercury concentrations in the blood are often used as indicators of recent exposure levels [23]. However, blood cadmium levels also tend to reflect cumulative exposure in environmentally exposed subjects [4]. Mercury levels in the blood reflect exposure to both the organic and inorganic (Hg^{2+}, Hg^{0}) forms of mercury. However, exposure to the inorganic form of mercury is usually much lower. Increased levels of mercury in blood are most often associated with frequent consumption of fish and other seafood containing methylmercury, and the inorganic mercury represents usually a marginal proportion of total mercury in the blood [24].

The aim of the current study was to assess the levels of exposure to lead, cadmium, and mercury in 80 upper middle-aged women living in Wrocław, a city in southwestern Poland. Lead, cadmium, and total mercury concentrations in the blood were used as biomarkers to evaluate exposure. We also attempted to identify certain environmental, sociodemographic, and lifestyle factors that may have influenced the levels of these heavy metals in the blood of women in this age group. The women in the present study were selected from the same region as the children who were examined in the previous study, in an effort to directly compare the exposure patterns for both of the studied groups.

Materials and Methods

This study was conducted on a group of 80 women, 50-59 years of age, who were recruited from a mammographic screening program in Wrocław, one of the major cities in Poland, during March 2009. Participation was voluntary and the local Biomedical Ethics Committee approved the study protocol. The women were asked to complete a questionnaire, which asked about their dietary habits, living conditions, occupation, possible occupational exposure to lead, cadmium and mercury, education, the number of teeth filled with amalgam, menopausal status, the number of children delivered, and cigarette smoking. Women were also asked whether they had certain chronic diseases and whether they regularly took medication. Venous blood samples were drawn into vacuum test tubes containing lithium heparin (Vacutte) and stored in a freezer until analysis. The concentrations of lead and cadmium in whole blood (B-Pb) were measured using graphite furnace atomic absorption

spectrometry on a Perkin-Elmer 4100ZL instrument [25, 26]. For lead determination the detection limit was 3 μg/l and precision of the method σ% = 4.4 and for cadmium the detection limit was 0.10 μg/l and precision of the method σ% = 5.4. Mercury levels in the blood were determined using the Cold Vapour Atomic Absorption Spectrometry technique on a Unicam 939 instrument after sample decomposition in concentrated nitric acid in closed perfluoroalkoxy (PFA) vessels (Savillex, USA), and initial preconcentration of mercury on gold wire. For mercury determination the limit of detection was 0.10 μg/l and precision of the method σ% = 5.6. Blood analysis for metal content was performed at the Institute of Occupational Medicine and Environmental Health in a laboratory that regularly participates in two proficiency tests (Lead and Multielement Proficiency – CDC in Atlanta and METOS Program – Istituto Superiore di Sanita in Rome) and fulfilled the requirements for the measured parameters.

The possible associations between log-transformed metal levels in the blood and potential correlates were tested using Student's t-test, analysis of variance (ANOVA) and the Spearman rank correlation test, as appropriate. Any factor that had an association of $p<0.15$ with lead, cadmium or mercury concentrations in the univariate analysis was entered in stepwise multivariate models. To model the effects of explanatory variables (body mass index – BMI, dietary habits, and others) on outcome (metal levels in the blood), general linear models were used. Following model fitting, the exponentiated parameters estimate was used to examine relative changes in the blood concentrations of lead, cadmium and mercury for each independently categorized variable and a corresponding 95% confidence interval (95% CI). Those results for which the significance level was $p<0.05$ were accepted as significant. All p-values refer to two-sided hypotheses. Statistica Analysis Software version 9.1 was used to perform the statistical evaluations.

Results

Descriptions of the study population and summaries of the blood analysis results are presented in Table 1. All sample levels were above the method detection limit of each of the elements. GMs (geometric mean) for blood cadmium levels in non-smokers and smokers were 0.49 μg/L (95% CI 0.43-0.56) and 1.53 μg/L (95% CI 1.13-2.05), respectively. Fig. 1 presents the distribution of lead, cadmium and mercury concentrations measured in the blood of middle-aged Polish women. Blood levels of lead exceeding 100 μg/L and blood levels of cadmium exceeding 5 μg/L were not recorded. Concentrations of mercury higher than 5 μg/L were obtained in one study subject.

Table 2 shows the association between metal concentrations in the blood and explanatory variables, which were significantly correlated with lead, cadmium, and mercury levels in the blood in multivariate linear regression models. BMI was significantly associated with lead levels in the blood. Women who had a BMI under 25 kg/m^2 had approximately 1.2 times higher lead levels than women who were overweight or obese. In postmenopausal women, the levels of lead in the blood were approximately 1.3 times higher than the levels in menstruating women. Smoking cigarettes, exposure to trucks passing through residential areas (dichotomized between categories "seldom or never" and "frequently or constantly") and the use of household heating systems other than electricity and central heating for the whole building (primarily wood- and coal-burning) were also associated with significantly increased levels of lead in the blood. All of these explanatory variables accounted for 33% of the variance in blood lead concentrations in our model.

Only smoking habits and education were significantly correlated with cadmium levels in the blood, and these independent variables explained 59% of the variance in blood cadmium concentrations in our model. Compared to non-smokers, current smokers and past smokers had on

Table 1. Characteristics of study participants and measurement of biomarkers of exposure.

Parameter	Values
No (n)	80
Age (years)	
Mean±SD	55.5±2.7
range	50-59
Weight (kg)	
Mean±SD	68.4±11.2
range	47-112
BMI (kg/m^2)	
Mean±SD	25.9±3.7
range	18.8-39.7
Lived in the city (years)	
Mean±SD	48.2±11.6
range	17-59
Blood lead (μg/L)	
Geometric mean (95% CI)	21.5 (20-23)
Median	21
range	9-48
Blood cadmium (μg/L)	
Geometric mean (95% CI)	0.67 (0.56-0.79)
Median	0.59
range	0.16-4.52
Blood mercury (μg/L)	
Geometric mean (95% CI)	0.75 (0.64-0.87)
Median	0.77
range	0.11-5.82

average 3 and 1.5 times higher concentrations of cadmium in the blood, respectively. In the case of education, cadmium levels in the blood were higher in less educated women than in women who were better educated.

As expected, the number of meals containing fish and the number of amalgam tooth fillings were positively correlated with the levels of mercury in the blood in the multivariate model. On average having 4-6 teeth with amalgam fillings nearly doubled the concentration of mercury in the blood, whereas increased concentrations in the group with lower amounts of amalgams were only marginally significant. Regular fish intake, between 2 to 6 and more than 6 meals per month, increased the levels of mercury in the blood by approximately 2 and 3 times, respectively, as compared to the levels in subjects with very low fish consumption. Taken together, fish consumption and the number of teeth containing amalgam fillings explained 21% of the variance in the blood mercury concentration model.

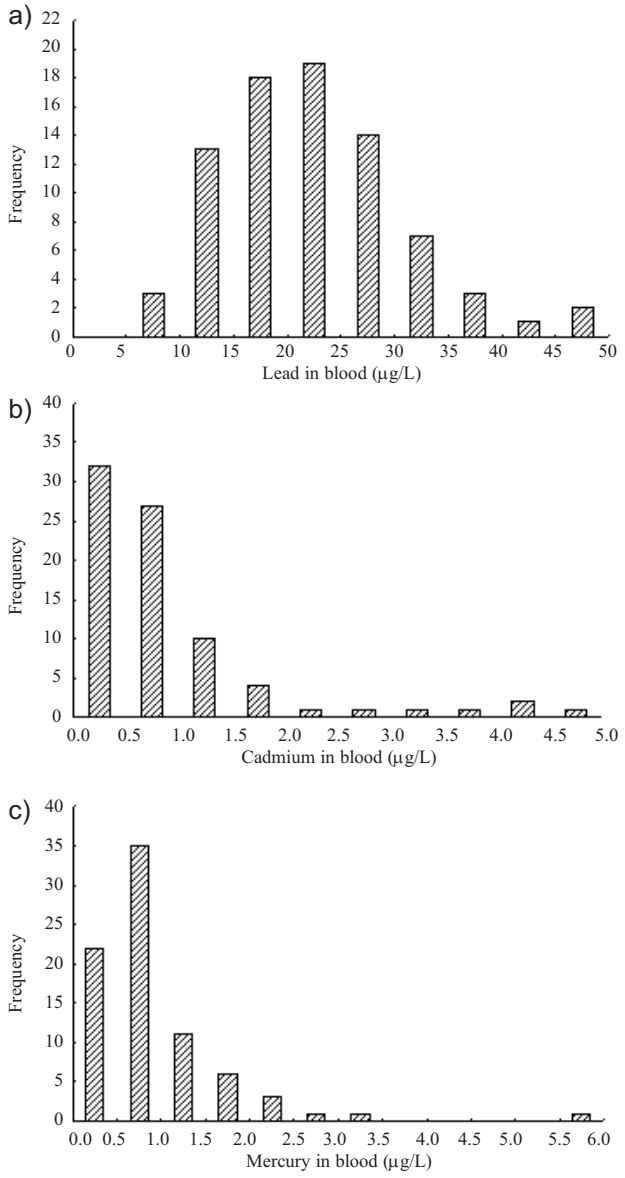

Fig. 1 Frequency distribution of lead (a), cadmium (b), and total mercury (c) concentrations in the blood samples of women participating in the study.

Discussion

The results of our study indicate that the mean concentrations of the investigated metals in the blood of examined women (GM) were 21.5 µg/L for lead, 0.67 µg/L for cadmium and 0.75 µg/L for total mercury. Because the study subjects were Polish city residents, the data collected for blood lead, cadmium, and mercury reflects typical exposure levels in an urban setting. The median values (with 5-95% percentiles) of blood lead reported for southern Swedish women were 22 µg/L (11-46), a value that is nearly identical to the value obtained in our study for women in the same age group [4]. The Swedish study also found the median value for cadmium in the blood to be 0.38 µg/L, which was nearly two times lower than the levels detected in our investigation. The women in our study had slightly lower blood lead concentrations, and three times higher blood cadmium concentrations, than 247 post-menopausal women recruited from hospital staff in a Spanish study, which reported that the median values for lead and cadmium levels in the blood were 26 and 0.22 µg/L, respectively [27]. In turn, adult women from New York City had a lower geometric mean for blood lead, which was 15.4 (95% CI 14.8-16.2), and a slightly higher geometric mean for blood cadmium, which was 0.79 µg/L (95% CI 0.76-0.82), as compared with the women in our study. However, both of these values were higher than data obtained from national estimates of the US population as a whole [28]. In European population studies that were conducted in the last decade, the mean level of blood lead in adult women was very similar to the level found in our study [29, 30]. It has been suggested that the fact that European women have higher mean blood lead concentrations than women from the United States may be the result of a delay in the ban on the use of leaded gasoline. Lower levels of blood lead in women recruited in peripheral parts of Europe (GM 13.4 µg/L in northern Sweden) compared to women from other European countries could confirm this theory because northern Sweden has a low density of automobiles and a limited environmental load of petrol lead [31]. The geometric mean that we obtained for cadmium concentrations in the blood was higher than that obtained in other parts of Europe, and seems to be only slightly lower than it was approximately two decades earlier, when the geometric means among non-smokers and smokers living in Polish cities were 0.53-0.61 µg/L and 1.15-2.86 µg/L, respectively [32]. Therefore, unlike lead, there was no indication of a substantial decrease in cadmium exposure.

The geometric mean blood mercury levels in our study were observed to be in the low range of the average exposure levels reported in the population in Europe [33]. Mercury levels in the blood slightly higher than 5 µg/L were obtained only in one case. However, this value is considered to be only an indication of increased exposure to mercury from the diet. Blood mercury was recently found to have the most geographical variation, even among European countries, due to large differences in fish intake, fish contamination and the prevalence of dental amalgam fillings [31]. In Swedish women of childbearing age, the

Table 2. Association between metal concentrations in the blood and potential variables in a multivariate linear regression model (log-transformed metals in the blood) and crude weighted geometric means (µg/L).

	Crude weighed geometric mean µg/L (95% CI)	Adjusted relative change in mean (95% CI)	R^2 [%]	p
Pb				
BMI				
≥25	19.7 (17.8-21.7)	Ref.		0.013
< 25	25.3 (23.1-30.2)	1.23 (1.05-1.45)		
Menopausal status				
Menstruating	17.6 (14.9-20.8)	Ref.		0.018
Menopause	22.2 (20.3-24.3)	1.33 (1.05-1.69)		
Smoking status				
Non-smokers	20.3 (18.2-22.7)	Ref.	33	0.034
Current smokers	24.5 (22.0-27.3)	1.19 (1.01-1.40)		
Truck passing frequency				
Never or seldom	20.4 (18.2-22.8)	Ref.		0.006
Frequently or constantly	23.9 (21.2-26.9)	1.24 (1.07-1.44)		
Heating source				
Central heating or electricity	20.0 (18.3-21.9)	Ref.		0.031
Local heating system	25.0 (21.1-29.7)	1.19 (1.02-1.40)		
Cd				
Smoking status				
Never-smokers	0.44 (0.38-0.51)	Ref.		<0.0001
Former smokers	0.66 (0.54-0.80)	1.58 (1.19-2.09)		
Current smokers	1.59 (1.18-2.14)	3.40 (2.62-4.43)	59	
Education				
Diploma or university	0.53 (0.43-0.64)	Ref.		0.004
Secondary	0.73 (0.58-0.93)	1.26 (1.00-1.59)		
Primary or apprenticeship	1.32 (0.46-3.77)	1.97 (1.31-2.96)		
Hg				
Fish meals per month				
0-1	0.36 (0.14-0.94)	Ref.		0.001
2-6	0.72 (0.61-0.85)	1.95 (1.11-3.40)		
7-20	1.19 (0.67-2.12)	3.46 (1.74-6.88)	21	
Number of amalgam fillings				
0	0.63 (0.51-0.78)	Ref.		0.014
1-3	0.82 (0.58-1.16)	1.27 (0.91-1.80)		
4-6	0.97 (0.58-1.62)	1.68 (1.04-2.73)		

median values of organic and inorganic mercury in the blood of women with high fish consumption (several times per month) were 1.7 µg/L and 0.24 µg/l, respectively [34]. French women who heavily consumed fish developed median values of methylmercury (inorganic and total mercury not reported) of 3.67 µg/L [35]. As dietary methylmercury is the predominant source of environmental exposure to mercury, the results of our study indicate rather low fish consumption among the examined women. In a previous study, blood was collected on the delivery day from women

aged 18-35 years old in Kraków and the neighboring vicinity, and the geometric mean was 0.55 μg/l, with a 95% CI 0.50-0.60 [36]. Assuming that the last months of pregnancy are associated with blood hemodilution, the concentrations were similar to those obtained for the women in the older age group.

Compared to the study of 7-year-old children (sampled in the same city and during the same time period as the women in our study), we found that the GMs for all three metals in the blood were higher in women than in children, even when the cadmium levels of the children were compared with only the women who were never smokers [37]. Women had 1.3-fold higher GM for blood lead, 2.9-fold higher GM for blood cadmium (restricted only to women who were never smokers) and 6.2-fold higher GM for mercury levels when compared to the results of the study in children. The higher GM for blood lead in women as compared to children was unanticipated and, to a great extent, is most likely the result of exposure from endogenous sources of lead in women, which had accumulated in the bone tissue. Higher levels of cadmium in women than in children are expected because blood cadmium levels reflect not only recent exposure but also cumulative exposure, which peaks during upper-middle age. Therefore, the lower levels of blood cadmium in children may not indicate significant decreases in environmental exposure. The GM for blood mercury differed the most between children and women. This was expected because the two most important factors influencing exposure to mercury are dental amalgam fillings and fish intake, both of which are far less common in children than in adult women.

Air and soil pollution continue to be important sources of environmental exposure to lead. Blood lead levels were strongly influenced by truck coursing frequency and type of heating source. Frequent or constant truck coursing through residential areas usually indicates that one lives in the vicinity of a road with high traffic density, which may be associated with higher exposure to lead due to past contamination of the area by leaded gasoline. Burning coals and wood in the home may also raise exposure to lead, which is likely due to mobilization of this metal from the fuel source used that leads to local air and soil pollution. Lead levels in the blood were strongly associated with smoking status, suggesting that smoking cigarettes is a significant predictor of higher blood lead concentrations. The association between smoking and blood lead levels does not necessarily indicate that cigarettes are an important source of lead exposure. Smoking may simply be a marker of some other source/pathway of exposure, for example, frequent hand-to-mouth contact. Direct exposure from tobacco smoke is also a possible explanation, according to recent estimations that approximately 11% of the lead contained in a cigarette is released into the smoke [38].

As expected, menopausal status had a significant influence on blood lead levels. This observation was consistent with other studies that suggested that the release of bone lead stores increases during the menopausal period [39, 40]. Lower estrogen levels during menopause are the main reason for higher bone turnover and mobilization of lead from the bones. In women, bone loss increases 5-10 years after menopause, resulting in approximately 15% of total bone being lost during the first 5 years after menopause [41]. Lead, which is released from the bone into the blood stream during bone demineralization, may be the reason that menopausal women are at an increased risk of hypertension, as has been suggested in other studies [42]. Previous evidence indicates that bone lead, which is mobilized during menopause, appears to contribute to toxic effects on bone cell activity, and may be an additional risk factor for the development of osteoporosis [43]. Lead levels in the blood decreased as BMI values increased, and lower levels of lead in the blood were observed in women with BMI values over 25 kg/m^2. Blood lead levels were suggested to decrease with increasing BMI in an earlier study of women undergoing surgical menopause, but the effect was not statistically significant [40]. Women with high BMI values have higher levels of endogenous estrogens that are produced by adipose tissue, which contributes significantly to the circulating pool of estrogens. Additionally, sex hormone-binding globulin levels decrease with increasing BMI, thus increasing the proportion of free estradiol available to enter the cell [44]. Thus, women who are overweight and obese are less prone to demineralization of bone tissue due to the protective role of endogenous estrogen on bone, especially after menopause. Considering that approximately 90% of the total body burden of lead is localized to the bone, even a minor decrease in skeletal turnover could affect the levels of lead in the blood among women in the investigated age group.

Smoking habit was the most important factor influencing blood cadmium levels in women participating in this study, and explained the majority (52%) of the variability in our blood cadmium concentration model. According to the Global Adult Tobacco Survey 2009-10, 33.4% (95% CI 29.3-37.7) of women aged 50-59 smoke cigarettes daily in Poland [45]. The cadmium content in cigarettes sold on the Polish market is in the lower range of concentrations reported for different brands of cigarettes sold across other countries [38]. A similar observation has been reported for lead. However, unlike lead, cadmium transfers linearly from the cigarette into the smoke during cigarette burning and is therefore a larger source of cadmium exposure than lead exposure. The authors mentioned above estimated that subjects smoking Polish cigarettes may inhale 0.196 to 2.644 μg of cadmium daily. Former smokers had approximately 1.6-time higher levels of cadmium in the blood than never smokers, confirming that cadmium levels in the blood may be a useful indicator of previous exposure in environmentally exposed subjects. Education was another covariate contributing to cadmium concentrations in the blood. Lower education levels were correlated with increased cadmium exposure, even though the analysis was restricted to only non-smoking individuals. Socioeconomic status has been previously related to lead exposure, but in our study was related only to cadmium levels. It is difficult to explain why cadmium levels vary with the level of education. It is possible that a diet poorer in iron and other nutrients may be responsible for higher cadmium absorption in less-edu-

cated women. Dietary absorption of cadmium in the intestine increases when iron stores are low, which is a common occurrence in women prior to menopause [9]. We did not find a significant association between blood cadmium levels and offal and shellfish intake, which was expected. Shellfish is very rare in the regular Polish diet, in contrast to offal, which is eaten more frequently. It is likely that the amount of offal consumed per meal differed too widely, and the sample size was too small to obtain relevant results. Cadmium exposure in women should receive greater attention, considering that evidence exists indicating that women are more sensitive to cadmium toxicity than men and that the exposure levels observed in this study exceeded the levels suggested to cause clinical effects, such as osteoporotic fractures and kidney effects [4, 12].

Among women participating in this study, fish consumption and the number of amalgam fillings significantly influenced the concentrations of mercury in the blood. Similar results were observed in many other studies [34, 46, 47]. The use of mercury in the practice of dentistry has decreased gradually in Poland, and nearly half of the participants had none of these types of fillings. The women in the present study reported relatively low fish consumption. However, as reported in recent studies, the consumption of fish highly influences mercury concentration in the blood, even in populations with rather low fish consumption [36]. Fish and fish products are the main Polish dietary seafood staples. The concentration of mercury in fish and fish products on the Polish market varies, but is generally rather low. Among Baltic sea fishes, the highest mercury content was found in flounder, and the lowest content was found in sprat. Among fish products, the highest mercury concentrations were found in smoked fish, especially in Baltic sea salmon and deep sea herring [48]. Among imported fish on the Polish market, butterfish had the highest mercury concentration, although it was only rarely consumed [49]. The reported data showed that, with the exception of butterfish, the levels of mercury were in the range of 5.9%-10.5%, with a maximum limit value of 0.5 ppm for mercury in fresh fishery products. Because most of the available fish and fish products had comparable mercury concentrations, we decided not to distinguish consumption of fish species according to different mercury levels. Owing to low fish consumption and the low mercury concentrations in the market fish, the concentrations of mercury in the blood confirm the low methylmercury burden in the investigated study group.

In conclusion, this study provided informative biomonitoring data, which may reflect current exposure levels to lead, cadmium, and mercury in Polish upper-middle aged women living in urban areas. However, due to our small sample size, the results may not be generalizable to other Polish women of similar age and should be interpreted with caution. Extending our study to a much larger sample size will be necessary to confirm the results and associations between the various factors investigated and the levels of blood metals, particularly lead. Nevertheless, our study indicates that in women in the early stages of menopause, the cumulative nature of lead is an important environmental health concern, and reduced exposure to exogenous sources is strongly recommended. Another important concern relates to cadmium exposure, which still seems to be higher than in other parts of Europe. Therefore, there is a need for intensive action to decrease cadmium exposure levels. The present results did not indicate excessive exposure to mercury in the majority of examined women.

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