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Cadmium in Blood as an Indicator of Integrated Exposure to Cadmium in the Urban Population

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The concentration of cadmium in blood (CdB) is generally regarded as the best biological indicator of recent exposure to cadmium. However, since cadmium is a cumulative toxic agent with a biological half-life in the human body of about 20 years, it is not clear to what extent the CdB level reflects the body burden and recent exposure in conditions of low exposure to cadmium in the general population. The influence of duration of exposure to cadmium on the CdB level was examined in teachers and school children who attend the same schools and live in the same urban area of Zagreb. The results have shown 2.5-3 times higher CdB levels in adult nonsmokers as compared to children ($P<0.001$). Since the current environmental exposure to cadmium can be regarded as being comparable in the two groups, it appears that more than 60% of the CdB level in adults (nonsmokers) could be attributed to the influence of the body burden, i.e. the long-term integrated exposure to cadmium. The additional exposure to cadmium through the smoking habit can result in a 5-6 fold increase in the "normal" CdB level of adults nonoccupationally exposed to cadmium.

MATERIALS AND METHODS

The concentration of cadmium in blood (CdB) was measured in 192 teachers (60 males and 132 females) and 52 children (30 boys and 22 girls) attending the same schools and living in the same urban area of Zagreb. Heparinized venous blood samples were used for the analyses. CdB was determined according to the modified nitric acid precipitation/ET-AAS method (Stoeppler and Brandt 1980), with calibration performed by the addition of Cd-standards in blood. The accuracy of the applied method was verified by participation in the UNEP/WHO quality control programme for CdB analyses (Vahter 1982). All determinations were performed in duplicate, and the mean values were used for calculations. Due to a skewed distribution of data, the results are presented as median and range values, and the significance of the difference between the groups was tested by the nonparametric median test (Siegel 1956).

RESULTS AND DISCUSSION

The results of the CdB determination, together with data on age, sex and smoking habits within the subgroups of the population examined, are shown in Table 1.

Table 1. Median and range values for age and the concentration of cadmium in blood (CdB) within the subgroups of the population examined

Subgroups		Age/years	CdB/$\mu g\ l^{-1}$
Adult males (N=60)	smokers (N=27)	39 (23-58)	3.6 (0.2-13.2)
	ex-smokers (N=3)	49 (44-53)	0.5 (0.3- 1.6)
	nonsmokers (N=30)	47.5 (29-65)	0.6 (0.1- 1.5)
Adult females (N=132)	smokers (N=45)	39 (20-56)	2.7 (0.1-12.7)
	ex-smokers (N=3)	36 (35-49)	0.5 (0.2- 1.1)
	nonsmokers (N=84)	42 (23-59)	0.5 (0.1- 2.0)
Children (N=52)	boys (N=30)	9 (8-10)	0.2 (<0.1-0.6)
	girls (N=22)	9 (8-10)	0.2 (<0.1-0.8)

The cumulative percentage distributions of the CdB values in adult nonsmokers and in children are presented in Figure 1, while the corresponding data for adult smokers are shown in Figure 2.

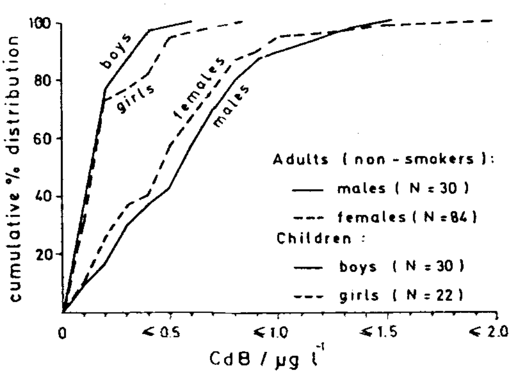

Figure 1. The cumulative percentage distributions of the concentrations of cadmium in blood (CdB) in adult nonsmokers and in children

The results show a highly significant influence of smoking habit on the CdB levels in adults, i.e. a 5-6 fold increase in the CdB of current smokers as compared to nonsmokers. The difference between the current smokers and nonsmokers was highly significant both in males ($\chi^2=31.033$, $P< 0.001$) and in females ($\chi^2=41.805$,

$P < 0.001$).

The relative impact of smoking on the CdB levels in our population (i.e. the smokers/nonsmokers CdB ratio) appears to be more pronounced in comparison with other data in literature. This is due not only to the relatively high CdB levels in smokers, but also to the relatively low CdB in nonsmokers. For example, the results obtained in the UNEP/WHO project (Vahter 1982) indicate the following order of the median CdB values for current smokers: India $<$ $<$ USA $<$ Japan $\leq$ Israel $\leq$ China $\leq$ Sweden $<$ Peru $<$ Belgium $<$ Yugoslavia $\leq$ Mexico, while the corresponding data for nonsmokers are in the order of: Sweden $<$ Mexico $\leq$ Israel $<$ Yugoslavia $\leq$ USA $<$ $<$ China $\leq$ Peru $\leq$ India $<$ Belgium $\leq$ Japan. However, it is not yet clear whether the relatively high CdB levels in our smokers can be attributed to the differences in smoking habit (greater number of cigarettes per day and/or deeper inhalation of cigarette smoke), or to the higher content of cadmium in our cigarettes. Recent data on the determination of cadmium in several brands of Yugoslav cigarettes have shown a range of 1-4 µg Cd/g tobacco (roughly equivalent to 1-4 µg Cd per cigarette) which is in the upper range of the values obtained in different countries, i.e. 0.9-2.3 µg Cd per cigarette (WHO 1980). Moreover, the corresponding data on cadmium content in the mainstream smoke (using smoking machine) have indicated relatively high values (0.2-0.3 µg Cd per cigarette) in comparison with data from other countries (Ivičić et al., prepared for publication).

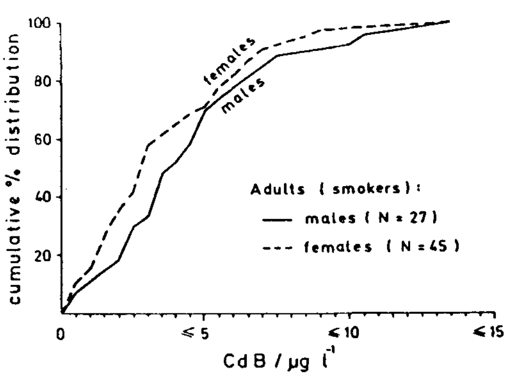

Figure 2. The cumulative percentage distributions of the concentrations of cadmium in blood (CdB) in adult smokers

With regard to "normal" values of CdB in the adult population nonoccupationally exposed to cadmium, a level "usually below 5 µg Cd/l blood" has been quoted (WHO 1980, Alessio et al. 1983). However, since the role of smoking appears to have been insufficiently recognized in earlier studies, it is possible that some of the "normal" CdB levels reported in literature might have been overestimated.

The present results have indicated no significant difference in CdB with respect to sex, either in adult nonsmokers, i.e. between males and females ($\chi^2=1.131$, $P>0.20$), or in children, i.e. between boys and girls ($\chi^2=0.102$, $P>0.50$), which is in agreement with data of other authors (Kowal et al. 1979, Alessio et al. 1982).

Our results have shown the highly significant influence of age, indicating a 2.5-3 fold increase in the CdB levels of adult nonsmokers as compared to children. The difference was highly significant both in males, i.e. between adult male nonsmokers and boys ($\chi^2=20.934$, $P<0.001$), and in females, i.e. between adult female nonsmokers and girls ($\chi^2=11.828$, $P<0.001$). The correlation between CdB (µg Cd/l blood) and age (years) was highly significant only in males (CdB=0.1404 + 0.0095 Age; N=60, r=0.557, $P<0.001$), and less significant in females (CdB=0.2448 + 0.0066 Age; N=106, r=0.298, $P<0.01$), which might be due to the higher rate of cadmium excretion in females through the menstrual blood loss. However, since the current level of environmental exposure to cadmium through the air, food and water can be regarded as being comparable in adults and children (attending the same schools and living in the same urban area of Zagreb), it appears possible that the increase in CdB of adult nonsmokers could be attributed to the longer exposure to cadmium and higher body burden, as compared to those in children.

The level of CdB has usually been regarded as an indicator of the current (recent) exposure to cadmium (Lauwerys 1977 & 1979, Piscator 1979, WHO 1980, Alessio et al. 1983), as opposed to the urinary excretion of cadmium as an indicator of the body burden (in low exposure conditions, and in the absence of renal damage). Contrary to the concentration of cadmium in urine (CdU), which indicated a significant correlation with age on a group basis (Lauwerys et al. 1976, Elinder et al. 1978, Tsuchiya 1978, Kowal et al. 1979, Alessio et al. 1982), no significant correlation between CdB and age or duration of exposure, independently of the exposure level, has been found (Friberg et al. 1974, Lauwerys et al. 1976). However, the recent data of Alessio et al. (1984), obtained in 10 male workers examined more than 3 years after cessation of occupational exposure to cadmium (0.1-1.5 mg Cd/m^3), have indicated an even better (although not significant) correlation between the duration of occupational exposure to cadmium and CdB (r=0.60, $P>0.05$), than that with CdU (r=0.42, $P>0.10$). Our results on the significant influence of age on CdB levels appear to be in accordance with the latter data (Alessio et al. 1984) indicating that not only CdU, but also the CdB levels can be greatly influenced by the long-term integrated exposure to cadmium and the quantity of cadmium deposited in the body.

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