Scand J Work Environ Health 1979;5(1):16-22

<https://doi.org/10.5271/sjweh.2670>

Issue date: Mar 1979

Biologically active metals in human tissues. II. The effect of age on the concentration of cadmium in aorta, heart, kidney, liver, lung, pancreas and skeletal muscle.

by [Vuori E](#), [Huunan-Seppälä A](#), [Kilpiö JO](#), [Salmela SS](#)

Key terms: [age](#); [aorta](#); [biologically active metal](#); [cadmium](#); [concentration](#); [heart](#); [human tissue](#); [kidney](#); [liver](#); [lung](#); [pancreas](#); [skeletal muscle](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/441705

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Biologically active metals in human tissues

II. The effect of age on the concentration of cadmium in aorta, heart, kidney, liver, lung, pancreas and skeletal muscle

by ERKKI VUORI, M.D., M.Sc., ANTTI HUUNAN-SEPPÄLÄ, M.D., JUKKA O. KILPIÖ, M.Sc., and SEPPO S. SALMELA, M.Sc.¹

VUORI, E., HUUNAN-SEPPÄLÄ, A., KILPIÖ, J. O. and SALMELA, S. S. Biologically active metals in human tissues: II. The effect of age on the concentration of cadmium in aorta, heart, kidney, liver, lung, pancreas and skeletal muscle. *Scand. j. work environ. & health* 5 (1979) 16–22. Specimens of aorta, heart, kidney, liver, lung, pancreas and skeletal muscle were collected at autopsy from 86 traumatic accident victims. After dry-ashing, the cadmium concentration in each tissue was determined with atomic absorption spectrophotometry. The cadmium concentration was highest in kidney, the level becoming less in the different tissues in the following order: liver, pancreas, lung, aorta, heart and muscle. The mean (geometric) cadmium concentration of kidney samples in the age group of 40–50 years was 86.9 $\mu\text{g/g}$ of dry weight, corresponding to approximately 26 $\mu\text{g/g}$ of wet weight in kidney cortex. All values for cadmium in kidney were well below 200 $\mu\text{g/g}$ of wet weight, a limit considered tentatively as a critical concentration in kidney cortex. When the effect of age on the cadmium concentration of tissues was studied, the same general pattern was seen, i.e., the median values were low in the early years of life and increased thereafter. In the cases of heart, kidney, lung and pancreas a maximum was found at the age of maturity, but the median concentration in aorta, liver and muscle reached the maximum in older age. The cadmium concentration of muscle showed the best correlation with age. From the data obtained from the correlation matrix of cadmium in the tissues investigated, a clear trend was noticed; if the concentration was high in one tissue it was likely to be high also in other tissues. The cadmium concentrations show that the exposure of the general public in Finland to cadmium corresponds to that found in other nonpolluted countries.

Key words: cadmium, human tissues.

Cadmium is a nonessential trace element that is known to accumulate in human tissues with increasing age (6). For people not occupationally exposed, the most important source of cadmium is through ab-

sorption from food (6). The normal tissue cadmium concentrations of a given population are affected by several factors, e.g., degree of exposure, age and smoking habits (3, 9, 10, 13, 17). Cadmium is known to accumulate in human kidney, and kidney cortex is considered as a critical organ, showing the highest concentration at the age of 50 years (6).

Cadmium causes tubular damage in kidneys, where the critical concentration is tentatively considered to be 200 $\mu\text{g/g}$ of

¹ Department of Public Health Science, University of Helsinki, Helsinki, Finland.

Reprint requests to: Dr. Erkki Vuori, Department of Public Health Science, University of Helsinki, Haartmaninkatu 3, SF-00290 Helsinki 29, Finland.

wet weight (6). Other chronic harmful effects of cadmium are anemia, hypertension [although doubted in the case of humans (14)], liver disturbances, altered calcium and phosphorous metabolism in bones, and carcinogenic and genetic effects (6).

Most studies on cadmium in human tissues have been limited to kidney cortex, liver and pancreas, and investigations concerning other tissues are relatively few. In most cases, due to the low levels, it has not been possible to give exact concentrations since the levels have been below the limit of detection (4, 9, 10, 18, 19). In order to get more detailed information on cadmium in human tissues and to estimate the degree of exposure in the Finnish population, we have analyzed the cadmium concentrations of aorta, heart, kidney, liver, lung, pancreas and skeletal muscle in the present study.

MATERIAL AND METHODS

Autopsy specimens of aorta, heart, kidney, liver, lung, pancreas and skeletal muscle were collected from 86 humans who had died in an acute traumatic accident and who were at autopsy verified not to have suffered from any chronic dis-

eases. The autopsies were performed at the Department of Forensic Medicine, University of Helsinki. The material has been described earlier in detail (20). In this context two aspects must be emphasized. First our sample of kidney represented whole kidney taken as a segment, and second age affects the dry weight/wet weight ratio. Thus, when our results are converted to wet weight, age specific values must be used for the ratios (table 1).

After drying at 105°C overnight, the samples (about 2 g wet weight) were ashed at 450°C for 48 h, and small amounts of concentrated nitric acid were used to complete the ashing. The ash was dissolved with the use of 2 ml of 4 M hydrochloric acid and gentle warming. The crucibles and covers were rinsed with deionized water, and the samples were diluted to the final volume of 10 ml (20). The cadmium concentration was measured by atomic absorption spectrophotometry (AAS) with the flame AAS method (Perkin-Elmer, model 300) and the electrothermal AAS method (Perkin-Elmer, model 300, HGA-70 or HGA-2100) depending on the concentration of cadmium in the samples. Deuterium background correction was used. Bovine liver (reference material no. 1577, The National Bureau of Standards, Washington, D.C.) was used as a control. Our mean result from eight determinations was 0.31 µg/g of dry weight with a range of 0.28–0.34 µg/g, i.e., a value slightly greater than that certified (0.27 ± 0.04 µg/g) by the Bureau. The practical limit of detection for cadmium was about 0.03 µg/g of dry weight in tissues.

Table 1. The median dry weight of the wet weight of tissues (%) and the number of subjects studied in each age group.

Tissue	Age group (years)							
	0–9 (N = 3)	10–19 (N = 16)	20–29 (N = 24)	30–39 (N = 12)	40–49 (N = 14)	50–59 (N = 7)	60–69 (N = 4)	≥ 70 (N = 6)
Aorta	31.0	29.0	28.4	28.2	27.4	26.3	26.9	24.8
Heart	21.8	20.5	21.7	21.9	21.4	19.5	20.9	21.9
Kidney	20.9	20.4	21.1	20.1	20.4	19.9	18.3	17.0
Liver	27.8	26.2	28.2	29.8	28.8	29.8	27.7	28.1
Lung	20.7	20.0	21.4	20.3	20.9	20.2	18.2	17.9
Muscle	24.0	23.6	24.1	24.7	25.2	24.7	27.9	24.9
Pancreas	21.7	21.1	22.5	24.6	24.3	27.0	31.3	34.9

Table 2. The correlation matrix of cadmium in the tissues examined. Calculated from log values; the missing values have been replaced with age-specific median values.

	Aorta	Heart	Muscle	Lung	Pancreas	Liver
Heart	***					
Muscle	***	***				
Lung	***	***	***			
Pancreas	**	NS	*	***		
Liver	*	NS	NS	*	***	
Kidney	***	*	*	***	***	***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS not significant.

RESULTS

From the total of 593 cadmium determinations two results were excluded from the statistical analysis (one cadmium in aorta, 19.8 $\mu\text{g/g}$, and one in pancreas, 47.3 $\mu\text{g/g}$) due to the exceptionally high results. The results were regarded to be unreliable because further analysis revealed that the cadmium concentrations in the other tissues of these subjects were not exceptionally high. However, high single values for heart, lung and liver tissue were included in cases with concentrations above the medians in every tissue investigated. This practice is justified since cadmium has a good correlation between tissues, as can be seen in table 2.

The average cadmium concentration was highest in kidney, the level becoming less in the different tissues in the following order: liver, pancreas, lung, aorta, heart and muscle. The fraction above the limit of detection/number of cases varied from 1.00 in kidney samples to 0.62 in heart samples (table 3).

The effect of sex on the cadmium concentration of tissue samples ought to be evaluated in each age group separately. However the low number of females in most age groups studied did not allow us to make such a comparison.

When the effect of age on the cadmium concentration of the tissues under investigation (both sexes included) was studied, the same general pattern could be seen. The median values were low in the early years of life and increased thereafter (table 3, fig. 1—2). For the heart, kidney, lung

and pancreas a maximum concentration was found at the age of maturity, but the median concentration in aorta, liver and muscle reached the maximum in the older decades of life. The cadmium concentration of muscle showed the best correlation with age ($N = 86$, $r = 0.404$, $p < 0.001$). However, if we limit age to the 50th year of life, the cadmium concentration in kidney shows an even better correlation with age ($N = 63$, $r = 0.580$, $p < 0.001$).

Due to the great effect of age on the cadmium content of tissues, it is difficult to compare our results with those of earlier studies if the age distribution has not been given. However, table 4 makes possible the comparison of our results for cadmium in kidney with those of earlier studies from the 1970s, with the average concentrations in the age group of 40—50 years as a basis. To make such a comparison simpler, we have converted our geometric mean to represent only cortex by multiplying by 1.5 (9), and we have used an age specific value for the dry weight/wet weight ratio to determine wet weight (table 1).

DISCUSSION

The method by which our material has been collected has been discussed earlier in detail (20). Smoking habits have been

shown to play a role in the accumulation of cadmium in the human body (3, 10). Unfortunately it was not possible to obtain information on the smoking habits of

our subjects. Smokers have been shown to have a higher cadmium concentration not only in kidney cortex but, in some age groups, also in the pancreas and liver

Table 3. The average cadmium concentration in the tissues examined (geometric means and medians), the ranges and the number of samples above the detection limit/number of samples in each age group; both sexes are included.

Tissue	Age group (years)							
	0—9	10—19	20—29	30—39	40—49	50—59	60—69	≥ 70
Aorta								
Mean	0 ^a	0.05	0.20	0.53	0.41	0.50	1.03	0.15
Median	0	0.11	0.36	0.38	0.56	0.57	1.38	0.47
Minimum	0	0	0	0.17	0	0	0.20	0
Maximum	0.15	0.60	12.0	9.49	5.31	4.54	5.96	0.82
N	1/3	10/16	19/24	11/11	11/14	6/7	4/4	3/5
Heart								
Mean	0	0	0.05	0.06	0.09	0.06	0.22	0
Median	0	0	0.09	0.09	0.22	0.10	0.21	0
Minimum	0	0	0	0	0	0	0.14	0
Maximum	0.03	0.38	0.89	0.74	0.56	0.32	0.42	0.63
N	1/3	7/16	16/24	8/12	10/14	5/7	4/4	2/6
Kidney								
Mean	6.73	25.3	49.4	78.1	86.9	83.7	87.1	58.7
Median	15.8	24.9	54.9	74.5	99.3	78.7	100	76.2
Minimum	1.11	11.4	2.40	33.0	17.8	49.3	48.7	21.8
Maximum	17.4	44.6	197	150	239	178	123	143
N ^b	3/3	16/16	23/23	9/9	13/13	7/7	4/4	5/5
Liver								
Mean	0.25	2.44	3.06	2.69	3.72	2.39	4.47	3.38
Median	1.40	2.41	3.36	2.75	3.69	2.85	4.39	3.57
Minimum	0	1.24	0.57	0.38	0.97	0.12	3.09	0.54
Maximum	1.61	4.73	10.5	10.6	9.31	15.6	6.72	10.3
N	2/3	16/16	24/24	12/12	14/14	7/7	4/4	6/6
Lung								
Mean	0	0.27	0.66	1.35	0.67	0.73	0.87	0.03
Median	0	0.96	0.96	1.76	1.43	0.89	0.87	0
Minimum	0	0	0	0.07	0	0.21	0.53	0
Maximum	0.07	3.36	7.57	4.95	6.80	2.40	1.51	1.71
N	1/3	13/16	20/23	12/12	12/14	7/7	4/4	2/6
Muscle								
Mean	0	0	0.04	0.03	0.08	0.07	0.29	0.04
Median	0	0.03	0.07	0.06	0.18	0.11	0.29	0.08
Minimum	0	0	0	0	0	0	0.17	0
Maximum	0.03	0.22	0.39	0.17	0.29	0.48	0.50	0.47
N	1/3	9/16	16/24	7/12	10/14	5/7	4/4	3/6
Pancreas								
Mean	0.14	0.50	1.94	2.29	2.31	1.30	2.21	1.68
Median	0.47	0.83	1.90	2.23	3.05	0.64	2.31	1.44
Minimum	0	0	0.43	0.70	0.30	0.36	1.30	0.56
Maximum	0.85	1.89	10.3	9.71	9.08	8.13	3.41	3.46
N	2/3	14/16	23/23	12/12	14/14	7/7	4/4	5/5

^a 0 stands for "under the limit of detection," which was about 0.03 $\mu\text{g/g}$ dry weight.

^b Due to an accident in a series of analyses, four results of cadmium in kidney are lacking (subjects 26, 28, 31 and 32).

Fig. 1. The total range and median cadmium concentration ($\mu\text{g/g}$ dry weight, log-scale) of kidney as a function of age. (stars: females, dots: males)

Fig. 2. The total range and median cadmium concentration ($\mu\text{g/g}$ dry weight, log-scale) of muscle as a function of age. (stars: females, dots: males)

(3). In muscle samples no significant differences between smokers and nonsmokers have been found (9). It is known that smoking is more common among males than females in Finland; in the age group of 18–54 years 52 % of the males and 22 % of the females have been reported to be daily cigarette smokers and 30 % and 68 %, respectively, never smoke regularly (16). It has also been shown that smokers are involved in acute accidents more often than nonsmokers (2, 3, 5), and thus the

prevalence of smoking might be even higher in our material than in the general population.

Cadmium concentration has been shown to be higher in kidney cortex than in medulla (12), and therefore Kjellström (9) used a conversion factor of 2/3 when converting his results of cadmium in cortex to represent whole kidney. Our kidney samples were taken as a segment to represent the whole kidney, the cortex and medulla in equal proportions. The con-

Table 4. Average cadmium concentration of kidney cortex in the age group of 40–50 years in the 1970s according to different authors.

Mean ($\mu\text{g/g}$ wet weight)	Sex ^d	Reference	Geographic area
28 ^a	M	Anke and Schneider (1)	German Democratic Republic
15 ^a	F		
29 ^b	M—F	Piscator and Lind (15)	Sweden
29 ^c	M	Hammer et al. (7)	United States
29 ^c	F		
85	M—F	Tsuchiya et al. (19)	Japan
22	M—F	Elinder et al. (3)	Sweden
60	M—F	Iwao (8)	Japan
26 ^a	M—F	Present study	Finland

^a Converted from dry weight to wet weight (multiplication with 0.20) and kidney cortex (multiplication with 1.5).

^b Converted from dry weight to wet weight (multiplication with 0.20).

^c Converted from ash weight to wet weight (multiplication with 0.014).

^d M = males; F = females.

version factor of 1.5, which we used when estimating the cadmium concentration in kidney cortex (table 4), seemed rather to overestimate than underestimate the actual value.

Our determinations of cadmium content in tissues are in good agreement with results from Sweden (3, 9, 15), and therefore the exposure of the general public to cadmium seems to be of the same magnitude in the two Scandinavian countries. Only one study on the cadmium content of Finnish people has been published earlier (4). In that study tissue specimens similar to those analyzed by us were examined, but no distribution according to age or sex could be made because of the limited number of cases investigated. The median cadmium concentrations of kidney, liver, lung and pancreas tissue were above the limit of detection and were 40.7, 3.78, 1.14 and 0.85 $\mu\text{g/g}$ of dry weight, respectively (4). These earlier results are also comparable with those of the present study.

Schroeder and Balassa demonstrated that kidney showed the maximum cadmium concentration in the age group of 40–50 years (17). It is also known that the cadmium concentration of kidney varies with the geographic location (13). This geographic variation can also be seen in table 4, in which the average cadmium concentration in kidney cortex is summarized from studies done in this decade (1, 3, 7, 8, 15, 19).

The variation in individual values is striking (table 2), and much greater than that found from the same material for copper (20). However, the variation of a nonessential trace element can be assumed to be greater than that of an essential one, because the levels depend largely on the degree of exposure and are thus mainly externally controlled (11).

The cadmium concentration of kidney bears a good correlation with age up to the age of 50 years (17). In the case of liver the increase has been shown to continue up to the age of 80 (3, 8). In our material the cadmium content of muscle showed the best correlation with age when all age groups were included (fig. 2).

The correlation matrix of cadmium concentrations in tissue (calculated from log values) shows a general tendency for a

high cadmium concentration in one tissue to indicate a high concentration in other tissues as well (table 2). This phenomenon is understandable since cadmium does not appear to have any essential function and its concentration in tissues is determined by the degree of exposure.

ACKNOWLEDGMENT

The authors wish to thank Ms. L. Saarvo for her skillful technical assistance.

REFERENCES

1. ANKE, M. and SCHNEIDER, H.-J. Der Zink-, Kadmium- und Kupferstoffwechsel des Menschen. *Arch. Exp. Veterinärmed.* 25 (1971) 805–809.
2. CEDERLÖF, R., FRIBERG, L., HRUBEC, Z. and LORICH, U. *The relationship of smoking and some social covariables to mortality and cancer morbidity* (part 1). The Department of Environmental Hygiene, The Karolinska Institute, Stockholm 1975, pp. 59–62.
3. ELINDER, C.-G., KJELLSTRÖM, T., FRIBERG, L., LIND, B. and LINNMAN, L. Cadmium in kidney cortex, liver and pancreas from Swedish autopsies. *Arch. environ. health* 31 (1976) 292–302.
4. FORSSÉN, A. Occurrence of Ba, Br, Ca, Cd, Cs, Cu, K, Mn, Ni, Sn, Sr, Y and Zn in the human body. *Ann. med. exp. biol. fenn.* 50 (1972) 99–169.
5. FRIBERG, L., CEDERLÖF, R., LORICH, U., LUNDMAN, T. and FAIRE, U. DE. Mortality in twins in relation to smoking habits and alcohol problems. *Arch. environ. health* 27 (1973) 294–304.
6. FRIBERG, L., NORDBERG, G. and PISCATOR, M. Cadmium. In: *Toxicology of metals* (vol. II, environmental health effects research series). U.S. Environmental Protection Agency, Research Triangle Park, N.C. 1977, pp. 124–163.
7. HAMMER, D. I., CALOCCI, A. V., HASSELBLAD, V., WILLIAMS, M. E. and PINKERSON, C. Cadmium and lead in autopsy tissues. *J. occup. med.* 15 (1973) 956–963.
8. IWAO, S. Cadmium, lead, copper and zinc in food, feces and organs of humans. *Keio j. med.* 26 (1977) 63–78.
9. KJELLSTRÖM, T. Accumulation and renal effects of cadmium in man: A dose-response study (Doctoral thesis). The Department

- of Environmental Hygiene, Karolinska Institute, Stockholm 1977, pp. 23—24.
10. LEWIS, G. P., JUSKO, W. J. and COUGHLIN, L. L. Cadmium accumulation in man: Influence of smoking, occupation, alcoholic habit and disease. *J. chronic dis.* 25 (1972) 717—726.
 11. LIEBSCHER, K. and SMITH, H. Essential and nonessential trace elements: A method of determining whether an element is essential or nonessential in human tissues. *Arch. environ. health* 17 (1968) 881—890.
 12. LIVINSTON, H. D. Measurement and distribution of zinc, cadmium and mercury in human kidney tissue. *Clin. chem.* 18 (1972) 67—72.
 13. PERRY, H. M., TIPTON, I. H., SCHROEDER, H. A., STEINER, R. L. and COOK, M. J. Variation in the concentration of cadmium in human kidney as a function of age and geographic origin. *J. chronic dis.* 14 (1961) 259—271.
 14. PISCATOR, M. Cadmium and hypertension. *Lancet* 2 (1976) 370—371.
 15. PISCATOR, M. and LIND, B. Cadmium zinc, copper and lead in human renal cortex. *Arch. environ. health* 24 (1972) 426—431.
 16. RIMPELÄ, M., SIEVERS, K., LEPPÖ, K. ja KOSKELAINEN, O. Aikuisväestömmen tupakointitavat ja tupakoinnin aloittamiskä [Smoking habits of adult Finns and the age when smoking was started]. *Suom. lääkärilehti* (1974) 2340—2348.
 17. SCHROEDER, H. A. and BALASSA, J. J. Abnormal trace metals in man: Cadmium. *J. chronic dis.* 14. (1961) 236—258.
 18. TIPTON, I. H. and COOK, M. J. Trace elements in human tissue: Part II. Adult subjects from the United States. *Health phys.* 9 (1963) 103—145.
 19. TSUCHIYA, K., SEKI, Y. and SUGITA, M. Cadmium concentrations in the organs and tissues of cadavers from accidental deaths. *Keio j. med.* 25 (1976) 83—90.
 20. VUORI, E., HUUNAN-SEPPÄLÄ, A. and KILPIÖ, J. O. Biologically active metals in human tissues: I. The effect of age and sex on the concentration of copper in aorta, heart, kidney, liver, lung, pancreas and skeletal muscle. *Scand. j. work environ. & health* 4 (1978) 167—175.

Received for publication: 22 September 1978