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Cadmium, Lead, and Zinc Concentrations in Human Fingernails

Masatoshi Hayashi,[1] Kazuhiro Yamamoto,[1] Makoto Yoshimura,[1] Hitofumi Hayashi,[1] and Atsushi Shitara[2]

[1]Department of Public Health, Nippon Veterinary and Animal Science University, Musashinoshi, Tokyo 180, Japan and [2]Department of First Internal Medicine, Dokkyo University School of Medicine, Mibu, Tochigi 321-02, Japan

From an analytical point of view, the advantages of hair and nails as a biological index of environmental pollutant exposure of human beings are substantial. Nails and hair are:(a) easy to collect, (b) less precautions with respect to storage and transport, and (c) relatively simple to manipulate with respect to weighing and introduction into analytical instruments. They are formed in a relatively short time, after which the finished structure is expelled from the skin surface, becoming isolated from the body's continuing metabolic activities. Moreover, the hard, relatively impermeable keratinous outer structure seals in their constituents, holding them in place for a much longer time than is true for most other tissues.A considrable number of reports (Fukushima 1982; Vance 1988 ; Oluwole 1990) are to be found in the literature concerning trace metal analyses of human hair. Chemical analysis of nails has mainly been performed on essential elements such as calcium, sodium, magnesium and iron. However, little work has been reported on harmful metals within human nails (Henke et al. 1982; Kasperek et al. 1982).

The object of this study was to determine the range of cadmium (Cd), lead (Pb) and zinc (Zn) concentrations in nail samples taken from normal subjects that might be used as a basis of comparison for any further studies. The analysis study of human hair has revealed that trace element concentrations are related to factors such as the sex of donor, diet, occupation, age and season (Corridan 1974; Creason et al. 1975). Since hair and nails are somewhat chemically similar, the trace element concentrations in fingernails could also be related to these factors. For this reason, the results in this study are discussed in relation to sex, age and seasonal factors.

MATERIALS AND METHODS

In 1991, during the period from April through June, fingernail

Send reprint requests to Masatoshi Hayashi at the above address.

samples were obtained from 163 subjects (74 males and 89 females) and during the period from October through December from 152 (80 males and 72 females). The subjects in the Spring and Winter seasons were not the same subjects. These subjects were all healthy, and their ages ranged from 1 to 79 years. The nail samples were collected during the Spring and Winter seasons, because the differences in daily food consumption and the variation of available foodstuffs was considered to be experimentally valuable and significant. All the nail clippings were stored in polyethylene tubes before use. The nail samples were prepared for analysis by washing them in a 5 % solution of non-ionic detergent and then rinsing them four times with distilled water. The samples were placed in polyethylene tubes and dried at 40 ℃ for 24 hours. After cooling in a desicator, individual nail samples, weighing form 45 to 50 mg, were placed in polyethylene tubes. Weighed samples were transferred to crucibles and placed in a muffle furnace. The temperature was increased 100 ℃ per hour to 500℃ and the samples were held at 500 ℃ for an additional 10 hours. The ash in each crucible was dissolved in 3 ml of 5 N nitric acid. The determination of Cd, Pb and Zn was by atomic absorption spectrophotometry (Shimadzu, Model AA-610S). All atomic absorption readings were converted to μg/g dry weight. Differences between values were evaluated by Student's *t* test.

RESULTS AND DISCUSSION

Tables 1 and 2 show the concentrations of the trace metals according to season and age. In both sexes, Cd, Pb and Zn levels in nails were higher in the Spring than those in the Winter, although differences for all age groups were not significant. The geometric mean of Zn concentrations in the nails of 96 males and 121 females were 134 μg/g and 136 μg/g, respectively. In order to compare our data with data from other investigators, the arithmetic mean and standard deviation (mean $\pm$S.D.) were used. The values of Zn in the male and female nails was 138$\pm$38μg/g and 138 $\pm$36μg/g, respectively. The Zn concentration (mean $\pm$S.D.) in Japanese nails were 146$\pm$36μg/g (Ishizawa et al. 1967), and 73.6$\pm$18.9μg/g for males and 74.6$\pm$13.7μg/g for females (Ninomiya et al. 1982). We obtained no differences between the sexes in the Zn levels in nails, which agrees with the findings reported by Ishizawa et al. and Ninomiya et al. These Zn levels in Japanese nails were significantly lower than 178μg/g for male and 222μg/g for female (Harrison and Clemena 1971) ,and 184 for male and 153 for female (Kanabrocki et al 1979) in American nails. The daily Zn intake per capita ranged from 10.0 to 11.5 mg for Japanese adults (Ikebe et al. 1990). This Zn intake was sifnificantly lower than 18.5 mg/day for Americans (Ikebe et al 1989). These differences may be due to the difference in the intake of meats (Kotabe et al. 1981). Ohtsuka and Suzuki (1978) found that the

Table 1. Geometric means of cadmium, lead and zinc in male nails ($\mu g/g$).

Age		Spring				Winter		
group	n	Pb	Cd	Zn	n	Pb	Cd	Zn
1 - 9	11	6.6	0.134	179	12	5.5	0.191	179
		(4.1- 9.1)	(0.05-0.31)	(138-304)		(3.4- 9.9)	(0.31-0.32)	(114-272)
10 - 19	10	17.2	0.150	163	9	10.6	0.168	111
		(6.8-37.7)	(0.04-0.48)	(124-191)		(7.0-15.7)	(0.07-0.54)	(91-142)
20 - 29	8	14.3	0.140	141	9	7.2	0.186	113
		(7.2-24.4)	(0.05-0.28)	(94-195)		(3.8-23.2)	(0.07-0.49)	(88-142)
30 - 39	9	18.9 [a]**	0.112	128	10	7.5	0.082	102
		(14.5-30.7)	(0.05-0.37)	(99-156)		(5.4- 9.7)	(0.03-0.12)	(90-118)
40 - 49	12	12.4	0.180 [a]**	130	15	6.2	0.072	114
		(6.3-32.4)	(0.13-0.30)	(114-164)		(3.8-12.4)	(0.04-0.10)	(90-123)
50 - 59	9	10.5	0.148	150	10	5.9	0.114	127
		(3.3-30.7)	(0.06-0.57)	(100-228)		(2.1-11.2)	(0.08-0.22)	(104-149)
60 - 79	15	10.3 [a]*	0.087	130	15	4.9	0.116	135
		(8.3-11.6)	(0.05-0.13)	(115-163)		(1.3- 9.9)	(0.06-0.26)	(119-154)
Total	74	12.1 [a]**	0.134	145 [a]*	80	6.7	0.126	122

n:number of samples. The minimum and maximum values are shown in parenthesis.

[a]Significantly different from winter values(*$p<0.01$,**$p<0.001$).

Table 2. Geometric means of cadmium, lead and zinc in female nails($\mu g/g$).

Age group	n	Spring Pb	Spring Cd	Spring Zn	n	Winter Pb	Winter Cd	Winter Zn
1 - 9	11	6.9 (4.5- 9.0)	0.133 (0.08-0.16)	126 (118-176)	10	6.6 (5.0- 8.5)	0.134 (0.11-0.16)	135 (122-165)
10 - 19	13	8.0 (2.7-25.0)	0.109 (0.03-0.30)	162 (135-227)	10	10.1 (8.0-17.9)	0.085 (0.04-0.15)	122 (90-141)
20 - 29	15	10.6 a** (4.4-21.1)	0.164 (0.07-0.61)	136 a** (96-188)	11	4.1 (1.7- 8.4)	0.076 (0.03-0.48)	111 (93-126)
30 - 39	10	7.6 b** (2.8-14.4)	0.107 (0.03-0.17)	158 (119-200)	9	6.8 (4.5-12.0)	0.069 (0.04-0.13)	134 (104-194)
40 - 49	14	8.3 (5.7-13.7)	0.082 b** (0.03-0.27)	147 a** (104-207)	11	5.9 (3.1-10.9)	0.051 (0.04-0.12)	108 (98-116)
50 - 59	16	11.3 a** (6.9-18.9)	0.133 (0.06-0.32)	141 (103-178)	10	4.9 (2.1- 9.4)	0.067 (0.02-0.15)	127 (98-164)
60 - 79	10	8.0 (4.2-33.9)	0.143 a* (0.05-0.53)	152 (128-173)	11	6.7 (3.6-17.8)	0.060 (0.02-0.15)	131 (107-177)
Total	89	8.9 a*b*	0.120 a*b**	149 a**	72	6.1	0.072	136

n:number of samples. The minimum and maximum are shown in parenthesis. [a, b] significantly different from winter and male, respectively(*p<0.01,**p<0.001).

level of hair Zn decreases with a decrease in the consumption of meats. Therefore, the difference in Zn levels in nails between the Spring and Winter seasons may be attributed to the seasonal difference of Zn intake in the diet.

The subjects in this study did not have any significant environmental or occupational exposure to metals. This is important since the major nonoccupational routes of human Cd and Pb exposure are dietary (Ryan et al. 1982; Horiguchi et al. 1983). From the present data it is apparent that the concentrations of Cd and Pb in human nails may vary considerably from individual to individual, and in certain instances, according to sex, age and season. Total daily intake of Pb from foods was 14.1-123.6 μg, with a mean of 32.0 to 73.1 μg (Ikebe et al. 1989; Ikebe et al. 1990). On the other hand, the dietary daily Cd intake was 5-50.2 μg, with a mean of 18.5 to 20.7 μg (Ikebe et al. 1989; Ikebe et al. 1990).

From the facts mentioned above, it is considered that there is a wide variation by day, by individual and by season due to the differences in composition of individual diets. The tendency for nails from male subjects to have higher concentrations of Cd and Pb than nails of female subjects may be related to a higher level of outdoor physical activity or a higher dietary intake attributed to males.

The concentrations among the observed values for family members are summarized in Table 3. Significant positive correlations were found between husband and wife in the levels of Pb, Cd and Zn. Furthermore, there are significant correlations between mother and daughter in the levels of Pb and Zn. Most of the married couples who were chosen as the object of this study were engaged in farming, and most of the daughters were young children. Therefore, these correlations may be explained by similar eating habits and life styles of such couples.

Table 3. Relationships between family members.

Correlated parameters	n	Correlation coefficients Pb	Cd	Zn
Husband vs. Wife	37	+0.456 **	+0.389 *	+0.411 *
Father vs. Son	26	-0.164	-0.264	-0.248
Father vs. Daughter	23	-0.064	-0.167	-0.041
Mother vs. Son	22	+0.179	-0.180	+0.422 *
Mother vs. Daughter	29	+0.499 *	-0.130	+0.510 **

*$p<0.05$, **$p<0.02$

The absence of a correlation of trace metals in the nails of family members experiencing dissimilar environmental factors is attributed to differences in age, sex, taste, diet, and time spent outdoors.

In this study Cd and Pb in nails did not aaccumulate with age. However, "abnromal" trace metals such as Cd and Pb accumulated in human tissues with age (Tsuchiya et al. 1976). This suggests that nails do not act as tissue stores under normal conditions.

The results from normal subjects in the present study indicate the background levels of Cd, Pb and Zn in nails of the general population. However, a great deal more data is required from extensive studies of a large number of cases to clearly establish normal values for human nails.

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