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Absorption and Excretion of Lead in the Healthy Japanese Population; A Balance Study of Lead and Total Body Burden of Lead

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It is a great pleasure for me to be present at this meeting and to give a talk about my work. And I am grateful to Professor Dr. Myung Ho Kim, the president of Korean Society for Preventive Medicine, for his kind invitation.

I have majored in occupational health for the past 20 years, especially prevention of poisonings due to lead including other heavy metals, and those due to organic solvents such as benzene, toluene, xylene and so on, and the cervico-brachial syndrome of occupational origin.

Today, I would like to speak on a balance study of lead in the healthy Japanese population performed recently in my department.

As is generally known, a small amount of lead contained in daily foods and inhaled air is introduced into the bodies of those not exposed to lead occupationally. Lead thus introduced into the body is absorbed through the digestive and respiratory tracts, transported, remained or deposited in the body, and then excreted into urine and feces. In my department, studies have been made on lead intake, lead content in the body constituent, and lead excretion in both human beings and experimental animals. On the basis of the above data, an attempt is made to estimate (1) the balance sheet of absorption and excretion of lead of the Japanese with a comment of atmospheric lead concentration in the community environment and (2) the body burden of lead in the normal Japanese with no known occupational exposure to lead or to its compounds.

Report I. A Balance Study of Lead in Healthy Japanese

1. Lead Intake from Food and Drink

Lead intake from food and drink of the Japanese was estimated for age and severity of labor. From these data, a calculation is made of the amount of lead intake and absorption in each age group up to age of fifty on the assumption that the absorption rate through the digestive tract is 5% and 10% respectively (Table 1).

2. Lead Intake from the Inhald Air

In a survey performed by my department in 1956-1957, lead in the air in residential districts in Osaka showed 4.5 mcg/m^3 and the higher concentrations were shown in the factory districts and the main streets with dense traffic. From the above data, lead intake from the air was estimated at about

Table 1. Lead Intake from Food and Drink

Age	Lead taken per day (mcg)	Period (day)	Lead taken during each period(mg)	Lead absorbed during each period		Cumulative lead absorption (mg)	
				(1) absorption rate, 5% (mg)	(2) absorption rate, 10% (mg)	(1)	(2)
0—10 Month	103	273.75	28.20	1.41	2.82	1.41	2.82
10—12	126	91.25	11.50	0.57	1.15	1.98	3.97
1—10 Year	164	3285	538.74	26.94	53.87	28.92	57.84
10—20	255	3650	930.75	46.54	93.08	75.46	150.92
20—30	277	3650	1011.05	50.55	101.11	126.01	252.02
30—40	277	3650	1011.05	50.55	101.11	176.56	353.13
40—50	277	3650	1011.05	50.55	101.11	227.12	454.23

Table 2. Urine Lead Excretion

Age	Lead in urine per day (mcg)	Period (day)	Lead in urine during each period (mg)	Cumulative lead in urine (mg)
0—10 Month	35×1/4	273.75	2.40	2.40
10—12	35×1/4	91.25	0.82	3.22
1—10 Year	35×1/2	3285	57.46	60.68
10—20	35	3650	127.75	188.43
20—30	35	3650	127.75	316.18
30—40	35	3650	127.75	443.93
40—50	35	3650	127.75	571.68

80mcg per day. In the subsequent survey in 1962, the high lead concentration in the air was also shown in the main street. The latest surveys performed by the other institutes showed 4-15mcg/m^3 in the various parts of Osaka, varing considerably in the different localities.

3. Lead Excretion into Urine

Lead excreted into urine may mean approximately for the lead absorbed into the body. A small part of lead absorbed is also excreted into bile and the intestines. According to our studies, the amount of urine lead excretion of the healthy Japanese was estimated at 35 mcg in average per day. Applying the above data, the amount of urine lead excretion was calculated for each age group in the same way as in the case of calculation of lead intake (Table 2).

The daily amount of urine of children seems

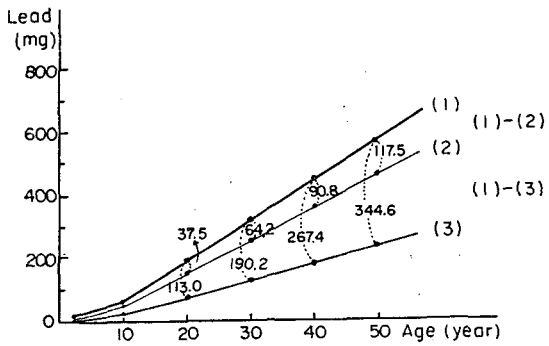

Fig. 1. Urine Lead Excretion and Lead Absorption through the Digestive Tract.
(1): Cumulative lead excretion
(2): Cumulative lead absorption through the digestive tract (Absorption rate, 10%)
(3): Cumulative lead absorption through the digestive tract (Absorption rate, 5%)

to be proportionate to the area of whole body surface; one fourth of adults in case of

infants and half of adults in case of children under 10 years old. Then, the urine lead excretion in infants and children was calculated multiplying the urine lead excretion in adults by the above factors.

4. Relation between the Lead Amount Absorbed through the Digestive Tract and that Excreted into Urine

Figure 1 shows the calculated cumulative amount of lead absorbed through the digestive tract and that excreted into urine at each age group up to fifty. This shows that the amount of lead excreted into urine is more than that absorbed through the digestive tract. However, It has been revealed that some amounts of lead are detected in the organ-tissues of the individual with no occupational exposure to lead, suggesting that lead is remained or deposited in the body. Here, lead in the inhaled air should be considered. The sum total of lead absorbed through the digestive tract and that through the respiratory tract may exceed the amount of lead excreted into urine, and the difference may be remained or deposited in the body.

5. Calculation of the Lead Concentration in the Air to be without Lead Deposition

It may be reasonable to assume that the difference between lead excreted into urine and that absorbed through the digestive tract is regarded as the amount of lead which is absorbed through the respiratory tract without occurring lead deposition in the body. The lead concentration in the air under the above condition may be calculated by the following method. Let us suppose that 50% of lead inhaled are absorbed and the volume of inhaled air is $10m^3$ per day in adults and $5m^3$ in children. Then, twice the lead amount of the difference mentioned above is divided by the cumulative volume of inhaled air in each age group as shown in Table 3; for example, the value is 1.5-4.4mcg/m^3 for a Japanese at 50 years of age. The value seems to be a material for the criteria of air quality in the community environment.

Report II. Body Burden of Lead in Healthy Japanese

1. Lead Concentration in Organs and Tissues

I studied in 1959 with my co-workers the lead concentration of different organs and tissues on samples obtained from autopsy cases on Japanese with no history of occupational lead exposure. It was found that the highest lead concentration was observed in teeth and bones and was followed by the liver and kidneys, while the lowest value was found in other soft tissues (Table 4). We

Table 3. Calculation of the Lead Concentration in Air without Lead Deposition

Age (year)	Inhaled air per day (m^3)	Period (day)	Inhaled air during each period (m^3)	Cumulative inhaled air (m^3)	Lead concentration in air without lead deposition (mcg/m^3)	
					(1)	(2)
0—15	5	5475	27375	27375	0.2	2.3
15—20	10	1825	18250	45625	1.6	5.0
20—30	10	3650	36500	82125	1.6	4.6
30—40	10	3650	36500	118625	1.5	4.5
40—50	10	3650	36500	155125	1.5	4.4

(1): in case where lead absorption through digestive tract is 10%.
(2): in case where lead absorption through the digestive tract is 5%.

Table 4. Lead Contents of Organ-tissue of the Normal Japanese Adults (mcg per 100gm)

Organ-tissues	No. of specimens	Lead contents		
		Minimum	Maximum	Arithmetic mean
Cerebrum	31	9	31	18
Cerebellum	27	8	25	14
Thyroid gland	17	10	36	20
Lungs	47	18	63	30
Heart	38	11	59	22
Liver	47	74	461	190
Pancreas	39	16	56	32
Stomach	37	16	85	40
Spleen	34	21	135	54
Kidneys	48	58	316	140
Large intestines	37	40	133	70
Small intestines	38	15	79	29
Muscle	38	14	75	25
Skin	33	11	94	27
Femur	45	311	2980	1194
Rib	42	215	1240	739
Vertebra	36	242	890	528
Humerus	24	530	1620	976
Skull	6	635	1020	840
Scapula	4	418	1245	769
Bone marrow	5	1215	1660	1377
Fatty tissue	7	0	0	0
Uterus	12	7	46	21
Ovarium	11	0	7	0
Bladder	6	0	6	1
Placenta	11	16	120	57
Spinal fluid	6	12	45	23
Umbilical blood	6	25	90	55
Human milk	3	trace	12	9
Teeth	9	450	9788	3396

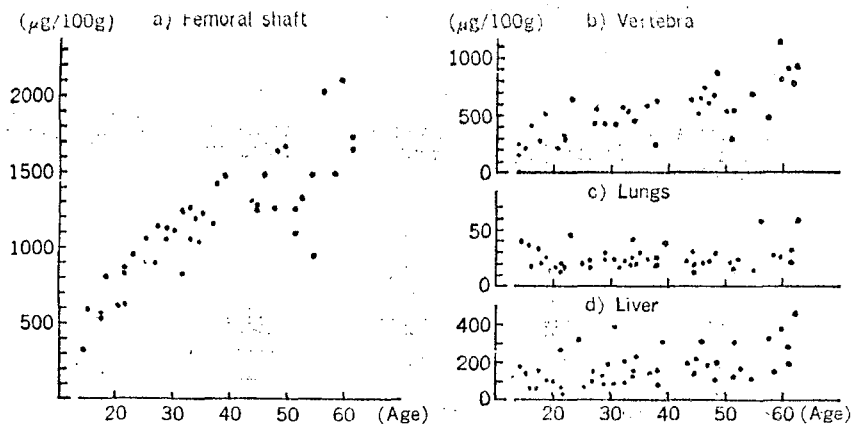

Fig. 2. Correlation Diagram between Lead Contents of Organ-tissues and Age.

also found that the lead concentraction in bones, especially in long bones increased with advancing age (Figure 2). An estimate given for the increase in concentration of lead in the femoral shaft was about 37mcg per year for 100gm of the bone. The vertebra and ribs showed a slighter change with age than that observed in the femur. As to the soft tissues such as the lungs and liver, there was no correlation between the lead concentration and age as shown in Figure 2.

2. Body Burden of Lead

The amount of lead contained in different organs was estimated by calculating from figures on lead concentration of each organ mentioned above and on the average weight of these organs in the Japanese male or female. By summing up the lead content of each organ and tissue, thus obtained, a total body burden of lead was obtained. Table 5 shows the results of the estimation on lead contents in various organs and tissues and on the total body burden of lead of the normal Japanese male and female. Total body burden of lead turned out to be approximately at 84 mg for a male and 76mg for a female. Figure 3 shows distribution of lead in different organs and tissues as expressed with the percentage to the total body burden of lead. It was found that the skeleton contained as much as 85% of total lead of the body

Since small amounts of lead are present in air and many kinds of food and drink, it inevitably invades a human body even if he spends an ordinary daily life. It has been reported in the United States that the total dietary intake of lead in recent years seems to stay unchanged from the level of 1943. Many reports, however, have been made of an increase in the atmospheric lead concentration in the cities with an increasing number of cars. If atmospheric lead concentration increases, total body burden of lead may also increase. Now, studies are scheduled at my

Table 5. Estimated Lead Contents per a Body of the Normal Japanese of Standard Body Weight; male 56kg. female 50kg.

Organs	Lead contents (μg)	
	Male	Female
Brains	240.7	223.4
Skeleton	72r332.0	65,098.8
Teeth	1,626.0	1,578.5
Muscle	3,500.0	3,125.0
Blood	583.3	465.9
Thyroid gland	3.7	3.4
Pancreas	22.5	20.1
Liver	2,301.6	2,154.5
Stomach	200.0	200.0
Small intestines	190.8	190.8
Large intestines	975.1	975.1
Spleen	67.6	64.5
Kidney	379.4	348.7
Lungs	189.0	189.0
Heart	60.0	51.3
Hair	148.5	292,0
Skin	864.0	783.0
Total	83,684.2	75,764.0

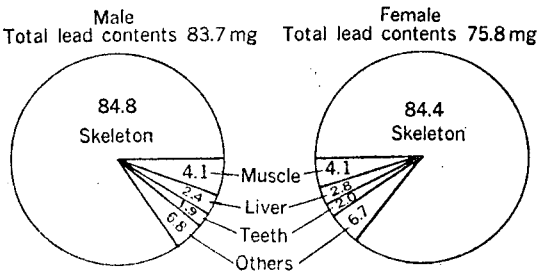

Fig. 3. Distribution of Lead in the Body (%).

department to re-examine the lead content in food and drink, in the body constituents and in excreta, and to compare them with the data previously obtained. (This manuscript was presented as the special lecture at the Annual Meeting of Korean Society for Preventive Medicine held in Seoul, Korea, October 6, 1973)