



# General Factors of the Korean Exposure Factors Handbook

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Risk assessment considers the situations and characteristics of the exposure environment and host. Various physiological variables of the human body reflects the characteristics of the population that can directly influence risk exposure. Therefore, identification of exposure factors based on the Korean population is required for appropriate risk assessment. It is expected that a handbook about general exposure factors will be used by professionals in many fields as well as the risk assessors of the health department. The process of developing the exposure factors handbook for the Korean population will be introduced in this article, with a specific focus on the general exposure factors including life expectancy, body weight, surface area, inhalation rates, amount of water intake, and soil ingestion targeting the Korean population. The researchers used national databases including the Life Table and the 2005 Time Use Survey from the National Statistical Office. The anthropometric study of size in Korea used the resources provided by the Korean Agency for Technology and Standards. In addition, direct measurement and questionnaire surveys of representative samples were performed to calculate the inhalation rate, drinking water intake, and soil ingestion.

**Key words:** Risk assessment, Environmental exposure, Environmental health

## INTRODUCTION

Exposure to harmful elements poses unique situations and characteristics for each nation and geographical area, which increases the need to measure physiological variables that reflect the characteristics of the population to make reliable exposure assessment [1,2]. General exposure factors including life expectancy, body weight, body surface area, inhalation

rate, intake of drinking water, and soil ingestion are the most essential and most frequently used variables in exposure or risk assessment [3,4]. Life expectancy is an important factor in the evaluation of the lifelong effects of exposure, such as cancer risk. Life expectancy refers to the remaining years of life calculated for an individual at a certain age, which estimates how long a person is expected to live. The life expectancy for a certain year is the statistical life expectancy at birth in the same year. Body weight affects inhalation rate, food intake, and body surface area. Although an exposure may be the same, it can have different effects on individuals of different weights. In general, average daily exposure to contaminants is standardized and based on mean body weights for assessment, and since body weight is an important exposure factor [5].

The body surface areas in contact with contaminants should be obtained to assess exposure through skin absorption. Absorption can occur through the entire body surface in such sit-

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uations such as swimming and bathing. On the other hand, skin exposure to chemicals may only happen to parts of the body. Both the entire body surface area and body part surface area are thus needed to estimate exposure through skin absorption accurately.

The amount of contaminants absorbed through inhalation are influenced by inhalation rate, therefore, data of standard inhalation rates are essential for the risk assessment of contaminants in the air. Inhalation rate varies according to gender, age, and physiological conditions. It can also vary within the individual depending on the intensity of physical activity. It is a very demanding task to perform first-hand measurements and calculations of average inhalation rates, and estimate inhalation rates for activity levels of the general population. This explains the preference for indirect measurements, such as heart rate and the use of accelerometers instead of inhalation rates [6,7].

The intake of drinking water can be a major exposure path for ingesting contaminants orally. There needs to be information about the consumption of drinking water to assess exposure to toxins through drinking water [8]. There are two definitions of drinking water intake: in the first definition, drinking water is defined as total tap water, whereas the second definition includes total fluid including such liquids as milk, non-alcoholic drinks, liquor, and water content in food materials. Total fluid has the potential for the over-reporting exposure to harmful materials through drinking water. It is common to use total tap water in exposure assessment. Total tap water includes all water used in daily life that is supplied through the water system, including drinking water, beverage, tap water used in dishes, underground water, and town waterworks.

In daily life, people can be exposed to contaminants by ingesting food containing soil particles or by putting a finger with soil on it into the mouth. Soil ingestion is thus another potential path of exposure to contaminants. Children especially, have greater exposure to contaminants through soil ingestion than adults do. Estimating the amount of soil ingested by humans as needed for exposure and risk assessment of contaminants through soil is required [9,10].

The factors related to somatological variables are important elements of risk assessments and the management of harmful substances. This review investigates the general exposure factors including life expectancy, weight, body surface area, inhalation rate, intake of drinking water, and soil ingestion by the Korean population. The review summarizes the processes of

making estimations as part of the research underlying the development of the Korean Exposure Factors Handbook in 2007.

## DEVELOPMENT PROCESS

### Life Expectancy

The Life Table, an annual publication of the National Statistical Office, was used to calculate recommended levels for life expectancy [11]. The Life Table of Korea was selected because the latest version of it was available in 2005, when research on the Korean Exposure Factors Handbook was in progress. The Life Table offers data on a closed population without immigration and international migration, and is based on the resident registration and death reports from the previous the year.

### Body Weight

The data on body weight and height came from the 5th Body Measurement Project for Korean People that was conducted by the Ministry of Commerce, Industry and Energy [12]. It was conducted at the city and county (gun) level across the nation in 2003 and 2004, directly measuring 16 217 Korean people aged 0 to 90. The present study divided the population into the age groups of 18 to 24 and 25 to 34 for the ease of comparison with foreign data.

### Body Surface Area

Body surface area was obtained by applying a conversion equation to measure body weight and height data. The findings of Lee et al. [13] were used for the conversion equation and the ratio of the entire body surface area to body-part surface area. Lee et al. [13]'s research on the body surface areas of male and female adults in Korea was the largest and most recent study on the calculation of body surface area in the nation. It measured the entire body and body-part surface areas of 65 male and female adults (34 males, 31 females) in Korea using the alginate method, and it developed an equation to calculate body surface area based on the results.

The equation to convert body weight and height into the entire body surface area is presented below. The average ratio of body-part surface area in relation to the entire body surface area was 7.6% for the head, 37.4% for the torso, 14.8% for the arms, 4.8% for the hands, 28.9% for the legs, and 6.5% for the feet [13].

$$\text{Body surface area} = 73.15 \times \text{body weight}^{0.425} \times \text{height}^{0.725}$$

The equation and ratio were applied to the body weight and height data from the 5th Body Measurement Project to calculate the distribution of values of the entire body and body-part surface area among the participants.

### Inhalation Rate

At the time of the study, there were no data available to calculate the recommended levels for inhalation rate. Thus, the present study performed a direct measurement and data analysis. Inhalation rate was classified into short-term inhalation rate to assess short-term exposure, and long-term inhalation rate to assess long-term exposure in daily life. For the survey of short-term inhalation rate, 193 subjects, aged between 10 and 49 years, were asked to perform an exercise stress session at various levels of intensity in the laboratory to measure their inhalation rate. Exercise stress involved resting, slow walking, fast walking, slow running, and fast running. The inhalation rate was used to obtain a weighted mean, by gender, age, and additionally, short-term inhalation rate ( $\text{m}^3/\text{h}$ ) was produced applying activity levels.

Heartbeats were measured during the experiment of short-term inhalation rate to construct an optimal regression model that predicted inhalation rate from heartbeats, controlling for gender, age, and activity level. The average inhalation rate in daily life, according to the activity types, was obtained by investigating heartbeats and time activity patterns of 188 male and female adults for three days, including a weekday and weekend. The subjects had a heartbeat meter attached to the body, which automatically measured heartbeats every 15 seconds. Activity patterns were recorded every ten minutes. Heartbeats were automatically measured with a heartbeat meter (S610; Polar, Kempele, Finland), which received the electromagnetic waves of electrocardiography.

Real-time heartbeat data were combined with the physical activity types recorded in the physical activity log at each point in time. Timed activity patterns were grouped into 99 categories. The distribution of heartbeats by activity patterns were obtained from the accumulated data of all subjects on each activity. The data were converted into inhalation rate for each activity pattern by inserting the number of heartbeats into the regression equation for average inhalation rate.

The inhalation rate by activity pattern was applied to the data of the Time Use Survey of 2004 of the National Statistical Office [14] to build a inhalation rate database for 32 000 Korean people. The database was statistically analyzed to obtain

long-term inhalation rates by gender, age, and activity level of Korean people [15].

### Drinking Water Intake

Although there are previous studies on the intake of drinking water in Korea, it is difficult to use the findings to estimate recommended values because of their limitations. These studies had extremely small group samples that were not representative of the population, or investigated only some aspects of drinking water. The present study used a sample that was proportional to the gender and age of 16 metropolitan cities and provinces across the nation. The sample was based on the population of autumn 2006 and consisted of subjects aged 20 or older from the online panel developed for polling surveys. The survey took place in May, the month in which the temperature reflects the average annual temperature of Korea and in August to track changes in drinking water intake by temperature. The survey conducted in May had 1092 respondents, while the survey in August had 58.8% of respondents in May and additional respondents for a total of 1148 respondents [15].

One day before the questionnaire was to be completed, the respondents received a document describing the survey. On the survey day, the participants listed the types of drinking water they had on that day, the amount of water, and the time they drank it. When it was common water, they had to state whether they drank it fresh or after boiling it. Pictures of various types of glasses were provided to help participants record the types of glasses they used and the amount of water they drank.

The US considers bottled water a type of beverage and categorizes it as total fluid but not total tap water. This classification reflects the minimal reflection of local environments across its vast territory. Korea, a relatively smaller country, consumes a smaller amount of bottled water imported from other countries. Based on the assumption that bottled water reflects the local environments to a great degree, it is included in the category of total tap water. The statistical values for the intake of only bottled water were also offered, so that researchers could use the data after leaving out the category, intake of bottled water, if necessary [15].

### Soil Ingestion

Soil ingestion is a particularly significant exposure factor for children because their body weight is lower but their intake

amount is greater than adults are. This issue is attributable to the harmful behaviors associated with habits of children's oral period habit and other causes.

Previous studies had not been performed to estimate soil ingestion in Korea. The present study, therefore, investigated the soil intake of children, and calculated recommended levels based on the results.

A total of 63 children, aged 0 to 7 years, participated in the investigation. The children were from kindergartens at three locations in Seoul and three locations in Gyeonggi, Gangwon, and Chungnam. Excrement samples were collected for 4 consecutive days and the body weight of all children were measured. Indoor and outdoor spaces where children spent the most time were selected at home and the kindergarten, based on the questionnaire and time-activity logs. A quadrant was set to accurately represent each area and collect soil and dirt samples. Of the total number of children, five formed the control group that engaged in no outdoor activities, to compensate for exposure to factors other than soil.

Based on the literature, hosts of tracers were selected to estimate soil intake including aluminum, barium, manganese, silicon, titanium, vanadium, yttrium, and zirconium. They were also used to conduct content analysis in excrement, soil, and dirt samples. We used the limiting tracer method, which considers a tracer of the lowest value in the soil intake to estimate various metals, to assess the smallest influences from the factors other than soil. As a result, soil intakes were calculated with aluminum-based estimations [10].

## RECOMMENDED VALUES

In Korea, the average life expectancy of the population was 78.6 years in 2005 and it has been on the rise since that time. The average life expectancy between 1975 (63.82 years) and 2005 (78.63 years) showed an approximately 15-year increase, or about 0.5 years per year. The previous age gap between men and women (of about eight years) began to decrease in the mid-1990s, and the gap was 6.75 years in 2005 (Supplemental Table 1).

Table 1 shows the average body weight and percentage distribution of body weight for male and female adults by age. The average body weight of Korean adults was 62.8 kg, with adult males weighing 69.2 kg and adult females, 56.4 kg.

The average total body surface area of the population aged 18 to 74 years was 17 804 cm<sup>2</sup>. The average body-part surface area was 1281 in the head and 6372 in the torso. The total body-surface-area of men was 18 318 on an average, with the surface areas of the head and torso measuring 1374 and 16 833, respectively. The total body surface-area of women was 15 853 on an average, with the head and torso measuring 1237 and 5945, respectively (Table 2, Supplemental Table 2).

Table 3 shows the recommended levels for the short- and long-term inhalation rates of adults. Men and women reported short-term inhalation rates respectively as follows: 1) 0.48/h and 0.40/h during a break (resting), 2) 1.04/h and 0.79/h during slow walking (light exercise), 3) 1.27/h and 0.94/h during fast walking (medium exercise), 4) 2.08/h and 1.57/h dur-

**Table 1.** Recommended values and statistics for body weight (kg)

Age group (y)	n	Mean <sup>1</sup> (SD)	5th	10th	50th	75th	90th	95th
18-24 Male	887	68.5 (10.3)	54.3	56.6	67.3	73.8	81.5	87.4
Female	853	53.9 (7.3)	44.2	45.7	53.0	57.5	63.1	67.6
25-34 Male	689	71.0 (9.7)	56.0	58.7	70.5	77.1	83.3	87.9
Female	710	55.0 (7.5)	45.2	46.7	53.9	58.4	64.2	68.9
35-44 Male	619	71.8 (9.23)	57.2	60.5	71.5	77.7	84.1	87.8
Female	604	57.1 (7.4)	46.1	48.6	56.3	61.6	66.2	70.0
46-54 Male	334	69.6 (9.1)	55.0	57.9	69.3	75.4	81.1	84.5
Female	366	59.2 (7.8)	47.4	49.5	58.4	64.0	69.3	73.5
55-64 Male	399	67.6 (8.8)	53.2	56.8	67.5	73.3	78.5	82.0
Female	393	59.6 (7.4)	47.8	50.8	59.8	64.3	69.0	71.3
65-74 Male	360	64.3 (8.9)	49.7	53.7	64.3	70.3	75.5	78.4
Female	373	57.2 (8.3)	44.4	47.0	57.1	61.8	67.6	71.1
Total	6587	62.8 (10.9)	47.2	49.6	61.7	69.9	77.1	81.9

SD, standard deviation.

<sup>1</sup>Arithmetic mean.

**Table 2.** Recommended values and statistics for surface area of whole body (cm<sup>2</sup>)

Age group (y)		n	Mean <sup>1</sup> (SD)	5th	25th	50th	75th	90th	95th
18-24	Male	887	18 523 (1406.2)	16 401	17 554	18 446	19 376	20 313	21 034
	Female	853	15 829 (1091.7)	14 171	1179	1226	1285	1344	1390
25-34	Male	689	18 677 (1331.8)	16 524	17 772	18 684	19 459	20 372	20 945
	Female	710	15 822 (1077.4)	14 227	15 091	15 728	16 420	17 214	17 778
35-44	Male	619	18 644 (1264.6)	16 621	17 804	18 663	19 427	20 323	20 750
	Female	604	15 938 (1067.7)	14 257	15 222	15 889	16 573	17 224	17 719
45-54	Male	334	18 156 (1256.1)	16 148	17 326	18 136	19 010	19 797	20 176
	Female	366	16 084 (1086.9)	14 285	15 326	16 096	16 798	17 477	17 869
55-64	Male	399	17 785 (1256.3)	15 569	17 028	17 822	18 613	19 367	19 809
	Female	393	15 971 (1054.3)	14 190	15 332	15 960	16 725	17 209	17 695
65-74	Male	360	17 305 (1297.9)	15 164	15 962	16 370	17 295	18 211	18 949
	Female	373	15 480 (1193.0)	13 535	14 681	15 521	16 300	16 993	17 453
Total	Male	3288	18 318 (1395.6)	16 029	17 392	18 268	19 193	20 096	20 665
	Female	3299	15 853 (1101.9)	14 135	15 131	15 797	16 531	17 239	17 735
Total		6587	17 084 (1760.0)	14 488	15 722	16 938	18 334	19 433	20 104

SD, standard deviation.

<sup>1</sup>Arithmetic mean.**Table 3.** Recommended values and statistics for short-term and long-term inhalation rate

Breathing types			n	Mean <sup>1</sup> (SD)	5th	25th	50th	75th	90th	95th
Short-term inhalation rate (m <sup>3</sup> /h)	Resting	Male	1490	0.48 (0.13)	0.28	0.41	0.48	0.55	0.63	0.70
		Female	1034	0.40 (0.12)	0.22	0.32	0.39	0.46	0.52	0.59
		Total	2524	0.45 (0.13)	0.25	0.37	0.44	0.52	0.61	0.67
	Light exercise	Male	1032	1.04 (0.22)	0.70	0.94	1.03	1.14	1.30	1.45
		Female	719	0.79 (0.18)	0.54	0.68	0.77	0.86	1.06	1.13
		Total	1751	0.94 (0.23)	0.59	0.77	0.94	1.07	1.23	1.36
	Medium exercise	Male	1032	1.27 (0.23)	0.83	1.14	1.27	1.40	1.53	1.64
		Female	719	0.93 (0.17)	0.69	0.82	0.91	1.02	1.14	1.28
		Total	1751	1.13 (0.27)	0.71	0.92	1.13	1.32	1.46	1.55
	Heavy exercise	Male	1036	2.08 (0.37)	1.48	1.84	2.07	2.29	2.53	2.70
		Female	734	1.57 (0.29)	1.18	1.37	1.53	1.69	2.02	2.11
		Total	1770	1.87 (0.43)	1.25	1.54	1.86	2.15	2.40	2.60
	Very heavy exercise	Male	1036	2.57 (0.50)	1.85	2.24	2.54	2.86	3.11	3.37
		Female	734	1.97 (0.33)	1.51	1.72	1.91	2.20	2.49	2.59
		Total	1770	2.33 (0.53)	1.58	1.92	2.29	2.66	2.99	3.16
Long-term inhalation rate (m <sup>3</sup> /d)	Male		1510	15.7 (1.2)	14.0	15.0	15.6	16.3	17.0	17.6
	Female		2367	12.8 (0.9)	11.5	12.2	12.8	13.4	13.8	14.3

SD, standard deviation.

<sup>1</sup>Arithmetic mean.

ing slow running (heavy exercise), and 5) 2.57/h and 1.97/h during fast running (very heavy exercise). The average long-term inhalation rate was 15.7/d for men and 12.8/d for women, reflecting the life-activity patterns of about 32 000 people.

The average daily intake of drinking water was 1660 mL for men and 1346 mL for women (Table 4). The 35 to 44 age-group

reported the highest intake (1552 mL), followed by the 45 to 54 age group (1519 mL) and the 25 to 34 age-group (1498 mL). The 65 or older age group reported the lowest intake (1417 mL). The average daily drinking water intake in summer was 1714 mL, overall; 1887 mL for men and 1541 mL for women. The 35 to 44 age groups reported the highest intake (1838 mL), fol-

**Table 4.** Recommended values and statistics for drinking water intake (mL/d)

Classification		Classification	n	Mean <sup>1</sup> (SD)	5th	25th	50th	75th	90th	95th
Spring	Gender	Male	545	1659.5 (833.8)	540	1060	1565	2120	2780	3380
		Female	547	1345.7 (700.4)	450	810	1260	1700	2230	2555
	Age	20-64	1060	1504.9 (781.7)	500	902	1417	1900	2510	3045
		20-24	99	1449.5 (726.8)	450	950	1400	1870	2435	2985
		25-34	318	1498.1 (780.6)	450	900	1400	1940	2410	3040
		35-44	251	1551.9 (773.8)	540	990	1440	1940	2520	3090
		45-54	266	1518.9 (785.2)	540	970	1437	1865	2410	3065
		55-64	126	1442.5 (837.9)	500	885	1275	1900	2370	2880
		≥ 65	32	1416.6 (906.2)	485	827	1197	1725	2270	3460
	Region	Major cities	533	1530.9 (836.8)	465	900	1440	1980	2520	3090
		Small/medium sized cities	430	1465.3 (733.6)	500	905	1350	1830	2375	2880
		Rural villages	129	1507.7 (731.7)	540	900	1440	1940	2520	2700
	Total		1092	1502.3 (785.3)	497	900	1400	1900	2510	3050
Summer	Gender	Male	574	1886.8 (943.5)	700	1260	1730	2385	3200	3780
		Female	574	1541.3 (833.8)	520	970	1400	1920	2645	3310
	Age	20-64	1114	1717.2 (911.8)	605	1080	1532	2160	2955	3470
		20-24	105	1649.5 (839.9)	465	1150	1500	2160	2645	3485
		25-34	334	1642.4 (859.1)	535	1020	1455	2135	2940	3360
		35-44	264	1838.1 (959.7)	630	1140	1642	2397.5	3135	3565
		45-54	273	1777.3 (933.9)	640	1080	1615	2160	3005	3800
		55-64	138	1599.6 (926.8)	630	970	1440	1870	2660	3230
		≥ 65	34	1611.0 (715.2)	465	1200	1440	1800	2520	3330
	Region	Major cities	561	1702.9 (929.1)	540	1075	1515	2120	2950	3450
		Small/medium sized cities	446	1708.0 (867.0)	680	1080	1537	2160	2910	3380
		Rural villages	141	1777.3 (941.3)	520	1150	1600	2250	3135	3740
	Total		1148	1714.0 (906.5)	605	605	1530	2160	2950	3450

SD, standard deviation.

<sup>1</sup>Arithmetic mean.**Table 5.** The amount of soil ingestion in a day based on detected concentration of aluminum after adjusting environmental background equivalent (mg/d)

	Arithmetic mean	Geometric mean	50th	90th	95th
Total	118.3	29.3	18.05	286.2	897.7

lowed by the 45 to 54 age group (1777 mL), and the 25 to 34 age group (1642 mL). The 55 to 64 age group reported the lowest intake (1611 mL). In the regional classification, town (eup) and township (myeon) recorded the highest intake (1777 mL), followed by medium and small towns (1708 mL), and metropolitan cities (1703 mL).

The average intake of tap water was 947.7 mL, Unknown water added to tea or juice was 319.2 mL, bottled water was 169.1 mL, and underground water and mineral water was 66.3

mL [15]. The intake of drinking water increased across the board in the summer compared to spring, except for “unknown water added to tea or juice” (Supplemental Table 3).

Table 5 presents the average daily soil intake of children in Korea. The mean was 118.3 mg/d, and the geometric mean was 29.3 mg/d. The children in the top 10% were found to have a soil intake of 286.2 mg/d.

## CONCLUSION

In 2005, the recorded life expectancy in Korea was 78.6 years (males, 75.1; females, 81.9), which was higher than the expected age of 75.0 years of the US, according to the Environmental Protection Agency (EPA) [4]. The US EPA handbook reports that the country's life expectancy has been maintained



at 75 since 1982, and issued a recommended value of 75 for the general population. In risk assessment, one sometimes assumes the life expectancy of the general population is 70 instead of 75. In Korea, the average life expectancy of the population has been rapidly rising, which can lead to increased life-long exposure and the emergence of adverse effects. These aspects should be considered in risk assessment.

The average body weight of Korean adults was 62.8 kg, which was about 9 kg lower than that of American adults (71.8 kg) [4]. Korean men and women reported 69.2 kg and 56.4 kg, respectively, which were higher by 5.6 kg and 3.9 kg than the body weights of Japanese men (63.6 kg) and women (52.5 kg). If the recommended US value is applied to risk assessment and the exposure to contaminants is the same, the risk for Korean or Japanese people may be underestimated [4,16].

Since the development of The Korean Exposure Factors Handbook, the result of the 6th Size Survey (Korean human body measurement survey) reported that the height of males and females reached a plateau in height growth since 2003.

The US EPA reports the body surface area as a median rather than a mean; 1.94 m<sup>2</sup> for males and 1.69 m<sup>2</sup> for females [4,17]. Based on these data, US EPA set a recommended value for body surface area in contact with water as 2.0 m<sup>2</sup>. Japanese men and women reported a mean of 1.69 m<sup>2</sup> and 1.51 m<sup>2</sup>, respectively, which were lower than those of their Korean counterparts were. Their small body surface area can be explained by low body weight and small height [16]. The calculation of body weight and body surface area in the study used data from the Body Measurement Project for Koreans conducted by the Korean Agency for Technology and Standards under the Ministry of Commerce, Industry and Energy. Since they claim their sample was highly representative of population groups, which include the latest updates of raw data, their recommended values based on them also seem to have high reliability [12].

The equation for calculating the body surface area for Korean people is similar to those used internationally, so it should be reliable. In contrast, the body part surface-area estimate, which uses the ratio from the same study, has its limitations because of the absence of other studies to compare and test it, and the shortage of methods to test its reliability [13].

The short-term inhalation rate calculated in the present study is somewhat different from the activity intensity reported in foreign studies, so it is difficult to make direct comparisons. Even though the experimental results used to calculate

short-term inhalation rates were not introduced in the study, they clearly show that the average inhalation rate of Korean men during fast running was 3.16 m<sup>3</sup>/h, which is similar to the 3.2/h rate recommended for intense exercise by the US EPA Exposure Factors Handbook [4]. The rates were 0.49/h for men and 0.41/h for women in Korea when they were sitting and taking a rest, and these are similar to 0.4/h recommended resting rates of by the US EPA Exposure Factors Handbook. There seems to be a similar level of inhalation rate for similar activity intensity in the two nations. The long-term inhalation rate recommended for Korean men and women was 15.7/d and 12.8/d, respectively, which were slightly higher than 15.1/d and 11.7/d recommended for American men and women, by EPA [4].

The long-term inhalation rate in the study seems to have high reliability because it was obtained through a direct estimation method that was based on heartbeat measurements and the life activity patterns of a large population sample, unlike the indirect method based on metabolism that was used in the US and Japan [4,15,16].

Since intake of drinking water can vary across seasons, the recommended levels of the study were based on the average daily intake of drinking water in spring, to reflect the average temperature conditions of the nation. The results of the analysis reveal that the average daily intake of drinking water was 1502 mL, 1660 mL for men and 1346 mL for women. The 95th percentile was 3050 mL. In the US, the recommended level for average daily intake of drinking water was 1.4 L [8]. While the intake of drinking water in Korea included bottled water, its American counterparts included water used in cooking instead of bottled water, which highlights methodological differences between the two countries. The present study also measured the intake of drinking water in summer, when intake is expected to rise. As expected, the average daily intake of drinking water increased by approximately 14% to 1714 mL in summer than in spring [15].

Assessment of soil intake is a rare research area worldwide. It is realistically very difficult to measure excrements accurately, and previous studies based on the US EPA Exposure Factors Handbook made assumptions about the actual level instead of making an actual measurement, thus increasing uncertainty [4]. The present study, on the other hand, collected all the excrement samples from the children and measured their dry body weight, thus, strengthening the quality of the assessment. Another strength of the study is its research design that includ-

ed a control group to control for the absorption of index metals derived from foods and other factors in addition to soil [15].

The study has a limitation in that no long-term investigation was conducted on a large number of subjects due to the inherent characteristics and various physiological uncertainties, but those limitations are common among the previous international studies. The recommended level for the average soil intake of children presented in the study was 118 mg/d, which is 18% higher than 100 mg/d recommended by US EPA [3,4].

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## CONFLICT OF INTEREST

The authors have no conflicts of interest with the material presented in this paper.

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**Supplemental Table 1.** Expected life-time in the year of 1975 to 2005 (y)

<b>Year</b>	<b>Male</b>	<b>Female</b>	<b>Total</b>
1975	60.19	67.91	63.82
1976	60.47	68.33	64.17
1977	60.75	68.74	64.51
1978	61.02	69.13	64.84
1979	61.28	69.51	65.17
1980	61.78	70.04	65.69
1981	62.28	70.54	66.19
1982	62.75	71.02	66.67
1983	63.21	71.47	67.14
1984	63.84	72.17	67.81
1985	64.45	72.82	68.44
1986	65.13	73.44	69.11
1987	65.78	74.04	69.76
1988	66.31	74.57	70.3
1989	66.84	75.08	70.82
1990	67.29	75.51	71.28
1991	67.74	75.92	71.72
1992	68.22	76.38	72.21
1993	68.76	76.8	72.81
1994	69.17	77.11	73.17
1995	69.57	77.41	73.53
1996	70.08	77.77	73.96
1997	70.56	78.12	74.39
1998	71.09	78.45	74.82
1999	71.71	79.22	75.55
2000	72.25	79.6	76.02
2001	72.82	80.04	76.53
2002	73.4	80.45	77.02
2003	73.86	80.81	77.44
2004	74.51	81.35	78.04
2005	75.14	81.89	78.63

**Supplemental Table 2.** Recommended values and statistics for surface area based on body lesions (cm<sup>2</sup>)

Body lesions		Mean (SD)	5th	10th	15th	25th	50th	75th	90th	95th
Head	Male	1374 (104.7)	1202	1244	1270	1304	1370	1439	1507	1550
	Female	1237 (82.6)	1103	1133	1151	1180	1232	1289	1345	1383
	Total	1281 (132.0)	1087	1120	1143	1179	1270	1375	1458	1508
Trunk	Male	6833 (520.5)	5979	6186	6318	6487	6814	7159	7496	7708
	Female	5945 (411.0)	5301	5446	5535	5674	5924	6199	6465	6650
	Total	6372 (657.0)	5404	5572	5683	5864	6318	6838	7249	7499
Upper extremity	Male	3627 (276.3)	3174	3284	3354	3444	3617	3800	3979	4092
	Female	3091 (218.2)	2756	2832	2878	2951	3080	3224	3362	3458
	Total	3383 (349.0)	2869	2958	3017	3113	3354	3630	3848	3981
Arm	Male	2729 (207.9)	2388	2471	2524	2591	2722	2860	2994	3079
	Female	2330 (164.2)	2078	2135	2170	2224	2322	2430	2534	2607
	Total	2545 (262.0)	2159	2226	2270	2343	2524	2732	2896	2995
Upper arm	Male	1594 (121.4)	1395	1443	1474	1513	1589	1670	1748	1798
	Female	1395 (95.9)	1244	1278	1299	1332	1390	1455	1517	1561
	Total	1486 (153.0)	1260	1300	1326	1368	1474	1595	1691	1749
Fore arm	Male	1136 (86.5)	994	1028	1050	1078	1133	1190	1246	1281
	Female	935 (68.3)	834	857	871	893	932	975	1017	1046
	Total	1059 (109.0)	898	926	945	975	1050	1137	1205	1246
Hand	Male	898 (68.4)	785	813	830	852	895	940	985	1013
	Female	761 (54.0)	678	697	708	726	758	794	827	851
	Total	837 (86.0)	710	732	747	770	830	898	952	985
Lower extremity	Male	6485 (494.0)	5674	5871	5996	6157	6467	6794	7114	7315
	Female	5596 (390.1)	4990	5126	5210	5341	5576	5836	6085	6260
	Total	6048 (623.0)	5129	5288	5393	5566	5996	6490	6879	7117
Leg	Male	5239 (399.1)	4584	4744	4844	4974	5225	5489	5748	5910
	Female	4613 (315.2)	4113	4226	4295	4403	4597	4811	5016	5161
	Total	4886 (503.0)	4144	4272	4357	4496	4844	5243	5558	5750
Thigh	Male	2729 (207.9)	2388	2471	2524	2591	2722	2860	2994	3079
	Female	2473 (164.2)	2205	2266	2302	2360	2464	2579	2689	2767
	Total	2545 (262.0)	2159	2226	2270	2343	2524	2732	2896	2995
Calf	Male	2510 (191.2)	2196	2272	2321	2383	2503	2629	2753	2831
	Female	2156 (151.0)	1922	1975	2007	2058	2148	2248	2344	2412
	Total	2340 (241.0)	1985	2046	2087	2154	2320	2512	2662	2754
Foot	Male	1246 (94.9)	1090	1128	1152	1183	1242	1305	1367	1405
	Female	967 (74.9)	862	886	900	923	964	1008	1052	1082
	Total	1162 (120.0)	985	1016	1036	1069	1152	1247	1321	1367

SD, standard deviation.

**Supplemental Table 3.** Seasonal amount of drinking water<sup>1</sup> intake based on beverage types (mL/d)

	General factors	Mean (SD)	5th	25th	50th	75th	90th	95th	99th
Spring time	Tap water	947.7 (683.4)	0	450	860	1330	1844	2190	3093.2
	With boiling	350.8 (509.9)	0	0	0	590	1080	1387	2192.8
	Without boiling	4.2 (61.6)	0	0	0	0	0	0	90
	Purified water	592.8 (647.7)	0	0	430	918.8	1440	1800	2889.8
	Underground water	66.3 (247.8)	0	0	0	0	0	571.5	1331.4
	With boiling	8.1 (84.5)	0	0	0	0	0	0	197.5
	Without boiling	58.2 (234.5)	0	0	0	0	0	507	1264.9
	Unknown water added to tea or juice	319.2 (365.6)	0	0	180	450	804	1080	1580
	Mineral water	169.1 (397.2)	0	0	0	125	610	990	1877.7
	With boiling	6.7 (64.4)	0	0	0	0	0	0	257.7
	Without boiling	162.4 (393.9)	0	0	0	90	540	977	1877.7
Summer time	Tap water	1112.5 (839.9)	0	540	970	1510	2230	2770	3600
	With boiling	410.5 (635.5)	0	0	0	720	1260	1715.5	2730.3
	Without boiling	6.3 (80.9)	0	0	0	0	0	0	90
	Purified water	695.7 (774.8)	0	0	540	1080	1737.5	2266.3	3231.6
	Underground water	100.2 (359.7)	0	0	0	0	180	970	1918.1
	With boiling	7.9 (98.6)	0	0	0	0	0	0	260.2
	Without boiling	92.2 (345.8)	0	0	0	0	0	916.5	1865.1
	Unknown water added to tea	286.2 (334.2)	0	0	180	430	720	970	1440
	Mineral water	215.1 (476.4)	0	0	0	180	792	1260	2320.4
	With boiling	9.4 (99.4)	0	0	0	0	0	0	260.2
	Without boiling	205.8 (460.9)	0	0	0	180	790	1260	2201.6

SD, standard deviation.

<sup>1</sup>Beverage does not include water added in cooked foods.