

■ BRIEF COMMUNICATION ■

Biological Profiles of Korean Atomic Bomb Survivors in Residence at Daegu and Kyungbuk, Republic of Korea

In 1945, many Koreans, in addition to Japanese, were killed or injured by the atomic bombs dropped on Hiroshima and Nagasaki, Japan. This study compared the biological profiles of Korean atomic bomb survivors in residence at Daegu and Kyungbuk, Republic of Korea with those of a representative sample of Koreans obtained during a similar period. We evaluated anthropometric measurements, blood pressure, blood cell counts, blood chemistry, and urinalysis of survivors (n=414) and age- and sex-matched controls (n=414) recruited from the third Korea National Health and Nutrition Examination Survey conducted in 2005. Univariate analyses revealed significantly higher systolic blood pressure, white blood cell count, and serum total cholesterol, triglycerides, high-density lipoprotein-cholesterol, and aspartate aminotransferase levels ($p<0.01$) in the survivors. Conversely, hemoglobin concentration, hematocrit, red blood cell count, and the proportion of positive urine occult blood ($p<0.01$) were lower in the survivors. Our findings suggest that biological profiles of Korean atomic bomb survivors were adversely affected by radiation exposure.

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In 1945, toward the end of World War II, atomic bombs were detonated over Hiroshima and Nagasaki, Japan. These bombs resulted in an estimated $140,000 \pm 10,000$ deaths in Hiroshima and $70,000 \pm 10,000$ in Nagasaki (1). At that time, Korea was occupied by Japan, and the Japanese Imperial Government had drafted numerous Koreans as soldiers and workers in munitions factories in Japan. Koreans had also moved to Japan to earn a living. Thus, the atomic bombs dropped on Hiroshima and Nagasaki killed or injured many Koreans, along with Japanese. Ichiba Junko has estimated that 30,000 Koreans died and 20,000 survived at Hiroshima and that 10,000 died and 10,000 survived at Nagasaki. Of the total 30,000 Korean survivors, about 23,000 returned to Korea and 7,000 stayed in Japan (2). According to the Korea Atomic Bomb Casualty Association, 2,650 Koreans were registered as atomic bomb survivors in the Republic of Korea in 2007 (3).

In 2004, Ju et al. investigated non-cancer diseases in Korean atomic bomb survivors living at Hapcheon, Republic of Korea. They reported that Korean atomic bomb survivors have a significantly higher prevalence of hypertension, chronic liver disease, and hypercholesterolemia compared to controls who were recruited from the second Korea National Health and Nutrition Examination Survey (K-NHANES II) conducted

in 2001 (4). Their study was the first epidemiological study to evaluate the health of Korean atomic bomb survivors, and suggested that radiation exposure adversely affects the health of Korean survivors, although several years have passed since the detonation. However, their study was limited to Korean atomic bomb survivors residing in Hapcheon only, and a 3-yr discrepancy existed between the health examination of atomic bomb survivors in Hapcheon and that conducted in the K-NHANES II.

A health examination of the Korean atomic bomb survivors in residence at Daegu and Kyungbuk and the third Korea National Health and Nutrition Examination Survey (K-NHANES III) were both conducted in 2005. This study compared the biological profiles of Korean atomic bomb survivors living in Daegu and Kyungbuk with those of a representative sample of Koreans obtained during a similar period.

The health examination for Korean atomic bomb survivors in residence at Daegu and Kyungbuk was supported by the Nagasaki Association for Hibakusyas' Medical Care (NAS-HIM), a nonprofit organization composed of governmental and nongovernmental organizations in Nagasaki, Japan, for the medical care of atomic bomb survivors around the world.

In all, 468 (204 men and 264 women) Korean atomic

bomb survivors resided in Daegu and Kyungbuk in 2005, and 414 (183 men and 231 women) survivors aged 59-90 yr participated in the health examination (participation rate, 88.5%). Of the 414 survivors, 13 were *in utero*, 274 were 0-10, 102 were 11-20, and 25 were 21-30 yr old at the time of the bombing (6 August 1945 in Hiroshima and 9 August 1945 in Nagasaki).

The controls in this study were recruited from the participants in K-NHANES III. K-NHANES III surveyed a random sample of the general Korean population to assess the health and nutrition status of the population through interviews and health examinations. In the survey, 7,597 Koreans aged ≥ 1 yr participated. We randomly selected a total of 414 (183 men and 231 women) participants aged 59-90 yr, with a matched number of controls.

Anthropometric measurements (height, weight, and body mass index [BMI]), systolic and diastolic blood pressure, blood cell counts (hemoglobin concentration, hematocrit, red blood cell count, and white blood cell count), blood chemistry (aspartate aminotransferase, alanine aminotransferase, fasting glucose, total cholesterol, triglycerides, high-density lipoprotein-cholesterol (HDL-C), blood urea nitrogen, and creatinine), and urinalysis (glucose, protein and occult blood) were analyzed in the two groups in the present study. We evaluated blood cell counts and lipid profiles (triglycerides and HDL-C) of Korean atomic bomb survivors, which were not reported in the study conducted in Hapcheon.

The PROC SURVEYSELECT procedure in the SAS statistical package (SAS Inc., Cary, NC, U.S.A.) was used for random sampling of the controls from K-NHANES III. Student's t-test and the chi-square test were applied to continuous and discrete variables, respectively, to compare the biological profiles between the two groups.

The average age of the survivors was 68.1 ± 6.5 yr and that of controls was 68.0 ± 6.8 yr. Univariate analyses revealed significantly higher systolic blood pressure, white blood cell count, serum total cholesterol, triglycerides, HDL-C, and aspartate aminotransferase levels ($p < 0.01$) in the survivors. Conversely, hemoglobin concentration, hematocrit, red blood cell count, and the proportion of those with positive urine occult blood ($p < 0.01$) were lower in the survivors. No significant differences were found in height, weight, BMI, diastolic blood pressure, alanine aminotransferase, fasting glucose, blood urea nitrogen, creatinine, or the proportion of those with positive urine glucose and protein (Table 1). These trends were not changed generally in sex-specific analyses of biological profiles of survivors and controls (data not shown).

In the present study, we found significant differences in various biological indicators in the Korean atomic bomb survivors compared to nonexposed persons. Therefore, our findings suggest that the biological profiles of Korean atomic bomb survivors are influenced by radiation exposure.

The clinical indicators evaluated in this study were well standardized and easily measured at a majority of the hospi-

tals and clinics in Korea. Thus, discrepancies among examiners and examining methods for the clinical indicators of the survivors and controls did not violate the comparability of the two groups.

The results of our study mostly concurred with previous reports on biological profiles and noncancer diseases in Japanese atomic bomb survivors and the health examination of Korean atomic bomb survivors in residence at Hapcheon in 2004. Sasaki et al. reported a significant effect of atomic bomb radiation on the longitudinal trends of both systolic and diastolic blood pressure (5). A reduction in hemoglobin concentration in Japanese atomic bomb survivors compared to unexposed persons was demonstrated as a late effect of radiation on the hematopoietic system (6). According to a study on persistent subclinical inflammation among atomic bomb survivors, radiation dose was significantly associated with leukocyte counts (7). Akahoshi et al. reported that the atomic bomb radiation dose is positively related to fatty liver and

Table 1. Biological profiles of Korean atomic bomb survivors in residence in Daegu and Kyungbuk and controls recruited from K-NHANES III conducted in 2005

Variables	Atomic bomb survivors (n=414)	Controls (n=414)	<i>p</i>
Height (cm)	157.1 \pm 8.8	157.3 \pm 9.0	0.7442
Weight (kg)	60.1 \pm 10.5	59.5 \pm 9.9	0.4568
BMI (kg/m ²)	24.3 \pm 3.4	24.0 \pm 3.1	0.2201
Systolic BP (mmHg)	136.8 \pm 18.9	131.4 \pm 19.0	<0.0001
Diastolic BP (mmHg)	79.7 \pm 12.6	79.5 \pm 10.0	0.7565
Hemoglobin (g/dL)	12.9 \pm 1.4	13.6 \pm 1.5	<0.0001
Hematocrit (%)	38.6 \pm 4.3	41.5 \pm 4.2	<0.0001
Red blood cell count ($\times 10^6/\mu\text{L}$)	4.2 \pm 0.4	4.4 \pm 0.5	<0.0001
White blood cell count ($\times 10^3/\mu\text{L}$)	6.8 \pm 1.6	6.2 \pm 1.9	<0.0001
AST (IU/L)	29.2 \pm 13.9	25.9 \pm 8.5	<0.0001
ALT (IU/L)	22.4 \pm 14.1	20.8 \pm 10.2	0.0601
Fasting glucose (mg/dL)	98.4 \pm 35.1	100.7 \pm 26.3	0.2787
Total cholesterol (mg/dL)	211.8 \pm 42.1	192.7 \pm 37.0	<0.0001
Triglyceride (mg/dL)	172.2 \pm 161.1	143.8 \pm 87.4	0.0025
HDL-C (mg/dL)	56.1 \pm 14.5	43.8 \pm 10.8	<0.0001
BUN (mg/dL)	17.1 \pm 5.6	17.1 \pm 4.8	0.8294
Creatinine (mg/dL)	1.0 \pm 0.4	1.0 \pm 0.2	0.7264
Urine glucose			0.3212
Positive	16 (4.0)	11 (2.7)	
Negative	386 (96.0)	393 (97.3)	
Urine protein			0.4998
Positive	12 (3.0)	9 (2.2)	
Negative	390 (97.0)	395 (97.8)	
Urine occult blood			0.0009
Positive	40 (10.0)	73 (18.1)	
Negative	362 (90.0)	331 (81.9)	

BP, blood pressure; AST, aspartate aminotransferase; ALT, alanine aminotransferase; HDL-C, high-density lipoprotein-cholesterol; BUN, blood urea nitrogen.

hypertriglyceridemia (8). In the Japanese atomic bomb survivor cohort, the mean increase in serum cholesterol levels from 1958 to 1986 for irradiated individuals was significantly higher than that for nonirradiated controls, in both men and women (9).

Elevated HDL-C levels in atomic bomb survivors compared to controls did not concur with previous reports. HDL-C levels in atomic bomb survivors ranged from 22 to 108 mg/dL, with a median level of 54 mg/dL. The levels in controls ranged from 24 to 103 mg/dL, with a median level of 42 mg/dL. Thus, the survivors had a wider distribution of HDL-C levels than the controls. However, we think that it is unreliable to postulate that the average of HDL-C levels in atomic bomb survivors was elevated by outlier(s). Lifestyle modification (such as aerobic exercise, moderate alcohol consumption, and fish oil consumption) and drug therapy (such as statins, niacin, and fibrates) are well-known measures for raising the HDL-C level (10). The practice of these measures in survivors could have contributed to the elevated the HDL-C levels. However, the higher cholesterol and triglyceride levels in survivors compared to controls in this study, and previous studies of low HDL-C levels in Japanese atomic bomb survivors (8), do not support this explanation. Therefore, a chance may be the most likely explanation.

Although the proportion of individuals with positive urine occult blood among atomic bomb survivors was lower than that in controls, levels of blood urea nitrogen and creatinine, biochemical indicators that reflect renal function, were not significantly different between the two groups. Therefore, the reduced proportion of those with positive urine occult blood among the atomic bomb survivors may also have been due to a chance.

Several limitations should be considered when interpreting our results. The majority of survivors were exposed to the atomic bombs during childhood or adolescence, and 60 yr had elapsed before we conducted this study. In Japan, information regarding individual A-bomb exposure histories, such as each survivor's location and detailed shielding situation at the time of the bombing, was obtained through interviews conducted during the late 1950s and early 1960s. Based on these data and dosimetry systems derived from theories of modern nuclear physics, individual radiation dose estimates are presently available for approximately 100,000 Japanese atomic bomb survivor cohort (11). On the contrary, a scientific and systematic survey of A-bomb exposure histories of Korean survivors has never been conducted in Korea. Therefore, this study simply compared atomic bomb survivors to nonexposed controls.

This study was limited to univariate analysis of biological profiles between atomic bomb survivors and controls because we could not obtain information on covariates of the survivors, such as past medical history, smoking, alcohol consumption, and socioeconomic status (SES). According to the previous study conducted at Hapcheon by Ju *et al.*, atomic

bomb survivors had relatively good health behaviors compared to controls (4). Because the survivors were warned that smoking and drinking might worsen their health in combination with their past atomic bomb exposure, they smoked and drank less than the controls. After returning to Korea, the atomic bomb survivors might not have been provided with sufficient resources and a low SES combined with atomic bomb exposure might have affected their health subsequently. The study conducted by Ju *et al.* revealed that only 2.7% of atomic-bomb survivors in Hapcheon graduated from a high school, college, or university (4). In other words, 97.3% of the survivors had less than a high-school education. We assume that these trends are applicable to the survivors in residence in Daegu and Kyungbuk. To examine whether low SES (predicted by education level) affected the biological profiles of atomic-bomb survivors, we randomly selected 414 controls (183 men and 231 women) who had less than a high-school education from the participants of K-NHANES III and compared their biological profiles with those of the survivors. Although the body weight and BMI scores were significantly lower in the replacement control group than in the survivor group ($p < 0.01$), all the other biological profiles showed the same directions of statistical significance as in the initial control group (data not shown).

The clinical indicators evaluated in this study were related to nutrition, but we could not evaluate the nutritional status of the survivors. Thus, further nutritional evaluations are needed. Despite these limitations, our findings suggest that radiation exposure is indeed associated with the health of Korean survivors. Additional studies investigating the health of Korean atomic bomb survivors are needed.

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