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DOSES OF SOLAR ULTRAVIOLET RADIATION CORRELATE WITH SKIN CANCER RATES IN JAPAN

Takaaki SUZUKI[1], Masato UEDA[1], Katsumi OGATA[2],
Takashi HORIKOSHI[3], Nobuo MUNAKATA[4], and Masamitsu ICHIHASHI[1]

[1]Department of Dermatology,
Kobe University School of Medicine

[2]Department of Dermatology,
Miyazaki Medical College,
Oazakihara, Kiyotake-Cho, Miyazaki 889-16, Japan

[3]Department of Dermatology,
Sapporo Medical University,
Chuo-Ku, Sapporo 060, Japan

[4]Section of Radioresearch,
National Cancer Research Institute,
Tsukiji, Chuo-Ku, Tokyo 104, Japan

INDEXING WORDS

non-melanoma skin cancer; UV dosimetry; epidemiology; ozone column

SYNOPSIS

We analyzed trends in the disease rate of skin cancers in the 1976-80 and 1986-90 intervals in the 27 university hospitals in Japan. We also measured doses of solar ultraviolet (UV) radiation at Sapporo, Kobe and Miyazaki to evaluate the relationship between the two in Japan.

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堀越貴志, 宗像信生, 市橋正光

The rates of basal cell carcinoma (BCC) and actinic keratosis (AK) were higher in 1986-90 than in 1976-80, whereas the rate of squamous cell carcinoma (SCC) was lower in 1986-90 than in the earlier period. The rates of SCC, BCC and AK in the southern part of Japan were about five times higher than those in the north, and the average daily UV dose measured with a Robertson-Berger meter in 1995 was about 1.8 times higher in Miyazaki than in Kobe. That measured by MS-210D UV dosimeter in Sapporo was about 0.53 times lower than in Kobe. These results demonstrate that solar UV dose is higher in the southern part of Japan than that in the northern part, explaining the higher rate of non-melanoma skin cancer in southern part of Japan. A significant increase of AK and BCC may reflect the trend of UV increase in Japan.

INTRODUCTION

The case-control and experimental studies present strong evidence that solar ultraviolet (UV) radiation from the sun is a major etiological agent for skin cancers.[4] Absorption of UVC and UVB radiation by stratospheric ozone is crucial for the protection of living organisms from the sun. Farman et al.[2] and Stolarski et al.[13] showed that springtime levels of ozone over the Antarctic decreased by 40% between 1975 and 1984. Any decrease in the ozone column increases the amount of solar UVB radiation that reaches the earth; for instance, a 10% decrease in total ozone concentrations would increase UV radiation at 305 nm by 20%, at 290 nm by 250%, and at 287 nm by 500%.[1,16] Canada's Atmospheric Environment Sunrise program showed that winter and summer levels of UVB radiation increased by 37 and 5% per year, respectively, between 1989 and 1993.[5] Fears and Scotto[3] have shown that the skin cancer incidence in the United States is increasing by about 3% per year, suggesting that an increase in harmful UVB radiation on earth increases the incidence of human skin cancer in the highly populated northern hemisphere, mainly among Caucasians. Miyaji[6] performed a statistical survey between 1956 and 1960 of the rate

of skin cancer in new patients attending dermatology clinics at university hospitals in Japan, and Tada and Miki[15] analyzed the disease rate between 1971 and 1975.

The present paper will report a recent survey of skin cancer patients at university hospitals in Japan in the 1976-80 and 1986-90 intervals. In order to evaluate the relationship between the rate of skin cancer and UV exposure, we measured UV doses with physical and biological dosimeters at several latitudes.

MATERIALS AND METHODS

Analysis of disease rate

The records of patients with squamous-cell carcinoma (SCC), basal-cell carcinoma (BCC) or actinic keratosis (AK) were surveyed in 27 university hospitals. The institutions that participated in this study are listed in Table 1. The age and sex of the patients and the diagnosis and site of the tumor were collected for the 1976-80 and 1986-90 intervals. In order to evaluate any change in disease rate between these two periods, age- and sex-standardized disease rates were calculated for each type of tumor by the direct method, using the populations in 1979 and 1989 as the standards for 1976-80 and for 1986-90, respectively. The analyses were as follows: the disease rate in each university hospital based on the total number of out-patients during each period: the disease rate per 100,000 population adjusted for age and sex during each period: and the rate of AK, BCC or SCC in northern and southern parts of Japan.

Measurement of solar UV dose

Physical UV dosimetry was performed at several locations using MS-210D (EKO Co., Japan) which measures fluence in mJ/cm^2 and Robertson-Berger (R-B) meter (Solar Light Co., USA) which measures sunburn unit (MED). Their spectral responses are shown Figure 1.

Table I. University hospitals that participated in the epidemiological survey.

University	City	Latitude
Sapporo Medical University	Sapporo	43° 4'
Hirosaki University	Hirosaki	40°36'
Tohoku University	Sendai	38°18'
Fukushima Medical College	Fukushima	37°48'
Niigata University	Niigata	37°54'
Shinshu University	Matsumoto	36°12'
Kanazawa University	Kanazawa	36°34'
Keio University	Tokyo	35°39'
Tokyo Medical and Dental University	Tokyo	35°39'
Nagoya University	Nagoya	35°10'
Nagoya City University	Nagoya	35°10'
Tokai University	Isehara	35°27'
Osaka Medical College	Takatsuki	34°54'
Kinki University	Sayama	34°54'
Kobe University	Kobe	34°41'
Osaka University	Osaka	34°41'
Okayama University	Okayama	34°36'
Hiroshima University	Hiroshima	34°30'
Nara Medical University	Kashihara	34°30'
Wakayama Medical College	Wakayama	34°12'
Tokushima University	Tokushima	34° 6'
Ehime University	Matsuyama	33°50'
Yamaguchi University	Ube	33°52'
Kurume University	Kurume	33°24'
Nagasaki University	Nagasaki	32°45'
Miyazaki Medical College	Miyazaki	31°54'
Ryukyu University	Naha	26°13'

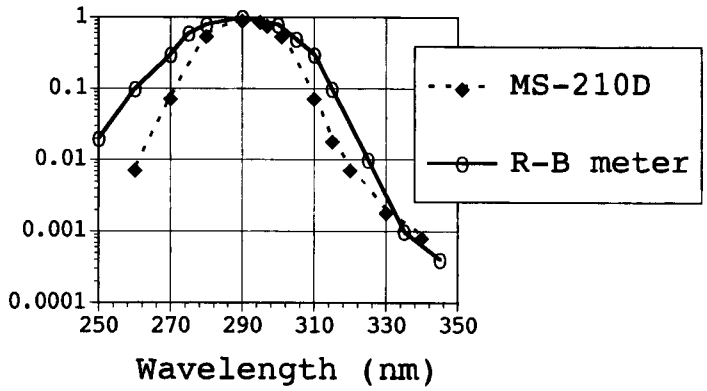

Figure 1. Spectral response of ultraviolet dosimeters used.

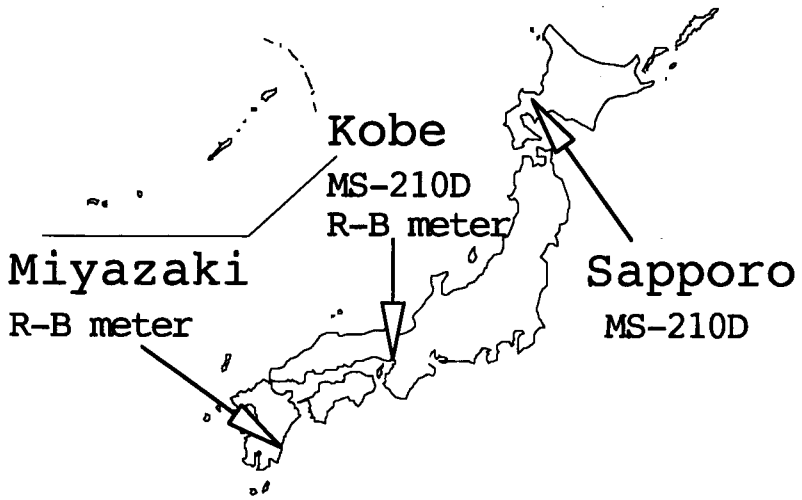

Figure 2. Locations of solar ultraviolet dosimeters used.

MS-210D meters were placed at Kobe and Sapporo and R-B meters at Miyazaki and Kobe (Figure 2).

UV doses at Miyazaki and Kobe were also measured biologically using spores of mutant *bacillus subtilis* strains.[7] Spore samples on a membrane filter (Millipore, GSW02500, pore size, 0.22 μm) were placed on a slide and then exposed to the sun near the locations of the physical dosimeters. After exposure, the center of the filter was cut out and placed in a test tube, to which 1 ml of water was added. The suspension was heated at 75 °C for 15 min, diluted appropriately in water and then pour-plated onto a medium consisting of Spizizen minimal agar[12] supplemented with casein hydrolysate enzymatic (ICN Pharmaceutical, 50 μg/ml), L-alanine (100 μg/ml), L-methionine (100 μg/ml), and L-leucine (100 μg/ml). After overnight incubation at 37 °C, the colonies were counted.[8,9] The inactivation dose (ID) was calculated as:

ID = -ln (no. of exposed colonies)/(no. of unexposed colonies)

In Kobe, dosimetry was performed from noon to sunset once a month in 1995 and 1996. In Miyazaki, dosimetry was performed from 9:00 am to noon on 13 March 1996.

RESULTS

Disease rate of SCC, BCC and AK

The rates of SCC, BCC and AK in university hospitals of Japan increase with decreasing latitude, except in Sapporo (Figure 3), and are higher in 1986-90 than in 1976-80 (Table 2). The rates of BCC and AK were significantly ($p<0.001$) higher in 1986-90 than in 1976-80, whereas the rate of SCC was not significantly lower in 1986-90. No significant differences were seen for unexposed body sites.

When the hospitals were divided into those in cities more than and less than 35 °N, the rates of all three types of skin tumors were higher in hospitals in the south than in the north of 35 °N

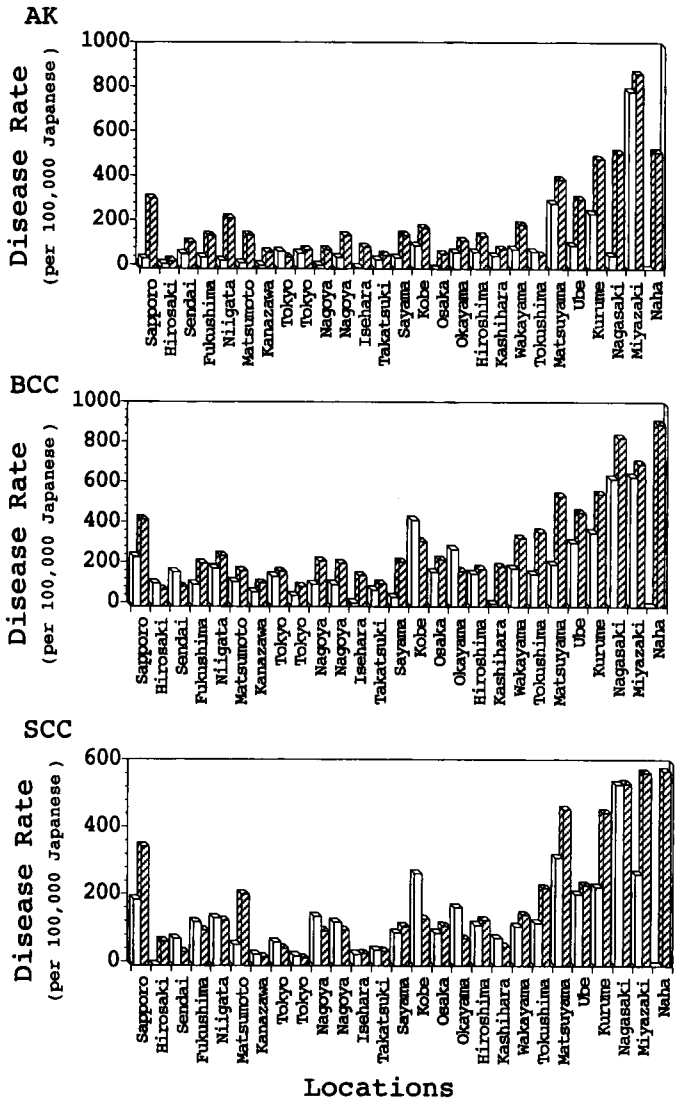

Figure 3. Rates of actinic keratosis (AK), basal-cell carcinoma (BCC) and squamous-cell carcinoma (SCC) in 27 university hospitals in Japan in 1976-80 (open columns) and 1986-90 (filled columns).

Table II. Rates of basal-cell carcinoma (BCC), squamous-cell carcinoma (SCC) and actinic keratosis (AK) on areas of the body exposed and unexposed to the sun in two periods (per 100,000 Japanese).

Body Sites	Period	BCC	SCC	AK
exposed[a]	1976-80	197.8	126.1	77.8
	1986-90	227.6	111.4	140.5
unexposed	1976-80	16.3	27.0	———
	1986-90	19.0	17.1	———

a: Face, neck, hand, forearm

Table III. Rates of basal-cell carcinoma (BCC), squamous-cell carcinoma (SCC) and actinic keratosis (AK) in hospiatals in cities >35 °N and <35 °N latitude in two periods (per 100,000 Japanese).

Skin cancer	Hospitals >35 °N		Hospitals <35 °N	
	1976-80	1986-90	1976-80	1986-90
BCC	163.3	178.1	174.4	232.2
SCC	101.4	95.0	117.3	115.4
AK	55.1	109.9	86.7	142.8

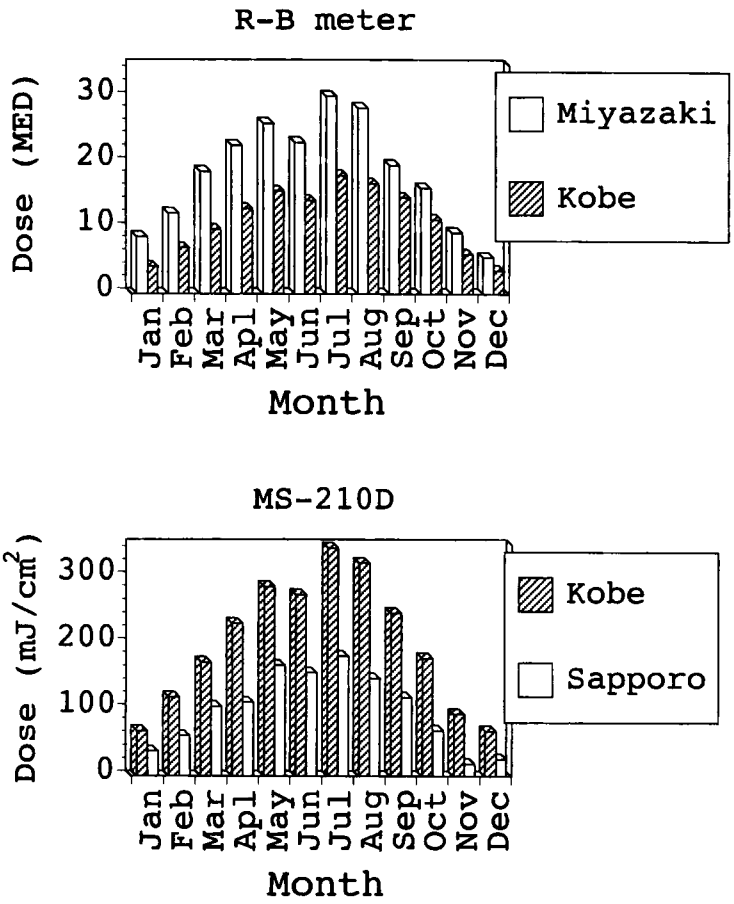

Figure 4. Geographical and monthly differences in daily ultraviolet dose in 1995 in Japan.

(Table 3). Significantly higher rates of BCC and AK were again found in 1986-90 than in 1976-80, while that of SCC was not significantly lower in the later period. The rates of all three types of skin tumors were five times higher in the Kyushu area (Kurume, Nagasaki and Miyazaki) in the southern part of Japan than in the northern Tohoku area (Hirosaki, Sendai and Fukushima).

Measurement of UV dose

The average daily UV dose measured by R-B meters in 1995 in Miyazaki was about 1.8 times higher than that in Kobe, and that measured by MS-210D meters in Sapporo was about 0.53 times lower than that in Kobe (Figure 4). Physical dosimeters can detect seasonal and daily changes (in Figure 4) in UV radiation. When measured in Kobe, 1 MED on the R-B meter equals 19.2 mJ/cm^2 on the MS-210D meter.

The biologically effective UV dose measured in Kobe and in Miyazaki were similar to the physical dosimetric values. An inactivation dose (ID) of 7.55 in *bacillus subtilis* is equal to 1 MED on the R-B meter (Figure 5).

DISCUSSION

Critical ozone depletion and increased UV radiation due to the release of chlorofluorocarbons (CFCs) have been reported since the early 1970s. It has been suggested that if depletion of the ozone column is not halted, skin cancer incidence in the USA will quadruple around the year 2100.[11] The present study has indicated that the age- and sex-standardized rates of BCC and AK in university hospitals in Japan were increased in 1986-90 than in 1976-80. A slight decrease, although not significant, in SCC may be due to detection of SCC at an early stage, such as AK, owing to widespread information about skin cancer. Munakata[10] reported an upward trend in solar UV in Tokyo between 1980 and 1990 that was sufficient to kill spores of *bacillus subtilis*. It is very likely that a

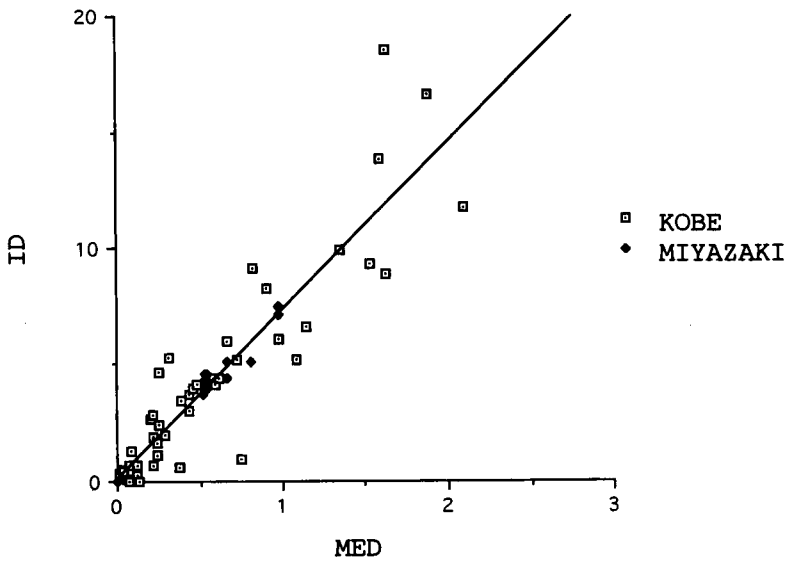

Figure 5. Correlation between inactivation dose (ID) in *bacillus subtilis* and ultraviolet dose (MED) by R-B meter.

significant increase of BCC and AK shown in this study may be due to increasing UV dose in Japan. Increased exposure to the sun during leisure activities and greater concern about skin cancer among the public and dermatologists may also have influenced these findings.

The rates of BCC, SCC and AK were significantly higher in the southern part of Japan than in the northern part. The ratio of disease rates for Kyushu to Tohoku each three hospitals was nearly five. As well, the ratio of solar UVB dose for Miyazaki to Sapporo was about 3.4 (Figure 4). The ratio of AK rates in the earlier and later periods was higher in the northern part than in the southern part (1.99 vs. 1.65). This may arise from a significant loss of the ozone column in the north, as reported by Stolarski et al.,[14] who showed a smaller loss of ozone column at median latitudes, a larger loss at high latitudes, and no loss near the equator.

We performed a nationwide UV dosimetry at biological effective wavelengths using MS-210D and R-B meters. Similar dosimetry was performed by the Japan Meteorological Agency using a Brewer instrument, which measures wavelengths between 280 nm and 325 nm. The average UV dose in Kagoshima was about twice of that in Sapporo (data of the Ozone Layer Monitoring Office). This value is lower than ours of a 3.4-fold difference between Miyazaki and Sapporo, probably because they analyzed a wider range of UVB dose (290-315 nm) than we did (280-300 nm). The ratio of physical and biological dosimetry values were similar in Miyazaki and Kobe, suggesting that our physical dosimeters which are sensitive to 280-300 nm UVB can monitor more efficiently the biological effect of solar UV than the Brewer instrument can.

The increasing trend of the rates of BCC and AK in 1986-90 suggests that skin cancers among Japanese will increase significantly if ozone depletion continues over the next few decades, even if the lifespan of Japanese reaches a plateau within a few years.

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