Skin Cancer, Melanoma, and Sunlight

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Abstract: Recent theoretical studies suggest that the earth's ozone layer which filters ultraviolet radiation may be depleted by a fleet of supersonic transports or by continued use of chlorofluoromethanes. It is now generally accepted that short wavelength ultraviolet radiation leads to the development of skin cancer. In this report we demonstrate an approach to estimating the increase in skin cancer incidence associated with increases in ultraviolet radiation. The purpose is to demonstrate the logic used and the assumptions that must be made when such estimates are made or cited. We emphasize that such estimates should be considered crude until the many assumptions can be investigated. (Am. J. Public Health 66:461–464, 1976)

Introduction

Surrounding the earth is a small amount of ozone, equivalent in mass to a layer at sea level only a few millimeters thick.[1] Despite its small thickness, this stratospheric ozone layer is vital, for it blocks much ultraviolet radiation from reaching the earth's surface. Recent theoretical studies have suggested that the ozone layer is in danger of being depleted. Estimates of the reduction due to a fleet of supersonic transports which cruise well into the stratosphere vary from .07 per cent for a small fleet[2] to 50 per cent for a fleet of 500.[3] A second danger is posed by the use of chlorofluoromethanes which theoretically can release chlorine into the stratosphere to combine with ozone.[4] Resultant reductions in ozone concentrations could be as large as 16 per cent by the year 2000 if Freon usage were to increase at 10 per cent per year.[5]

Clinicians and researchers alike believe that sunlight, and in particular short wavelength ultraviolet (erythema producing), leads to the development of human skin cancers in Caucasians. In this report we accept the evidence that short wave ultraviolet radiation causes skin cancer.[6–11] Using elementary models to analyze data recently collected by the National Cancer Institute, we demonstrate an approach to estimating the possible size of the increase in skin cancer incidence associated with small increases in ultraviolet radiation. Our purpose is to provide a general understanding for public health workers of the logic used and assumptions that must be made when such estimates are made or cited.

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The Data

The common types of malignancy of the skin are basal cell and squamous-cell carcinomas (nonmelanomas). Since these cancers are usually successfully treated in physicians' offices, they are often missed in the standard methods for case accrual in cancer registers, which depend heavily on hospital records. A special skin cancer incidence survey was therefore undertaken as part of the Third National Cancer Survey (TNCS).[12] This special survey was conducted in four TNCS areas and the results were given by Scotto et al.[13] The data was unique in that the survey was conducted over a broad range of latitude using a standard comprehensive procedure. Incidence rates for nonmelanoma skin cancer were found to be two to three times higher than those previously reported for the same areas. Nonmelanoma skin cancer is by far the most frequently occurring malignancy and therefore represents an important health care problem.

The frequently fatal but far less common form of skin malignancy (melanoma) is most often treated in hospitals so that the usual methods of case accrual for cancer registers can be considered satisfactory. Melanoma incidence rates for nine areas of the United States were obtained as part of the TNCS for the three year period 1969–71. While cancer morbidity surveys such as the TNCS are not conducted often, mortality data are routinely obtained and widely available. We use here the age adjusted mortality rates for the United States as given in Mason and McKay[14] as well as the nonmelanoma and melanoma incidence rates described above.

The Model: Skin Cancer and Latitude

Figures 1 and 2 show nonmelanoma incidence, melanoma incidence, and melanoma mortality plotted against latitude for white males and white females respectively. The response data are plotted on a log scale so that a straight line with a negative slope represents a constant percentage decrease. That is, we take as our model, $\log R = \alpha + \beta L$ where R is the age adjusted rate; α and β are real numbers; and L is latitude. The number α can be interpreted as an arbitrary base response and the number β as the change in log rate associated with a move of one degree latitude. We use this model because it allows us to consider the difference in latitude associated with a 100 per cent increase in the morbidity or mortality rate without reference to a specific latitude. One might with equal agreement to the data choose a linear model and express a latitude increment that would correspond to a

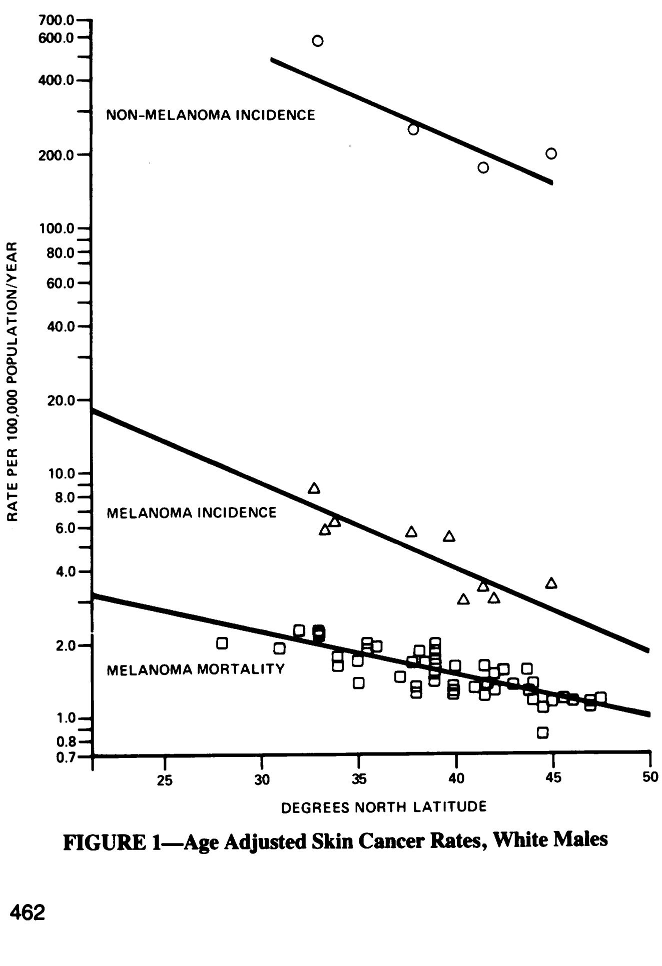

FIGURE 1—Age Adjusted Skin Cancer Rates, White Males

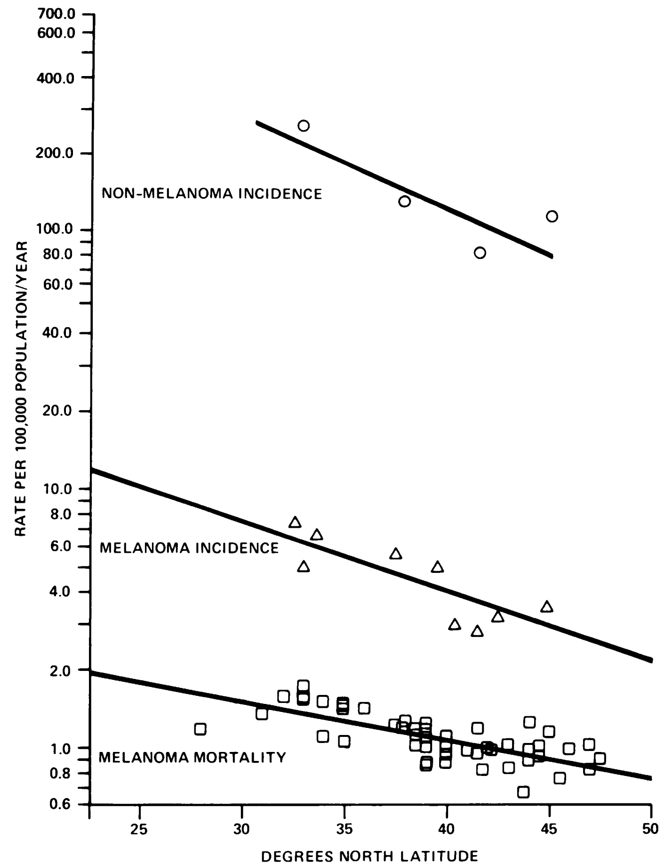

FIGURE 2—Age Adjusted Skin Cancer Rates, White Females

unit increase in risk independent of starting latitude.

With observations on only four areas, conclusions about nonmelanoma incidence cannot be precise. The individual regression slopes for males and for females are not statistically significant ($p > .05$). The individual regression coefficients for melanoma incidence are significant ($p < .01$) even though these regression lines are not so steep as for nonmelanomas. As expected, the more easily obtained and more broadly based melanoma mortality data show a latitude-response relationship similar to that of the incidence data. The observed slopes are less steep than those of melanoma incidence but the difference is not significant at the .05 significance level so may be ascribed to chance. If the less steep slope observed for melanoma mortality is not a chance finding, it may be a result of more effective control, diagnosis, and treatment, in areas of higher incidence. Table 1 summarizes the regressions of incidence and mortality rates on latitude including a doubling latitude which we define as the change in latitude associated with a two-fold increase in risk.

The Model: Sunlight and Latitude

Complex calculations must be performed to determine the geographic distribution of ultraviolet radiation and by

TABLE 1—Summary Statistics for Regressions of Skin Cancer Incidence and Mortality on Latitude

	MALES			FEMALES		
	Correlation Coefficient*	Regression Slope ± S.D.	Doubling Latitude	Correlation Coefficient*	Regression Slope ± S.D.	Doubling Latitude
Non-Melanoma Incidence	−.89	−.037 ± .013	− 8.1°	−.83	−.033 ± .016	− 9.2°
Melanoma Incidence	−.86	−.031 ± .007	− 9.8°	−.83	−.028 ± .007	−10.7°
Melanoma Mortality	−.81	−.017 ± .002	−19.9°	−.71	−.014 ± .002	−21.2°

*Simple correlation coefficient of log rate and latitude

how much ultraviolet radiation would increase if the thickness of the ozone layer were reduced. Basic to these calculations is the thickness of the ozone layer which varies by time of year as well as latitude; the extent to which the ultraviolet radiation is scattered by the molecules of the atmosphere; and the elevation of the sun.

We have obtained, from computations and graphs of Schulze,[1] estimates of the monthly totals of erythema-producing ultraviolet light, measured in "Biologically Effective Units" (BEU), for thirty-five locations around the world. These calculations are based on the distribution of ozone above the earth. To obtain radiation dose in BEU's Schulze weighted calculated doses of ultraviolet radiation (in mWh/cm^2) at representative wavelengths from the interval 295nm to 325nm with their erythema effectiveness relative to 295nm and summed. That is, summing over wavelengths,

$$\Sigma \text{ (UV dose} \times \text{erythema effectiveness)} = \text{Dose in BEU}$$

The sum of all twelve monthly doses will be called here the "total dose".

In Figure 3 we have plotted the theoretical total dose against the latitude for each of 33 locations in the northern hemisphere. Considering all locations, the simple correlation coefficient is .97 and the regression coefficient is significant ($p < .005$). The strong linear relationship between total dose and latitude has led us to use total dose, without transformation, as our dose metameter. In what follows, we use as our "exposure dose" the theoretical total of short wave ultraviolet radiation, as obtained by the simple relationship to latitude shown in Figure 3 and represented by: (total dose) = 2261.40 – 33.39 (north latitude).

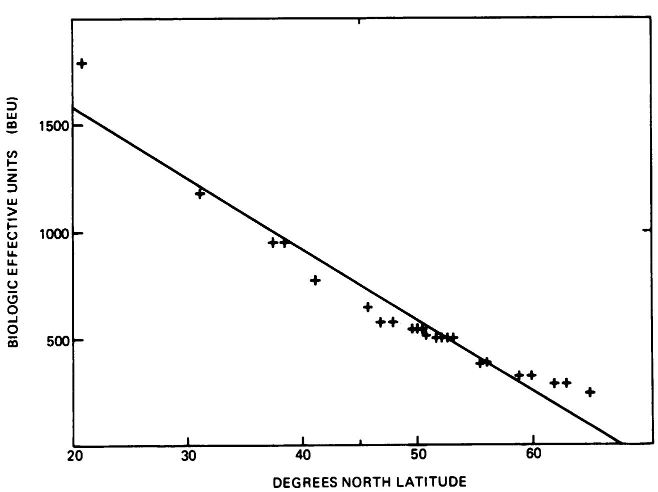

FIGURE 3—BEU by Latitude in Northern Hemisphere

The Results

In his theoretical study of carcinogenic ultraviolet radiation, Schulze[1] calculated that if the ozone concentration in the stratosphere were reduced by 10 per cent, the total ultraviolet radiation dose would be increased by 19 per cent in the middle latitudes (40° N to 60° N) and by 22 per cent in the Equatorial zone (30° S to 30° N).

In Table 2 we provide estimates of the relative effect (that is, percentage change) on skin cancer incidence and mortality by increases in radiation dose of 10 per cent to 30 per cent and representative 95 per cent confidence intervals. The estimates are based on the exponential models obtained from each of the previously discussed primary data sources and are made for base exposures of 650, 850, and 1050 BEU's. These exposures correspond roughly to those of the states at the latitudes of North Dakota, Iowa, and Oklahoma respectively. A 10 per cent increase in maximum month BEU for white males in Iowa, estimated on the basis of the U.S. data and models corresponds to 49.7 additional cases of nonmelanoma skin cancer per 100,000, .69 additional cases of melanoma per 100,000, and .13 additional deaths from melanoma per 100,000. The estimated increases are larger for nonmelanoma than for melanoma, larger for men than for women, and larger for incidence than for mortality. Because of our choice of models, the estimates also indicate that the absolute effect of increases in total dose would be substantially greater in those areas where exposure (and incidence) is now greatest.

Summary and Discussion

Relations used to make the estimates are:

a. Total dose increases with decreasing latitude;
b. Latitude decreases with increasing incidence;
c. Latitude decreases with increasing mortality.

The assumptions employed are:

a. Short wave ultraviolet is a cause of both melanoma and nonmelanoma skin cancer;

TABLE 2—Estimated Relative Increases in Skin Cancer Incidence and Mortality Associated with Changes in Erythema Dose**

	MALES			FEMALES		
	Increase in Total Dose			Increase in Total Dose		
	10%	20%	30%	10%	20%	30%
Non-Melanoma Incidence						
650 BEU	18% (−8,52)†	39%	64%	16%	34%	56%
850	24	54 (−20,197)†	92	21	47	79
1050	31	71	123*(−34,653)†	30	69	119*
Melanoma Incidence						
650	15 (7,24)†	32	52	13	29	46
850	20	44 (18,75)†	72	18	39	64
1050	25	57	96*(37,180)†	22	50	84*
Melanoma Mortality						
650	8 (6,10)†	16	26	6	13	21
850	10	22 (16,28)	35	9	18	28
1050	13	28	45 (33,58)†	11	22	36

*These estimates require extrapolation well beyond the range of the data.
**A sample computation is outlined:
A 10% increase in total dose at 48.25° N, where exposure is 650 BEU, equals 65 BEU
A change of 65 BEU is equivalent to a reduction in latitude of 1.93°
A change of 1.93° at 48.25° N is associated with an 18% increase in nonmelanoma incidence
†95% confidence intervals.

b. The carcinogenic action spectrum and the erythema action spectrum are roughly the same;
c. The total dose is the appropriate dose metameter;
d. The theoretical model of Schulze for UV is correct;
e. An exponential model of the dose response relationship is appropriate,
f. Other etiologically important variables may be ignored.

The available skin cancer data from the National Cancer Institute provide an estimate of increases in skin cancer that could result from reductions in atmospheric ozone. We emphasize that the assumptions employed to make such estimates can be altered in many reasonable ways.[2] Present estimates should be considered crude until the many assumptions such as those relating to problems of ethnic origin, internal migration in the United States, cloud cover, smog, and other possible distorting factors can be investigated.

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