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Rapid Communication

UV Doses of Young Adults¶

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ABSTRACT

Since 1986, people have been informed that they get about 80% of their lifetime ultraviolet (UV) dose by the age of 18. This belief originated from the mathematical conclusion that diligent use of sunscreens (sun protection factor 15 or higher) during the first 18 years of life would reduce the lifetime incidence of nonmelanoma skin cancers by 78%. These data were misconstrued to mean that individuals also got about 80% of their lifetime dose of UV by the age of 18 (linear relationship). However, these calculations were based on the incidence of nonmelanoma skin cancers being related to the square of the UV dose. Careful analysis of UV exposure data shows that Americans actually get less than 25% of their lifetime UV dose by the age of 18. This finding also appears to be true worldwide because Australia, UK and The Netherlands report a similar UV exposure pattern. UV-initiated damage early in life can be promoted by subsequent exposures to progress into tumors later in life. For example, the nonmelanoma skin cancer, squamous cell carcinoma, is dependent on the cumulative UV dose. Thus, a better educational approach for reducing skin cancers would be to instruct fair-skinned individuals to protect themselves throughout their lives from being exposed to too much UV radiation.

INTRODUCTION

Ultraviolet (UV) radiation affects health (1). It causes photoaging (2), eye diseases (3), sunburn (4), tanning (5), immune suppression (6–8), DNA mutations (8,9) and cancers (10–13). Of all the cancers, skin cancers are the most commonly diagnosed. Over one million new cases of nonmelanoma and melanoma skin cancers are now reported each year in the United States alone (14). The UV dose received by skin cells can be reduced by the use of sunscreens: this reduction depends not only on the formulation, *i.e.* UVB-absorbing (280–315 nm) and UVA-absorbing (315–400 nm) chemicals (15–17), but also on the sun protection factor (SPF). However, laboratory test conditions usually yield higher SPF than those obtained in practice because individuals apply a lesser amount of sunscreen to their skin than what is used to establish the SPF (18,19). Sunscreens, sunglasses, protective clothing and gear such as hats and umbrellas, and shade-seeking behavior have been the recent thrust in educational efforts that primarily emphasize protecting young adults from too much UV exposure.

This public message was based on mathematical calculations that assumed young adults got three times the outdoor UV dose as older adults and that the incidence of skin cancer increased by the square of the UV dose (20). From these assumptions, it was calculated that if young adults were protected by a sunscreen of SPF 15 or higher during the first 18 years of their life, the incidence of them developing nonmelanoma skin cancers would be reduced by 78% (20). This finding was misinterpreted to mean that a person also got about 80% of their lifetime UV dose by the age of 18 because it was assumed that the incidence of nonmelanoma skin cancer was linearly related to the UV dose. Although this situation might apply to melanoma, where the "effective" UV dose was once thought to be more important in one's earlier years of life (21), it does not apply to nonmelanoma skin cancer, squamous cell carcinoma (SCC). Unfortunately, it is possible that this belief may have contributed toward increasing the incidence of skin cancers, which has been increasing at the rate of 4–5% annually and has now reached a stage where over a million new cases are reported every year in the United States. This may have occurred because adults assumed that they no longer had to worry about getting too much UV exposure because they were told that most of the damage was done before 19 years of age.

We now have the calculated UV doses of Americans based on their daily outdoor activity profiles (22,23). From these data, we calculated the cumulative seasonal, annual and lifetime UV doses of individuals in the northern and southern United States, along with the percentage of the lifetime UV doses received by individuals who were 18, 40 and 59 years old. We find that individuals only get about 23% of their lifetime UV dose by the age of 18. They get about 46% by the age of 40 and about 74% by the age of 59, assuming that they live up to the age of 78. Using the calculated UV doses for Americans, we show that individuals get

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Abbreviations: SCC, squamous cell carcinoma; SPF, sun protection factor; UV, ultraviolet.

Table 1. Average UV dose/season/year for individuals 1–18 years of age, and cumulative seasonal, annual and lifetime UV doses (kJ/m^2) for different age intervals of females and males in northern United States

	1–18 years*	1–18 years†	19–40 years‡	41–59 years‡	60–78 years‡	Lifetime UV dose 1–78 years
Females						
Fall	2.7	45.9	35.63	27.16	35.50	143.74
Winter	1.0	17.0	15.72	12.35	16.90	63.73
Spring	4.6	78.2	109.28	108.24	92.65	388.57
Summer	10.1	171.7	146.83	214.33	226.37	760.11
Cumulative annual total	18.4	312.8	307.46	362.08	371.42	1356.15
Males						
Fall	3.2	54.4	64.56	69.77	80.88	271.36
Winter	0.9	15.3	20.82	20.01	27.49	83.13
Spring	6.2	105.4	106.76	149.85	145.91	508.16
Summer	11.1	188.7	192.03	270.63	183.21	843.52
Cumulative annual total	21.4	363.8	384.18	510.26	437.49	1706.18

*Average seasonal UV doses/year for individuals 1–18 years of age from Godar (23).
†Cumulative seasonal UV doses for different age intervals calculated using data from Godar (23) and Eq. (1) (see Materials and Methods). These values exclude vacations and assume that no UV exposure occurred before the age of 1.
‡Cumulative seasonal UV doses for different age intervals were calculated using Eq. (1) (see Materials and Methods) and data from Godar *et al.* (22). These values exclude vacations and assume that no UV exposure occurred before the age of 1.

about the same annual UV exposure regardless of their age, although older men (40+) tend to get higher UV doses.

UV-initiated cellular damage early in life can be promoted by subsequent exposures to convert and progress into tumors later in life. For example, the nonmelanoma skin cancer, SCC, is known to be dependent on the cumulative UV dose. Thus, our educational efforts should now be redirected from primarily concentrating on protecting young adults to protecting fair-skinned individuals of all ages throughout their lives from being exposed to too much UV radiation.

MATERIALS AND METHODS

We used the erythemally weighted (24) outdoor UV doses of Americans (22,23) from the mid 1990s to calculate the seasonal, annual, age interval and lifetime UV doses of females and males living in northern and southern United States as shown in Tables 1 and 2, respectively. Equation 1 was used to obtain the seasonal cumulative age-interval UV doses

$$\text{UV cumulative seasonal dose}_{(\text{age interval})} = \int_{a_1}^{a_2} \text{UV}_{(\text{seasonal dose/year})}\partial a \quad (1)$$

where a_1 is the younger age and a_2 is the older age of the age-interval group, and $\text{UV}_{(\text{seasonal dose/year})}$ is the average solar UV dose of each age-interval group for a particular season in an average year. The UV cumulative seasonal $\text{dose}_{(\text{age interval})}$ is the total UV dose obtained for a particular season during a given age interval. Annual UV doses are then used to get the cumulative annual UV dose for an age interval and for an entire lifetime (78 years). The corresponding cumulative lifetime percentages are shown in Table 3.

Note that these outdoor UV doses do not include vacation doses because they vary too much from person to person and from year to year. A conservative estimate of an average vacation dose in the continental United States (7.8 kJ/m^2) increases an American's UV dose from 25 to about 33 kJ/m^2/year. However, this increase does not change the percentages of one's lifetime UV dose at any age because it must be

Table 2. Average UV dose/season/year for individuals 1–18 years of age, and cumulative seasonal, annual and lifetime UV doses (kJ/m^2) for different age intervals of females and males in southern United States

	1–18 years*	1–18 years†	19–40 years‡	41–59 years‡	60–78 years‡	Lifetime UV dose
Females						
Fall	4.3	73.1	78.99	67.64	72.15	292.39
Winter	1.0	17.0	33.74	28.04	31.99	111.36
Spring	7.59	129.03	125.29	167.90	117.98	541.67
Summer	11.2	190.4	200.66	202.85	223.83	823.50
Cumulative annual total	24.09	409.53	438.69	466.43	445.95	1768.93
Males						
Fall	6.35	107.95	111.44	116.46	131.03	468.05
Winter	2.48	42.16	45.45	61.53	71.25	221.39
Spring	11.62	197.54	150.77	220.01	191.32	760.60
Summer	10.88	184.96	230.12	237.95	225.77	874.52
Cumulative annual total	31.33	532.61	537.78	635.96	619.37	2324.56

*Average seasonal UV doses/year for individuals 1–18 years of age from Godar (23).
†Cumulative seasonal UV doses for different age intervals calculated using data from Godar (23) and Eq. (1) (see Materials and Methods). These values exclude vacations and assume that no UV exposure occurred before the age of 1.
‡Cumulative seasonal UV doses for different age intervals were calculated using Eq. (1) (see Materials and Methods) and data from Godar *et al.* (22). These values exclude vacations and assume that no UV exposure occurred before the age of 1.

Table 3. Actual cumulative percentage of lifetime UV dose of an average American and the percentage of lifetime UV doses during different age intervals for females and males in northern and southern United States*

Sex	1–18 years	19–40 years	41–59 years	60–78 years
Northern females	23.20	24.51	24.81	27.48
Northern males	21.49	22.65	30.08	25.79
Southern females	23.33	24.90	26.47	25.31
Southern males	22.90	23.12	27.34	26.63
Average percentages	22.73	23.8	27.18	26.3
Cumulative age percentage	22.73	46.53	73.71	100

*These percentages were obtained from the cumulative UV doses in Tables 1 and 2, which excluded vacations, for each age interval, assuming that no UV exposure occurs before the age of 1.

assumed to be constant throughout an individuals's life. Furthermore, the outdoor UV doses do not account for any indoor UV exposures, such as those from tanning beds, fluorescent lights, halogen lamps or medical treatments. These calculated annual UV doses are primarily received by the face, hands and wrists of an individual throughout the year (on a horizontal plane).

RESULTS

Excluding vacations, the cumulative erythemally weighted lifetime UV doses (kJ/m^2), stratified by sex, season and age (1–18, 19–40, 41–59 and 60+), of northern and southern Americans in the United States (22,23) are shown in Tables 1 and 2, respectively. Because almost no UV exposure occurs before the age of 1 (25), we started the calculations at age 1. The lifetime UV doses for indoor workers (about 95% of the U.S. population) are about 1400 and 1700 kJ/m^2 for northern females and males, respectively, and 1800 and 2300 kJ/m^2 for southern females and males, respectively. Females get lower lifetime UV doses than males, and some northern females get half the lifetime dose that some southern males get. Females show a rather consistent UV dose profile throughout their lives, whereas males over the age of 40 have increased outdoor activities and consequently increased exposure to UV. In the continental United States, southwestern men over the age of 40 get the highest UV doses. UV doses for both males and females decrease during the child-raising or child-bearing years of life (19–40 years). Surprisingly, it is adults over the age of 40, *i.e.* 41–59 and 60+ years, especially men, who get the highest UV doses. The cumulative seasonal doses show that individuals usually get their highest UV doses in summer followed by spring, fall and winter.

An individual actually gets less than 25% of his or her cumulative lifetime UV dose by the age of 18, excluding his or her first year of life (Table 3). Even if the first year of life and the years from 19–21 are included (0–21 years), all the percentages for females and males in the North and South are still below 30% of one's lifetime solar UV dose by the age of 21 (D. E. Godar *et al.*, unpublished). An individual gets about 23, 46 and 74% of his or her lifetime UV dose by the age of 18, 40 and 59, respectively. The average American gets about 80% of his or her lifetime dose of UV by the age of 60, if he or she lives up to the age of 78.

DISCUSSION

Since 1986, people have been informed that they get about 80% of their lifetime UV dose by the age of 18. Misinterpretation of published data (20) initiated this belief, and it is still being

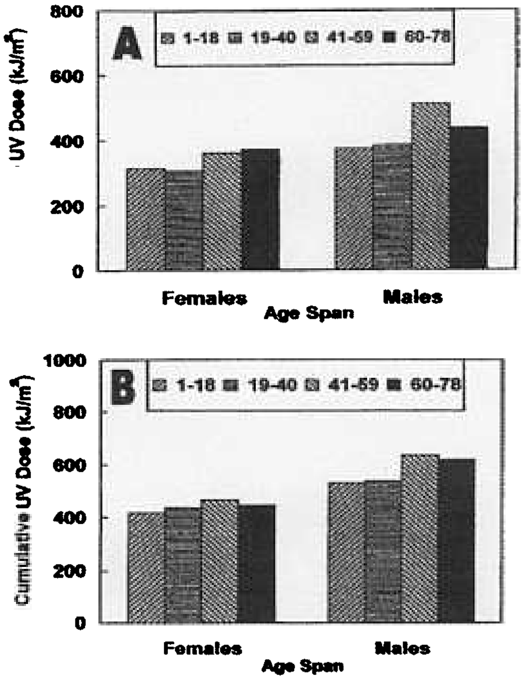

Figure 1. Actual cumulative UV doses (kJ/m^2) of indoor workers for different age intervals, excluding vacations. A: Northern females and males in the United States. B: Southern females and males in the United States. Values were obtained using Eq. (1) (see Materials and Methods) and data from Godar *et al.* (22) and Godar (23).

propagated (14). It has also spread worldwide—this information is imparted through some Internet sites (14). However, several recent studies with actual UV exposure data disprove this belief (22,23,25–30), and this study shows that Americans get fairly consistent UV doses during different age intervals throughout their lives (Figs. 1a,b, and 2). Calculations based on the outdoor UV doses of Americans (22,23) show that young adults (1–18 years) get less than 25% of their lifetime UV dose by the age of 18 (Fig. 2). Similar UV exposure patterns have recently been found in technologically oriented countries around the world (25–32).

It is important to explain the origin and propagation of this belief about young adults being exposed to large doses of UV. What was actually calculated was the reduction in the incidence of nonmelanoma skin cancers (20). Others misinterpreted these data to indicate that the same reduction occurred in one's lifetime UV dose (linear relationship). This was a huge mistake, because in these published calculations the incidence of skin cancer was assumed to increase by the square of the accumulated UV dose. Thus, if the incidence decreases by 78%, *i.e.* from 1.00 to 0.22, then the accumulated dose decreases to $\sqrt{0.22}$, or 0.47 (about half). Even after taking into account this misinterpretation, there are still large discrepancies among the data. We calculated the accumulated outdoor UV dose of individuals between the ages of 1 and 18 as 23% of the total lifetime dose. That is about half as much as what was previously calculated. This striking difference is attributed to the terrestrial model used for these calculations, which assumed heavier weighting toward doses received earlier in life (assumed that young adults got 3 times more UV than the average adult). In addition, a dramatic change in our culture occurred with the advent of the technological revolution. Along with television, electronic game devices, computers and the Internet are now

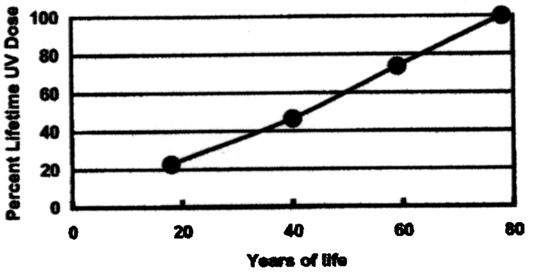

Figure 2. Average cumulative percentages of an individual's lifetime UV dose for different ages. On the basis of actual averaged U.S. data, *i.e.* the females and males in the North and South were averaged together.

available to motivate young adults to stay indoors during the daylight hours more than ever before. Apparently, it is true that young adults have decreased their UV exposures in this new era (1990s) because of this "technological sunscreen," but without previous measurements, we cannot be sure how much of a decrease has actually occurred. The previously calculated percentage apparently does not apply to melanoma either because although it was once believed that young adult UV doses contributed more toward its induction, this belief has also been recently challenged (33,34).

Because ozone depletion has increased the terrestrial levels of UVB over recent decades (35,36), it is now extremely important to also increase the public's awareness about the health risks associated with exposure to too much UV radiation. It is possible that this misinterpretation about young adult exposures may have contributed toward increasing the incidence of skin cancers because adults thought it was too late to do anything about their situation. However, UV-initiated damage early in life can be promoted by subsequent UV exposures to form tumors later in life, if one continues to be exposed to too much UV radiation. For example, the nonmelanoma skin cancer, SCC, is known to be dependent on the cumulative UV dose. Thus, educational efforts should now concentrate on teaching fair-skinned individuals to protect themselves throughout their lives from being exposed to too much UV radiation.

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