Sun Exposure Measurements in Populations

Margaret A. Tucker, MD

Measuring ultraviolet (UV) exposure in human populations is a complex task. The dominant source of ultraviolet radiation for humans is sunlight, which is always a mix of both ultraviolet A (UVA, usually 320–400 nm) and ultraviolet B (UVB, 320–280 nm). Ultraviolet C (<280 nm) is filtered by the atmosphere and does not reach the earth's surface. Researchers cannot separate the individual effects of the different wavelengths in humans as can be done in experimental animals. For some subpopulations, such as welders and those who use artificial UV sources for tanning, exposures other than sunlight may contribute to the total individual dose. In epidemiologic studies in which sun exposure is estimated, the usual end point is skin dose. The major acute toxicities of sun exposure are photosensitivity reactions and sunburn; chronic toxicities include melanoma, non-melanoma skin cancers, cataracts, and photo-aging of the skin.

Two major methodologies for estimating sunlight exposure have emerged: "geographic" estimates and personal, individual estimates. Geographic estimates of ground-level exposure must take into account latitude, altitude, day of year, time of day, cloud cover, ozone, particulates, smog, and reflectance from water, rock, or sand. All of these cofactors have important influences on the actual ground-level measurements. Several US agencies have had on-ground measurement devices in place for varying times. The National Cancer Institute (NCI) and the National Oceanic and Atmospheric Administration (NOAA) collaborated on placing Robertson-Berger meters, spectrometers measuring on-ground UVB flux, in areas with cancer registries. These meters were in place for extended periods of time. The limitations include only UVB measurements and yearly calibration of the instruments.[1] These data have been used in analyses of risk of non-melanoma skin cancer and melanoma.[1,2] The Environmental Protection Agency (EPA) had 21 multispectral (286.5–363 nm in 0.5 nm steps) Brewer meters spread over the United States in place for several years. The system is not functional now, but data are available for use.[3] The US Department of Agriculture (USDA) has 37 monitoring stations in 29 states, Canada, and New Zealand. These, too, are multispectral, but are focused on UVB. Most are placed in rural agricultural areas, since the major end point for these measurements is the effect of UVB on crops.[4] This system was initiated in the mid-1990s. NOAA has six stations in the western, central, and eastern United States with Brewer meters in place since late 2006.[5] Data are also available from these stations.

In addition to these on-ground measurement systems, NASA provides Total Ozone Mapping Spectrometer (TOMS) satellite data with on-ground estimates. The advantage of the TOMS data is that there is superior coverage from 180 degrees E to 180 degrees W and 65 degrees N to 65 degrees S from 1978–1993. The disadvantage is that the estimates cannot take into account cofactors that alter the ground measurements. One study compared TOMS estimates with on-ground measurements and found agreement within 12% overall, which improved with clear skies (within 8%). Based on measurements in two not very urban areas (Billings, OK and Las Cruces, NM), the effect of aerosols was less than 5%, but would likely be higher in more congested areas.[6]

In addition to the geographic measures, personal dosimeters have also been developed. Polysulfone badges have been used for over a decade. They are calibrated to erythemal-weighted UVB and measure total dose over a specified time period. Placement of the badges is crucial because the topography and movement of a human being determines the total exposure.[7] A major advantage of these badges is that they are easy to use and relatively inexpensive, making them feasible for moderate-sized studies. Multispectral dosime-

Dr. Tucker is with the Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rockville, Maryland, USA.

Please address all correspondence to: Dr. Margaret Tucker, Director, Human Genetics Program, Chief, Genetic Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, 6120 Executive Blvd., Room 7122, Bethesda, MD 20892-7236, USA; Phone: 301-496-4375; Fax: 301-402-4489; E-mail: tuckerp@mail.nih.gov.

doi: 10.1301/nr.2007.aug.S84–S86

ters are also available in multiple handheld or attachable models and can record temporal patterns of exposure. Again, placement is crucial. Electronic recording dosimeters are relatively expensive and not feasible yet for population-sized investigations. Both of these approaches can be used for estimating current exposure, but for historical exposures, questionnaire data are necessary.

Personal estimates of sun exposure are complex to capture by questionnaire for several reasons. Questionnaires often elicit information over specific periods of life, and respondents tend to average their routine daily experience to the best of their ability. Their exposure varies by behavioral patterns, such as seeking shade when outdoors, or using sunscreens or protective clothing. Host factors also impact exposure patterns: individuals who tan well tend to spend more time outdoors than individuals who do not tan.[2] Personal sun exposure is frequently assessed by asking about an individual's number of severe (blistering) sunburns, the number of hours spent outdoors (often including time of day, time of year, age at exposure, use of sun-protective measures, and patterns of exposure) either recreationally or at work, and places of residence. The reproducibility of these measures has been evaluated in several studies, from 6 months to 5 years after the initial interview (T.R. Fears, personal communication).[8,9] The results of the studies were similar: the occupational component of time outdoors appeared more reproducible than the recreational component, sunburns were moderately reproducible, and residential history reproducibility was excellent. Correlations between exposure diaries or observers and polysulfone badge estimates was also pretty good depending on the activity.[7,10]

In analyzing sun exposure measures in our large case-control study of melanoma, we used both geographic on-ground UVB flux data and questionnaire data to estimate individual UVB exposure. We used total life residence information to estimate residential UVB flux every 6 months of the participant's life.[2] Every 10% increase in residential UVB conferred a 19% increase in melanoma risk for men and a 16% increase in risk for women. We also evaluated hours outdoors for each 6-month interval of each residence using the occupational and non-occupational exposure history. We found no significant difference in time outdoors for ages under 20. Among adults, every 10% increase in time outdoors was associated with a 3% increase in risk of melanoma among men and a 6% increase in risk in women who tanned well. Among those who tanned well, melanoma risk rose with increasing time outdoors. Patterns of behavior varied by gender and skin type in the controls. Women were outdoors less than men; individuals who tanned well spent significantly more time outdoors than those who did not.

Lazovich and Forster reviewed several studies of adolescents' use of tanning beds.[11] Usage is higher in older teens, and much higher in girls than boys. Among the studies, prevalence of use among boys was 1% to 35%; among girls, it was 14% to 75%. In the most robust studies, 19% of boys and 40% of girls in Sweden, and 11% of boys and 37% of girls in the United States used tanning beds. Two recent reviews assessed the risk of melanoma associated with tanning bed use and both showed evidence for increased risk.[12,13] Despite the increasing body of data showing an association between melanoma risk and tanning bed use, it must be remembered that most tanning bed users also have other sun-seeking behaviors.

Although much progress has been made in recent years in assessing UV exposure, much more is necessary. The short- and long-term effects of chronic versus intermittent exposures are not clear. The relationship between questionnaire measure of exposures and biologic effects are just starting to be explored in the skin. The measures of UV exposure and measures of vitamin D have not been well validated at an individual level. Information for the public about risks of UV exposure is complex; the messages for individuals can vary widely depending on their personal risk factors and behaviors.

REFERENCES

1. Scotto J, Fears TR, Fraumeni JF. *Incidence of Nonmelanoma Skin Cancer in the United States*. Bethesda MD: National Cancer Institute, US Dept. of Health and Human Services; 1983, Publication (NIH) 83-2433.
2. Fears TR, Bird CC, Guerry D IV, Sagebiel RW, Gail MH, Elder DE, et al. Average midrange ultraviolet radiation flux and time outdoors predict melanoma risk. Cancer Res. 2002;62:3992–3996.
3. Kimlin MG. The climatology of vitamin D producing ultraviolet radiation over the United States. J Steroid Biochem Molec Biol. 2004;89-90:479-483.
4. US Department of Agriculture. UVB Monitoring and Research Program website. Available at: http://uvb.nrel.colostate.edu/UVB/home_page.html. Accessed June 21, 2007.
5. US Department of Commerce, National Oceanic & Atmospheric Administration. NEUBrew: NOAA-EPA Brewer Spectrophotometer UV and Ozone Network. Available at: www.esrl.noaa.gov/gmd/grad/neubrew/. Accessed June 21, 2007.
6. Slusser JR, Krotkov NA, Gao W, Herman JR, Labow G, Scott G. Comparisons of USDA UV shadow-band irradiance measurements with TOMS satellite and DISORT model retrievals under all sky conditions. In: JR Slusser, JR Herman, W Gao, eds. *Ultraviolet Ground- and Space-based Measurements, Models, and Effects*. *Proceedings of SPIE, Volume 4482*. Bellingham, WA: SPID; 2002:56–69.

7. Herlihy E, Gies PH, Roy CR, Jones M. Personal dosimetry of solar UV radiation for different outdoor activities. Photochem Photobiol. 1994;60:288–294.
8. English DR, Armstrong BK, Kricker A. Reproducibility of reported measurements of sun exposure in a case-control study. Cancer Epidemiol Biomarkers Prev. 1998;7:857–863.
9. Kricker A, Vajdic CM, Armstrong BK. Reliability and validity of a telephone questionnaire for estimating lifetime personal sun exposure in epidemiologic studies. Cancer Epidemiol Biomarkers Prev. 2005; 14:2427–2432.
10. Dwyer T, Blizzard L, Gies PH, Ashboth R, Roy C. Assessment of habitual sun exposure in adolescents via questionnaire—a comparison with objective measurement using polysulphone badges. Melanoma Res. 1996;6:231–239.
11. Lazovich D, Forster J. Indoor tanning by adolescents: prevalence, practices and policies. Eur J Cancer. 2005;41:20–27.
12. Gallagher RP, Spinelli JJ, Lee TK. Tanning beds, sunlamps, and risk of cutaneous melanoma. Cancer Epidemiol Biomarkers Prev. 2005;14:562–566.
13. IARC working group on artificial ultraviolet (UV) light and skin cancer. The association of use of sunbeds with cutaneous malignant melanoma and other skin cancers: a systematic review. Int J Cancer. 2006; 120:1116–1122.