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Weekend personal ultraviolet radiation exposure in four cities in Australia: Influence of temperature, humidity and ambient ultraviolet radiation

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ABSTRACT

Purpose: To examine the effects of meteorological factors on weekend sun exposure behaviours and personal received dose of ultraviolet radiation (UVR) in Australian adults.

Methods: Australian adults ($n = 1002$) living in Townsville (19°S, 146°E), Brisbane (27°S, 153°E), Canberra (35°S, 149°E) and Hobart (43°S, 147°E) were recruited between 2009 and 2010. Data on sun exposure behaviours were collected by daily sun exposure dairies; personal UVR exposure was measured with a polysulphone dosimeter. Meteorological data were obtained from the Australian Bureau of Meteorology; ambient UVR levels were estimated using the Ozone Monitoring Instrument data.

Results: Higher daily maximum temperatures were associated with reduced likelihood of wearing a long-sleeved shirt or wearing long trousers in Canberra and Hobart, and higher clothing-adjusted UVR dose in Canberra. Higher daily humidity was associated with less time spent outdoors in Canberra. Higher ambient UVR level was related to a greater clothing-adjusted personal UVR dose in Hobart and a greater likelihood of using sunscreen in Townsville.

Conclusion: The current findings enhance our understanding of the impact of weather conditions on the population's sun exposure behaviours. This information will allow us to refine current predictive models for UVR-related diseases, and guide future health service and health promotion needs.

1. Introduction

Exposure to solar ultraviolet radiation (UVR) has both adverse and beneficial effects on human health [17]. Exposure to UVR is the most important risk factor for melanoma and non-melanoma skin cancers (NMSC) [2], and eye disorders such as cataract and pterygium [30], and UVR-induced immunosuppression can cause reactivation of latent virus infections [20]. The best-known beneficial effect of UVR exposure is initiation of vitamin D synthesis in the skin. Adequate vitamin D is essential for bone health and may decrease the risk or improve outcomes of a wide range of diseases [12].

The balance of risks and benefits of UVR exposure and its contribution to the total disease burden at a population-level depends on demographic factors such as age and sex (e.g. NMSCs are more common in the elderly with higher incidence in men than women), as well as on the population distributions of different skin types and of levels of UVR exposure. The latter is a function of ambient UVR and sun exposure behaviour. In populations of similar ethnic origin, the incidence of NMSC increases as ambient UVR levels increase [29]. For any individual, their own risk of UVR-induced disease also depends on their sun exposure behaviour. Globally, outdoor workers receive about 10% of available ambient UVR and

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indoor workers and children receive about 3% [11]. Within a population, this dose can vary widely from one tenth to ten times the mean value [9].

Changes in weather conditions, such as temperature and humidity, alter people's sun exposure behaviour [10] but the level and direction of the effect may vary across population subgroups and locations. For example, on hotter days, people living in already hot climates may prefer to spend time indoors, whereas those in cool climates may spend more time outdoors. Whether sun exposure is more affected by changes in relative temperature – hotter or colder – or absolute temperature, is not clear. In a previous study of self-reported sun exposure behaviour on the preceding weekend, Australian adults were more likely to wear sunscreen, sunglasses and a hat on warmer than on cooler days. Of the participants who spent more than 15 min outside, the reported time outdoors was greater when it was warmer, and there were more sunburn episodes [10]. However, on hotter days (>28 °C), some participants did not spend more than 15 min outside, that is, during peak UVR times they stayed indoors. Understanding how people's sun exposure behaviour may change in relation to meteorological factors is crucial in the context of managing current behaviour and in predicting UVR-related health risks under future climate change scenarios.

Here, we examine the effects of meteorological factors (temperature, humidity, and ambient UVR) on weekend sun exposure behaviours (amount of time spent outdoors and use of sun protection such as clothing and sunscreen) and personal received dose of UVR (adjusted for clothing) in Australian adults living in four cities with different thermal and UVR climates.

2. Methods

This analysis uses data from the multi-centre AusD Study [4], the primary aim of which was to examine determinants of vitamin D status in adults (aged 18 + years) resident in four eastern Australian cities, each separated by approximately 8° of latitude: Townsville (19°S, 146°E), Brisbane (27°S, 153°E), Canberra (35°S, 149°E) and Hobart (43°S, 147°E). The latitude range of the study regions provided wide variation in ambient UVR levels and other meteorological factors, and standardised data collection across the four regions ensured comparable measurement of sun exposure behaviours.

The methods of the AusD Study have been described elsewhere [4]. In brief, 1002 adults aged 18–75 years were recruited from the Australian Electoral Roll between May 2009 and December 2010, approximately equally distributed by sex, age group and study region. Data were collected by self-administered questionnaire, face-to-face interviews (including physical examination and collection of blood) and daily sun-exposure diaries. Polysulphone UVR dosimeters were used to monitor personal UVR exposure [22].

The AusD Study was approved by the Human Research Ethics Committees of the participating institutions (Australian National University #2008/451; Queensland University of Technology #0600000224; James Cook University #H3124; University of Tasmania #H0010277). All participants signed written informed consent.

2.1. Demographic information

Questionnaires were self-completed at baseline and captured information about date of birth, education level (using the question "*What is the highest technical, professional or academic qualification that you have completed?*" with 8 options), type of employment (using the question "*Which of the following best describes your current employment status?*" with 9 options), and parents' ethnicity (using the question "*What is your mother's/father's ethnic origin (that is, the place where the most of their ancestors came from)?*" with 20 possible options) [4].

2.2. Assessment of personal sun exposure and duration of time spent outdoors

Participants recorded the amount of time spent outdoors during each hour from 5 am to 7 pm on 10 consecutive days, using the following categories: 0 min, <15 min, 15–29 min, 30–44 min, 45–60 min. They also recorded what clothing they wore on their upper body, lower body, head and feet for each hour of the day, according to pre-defined options with accompanying representative pictures. Daily use of sunscreen was recorded (yes/no) using the question "*Did you apply any sunscreen today?*" [4]. On each of the 10 days that they were completing diaries, participants were asked to wear a polysulphone dosimeter [18] on a wristband from the time they woke up in the morning until they went to bed at night, to measure daily personal UVR exposure. The dosimeters were replaced daily to avoid possible saturation of their capacity to register UVR exposure.

2.3. Meteorological data

Meteorological data (including daily maximum temperature, apparent temperature, and daily average relative humidity) were obtained from the Australian Bureau of Meteorology [3] for the entire study period for each study region. Daily surface ambient UVR levels weighted to the erythemal action spectrum [6] were estimated for the study period for each study region with Geographic Information System (GIS), using the National Aeronautics and Space Administration (NASA) Ozone Monitoring Instrument (OMI) data [16].

In order to examine the effect of "relative" weather (i.e., the deviation from the average weather conditions) on sun exposure behaviours, that is, the difference between the daily measure for each meteorological parameter (temperature, humidity, ambient UVR) and the season- and city-specific average.

2.4. Statistical analysis

Since we were primarily interested in the effect of climate on sun exposure behaviour that was not dependent on work-related constraints, we used data only from weekend days (both Saturday and Sunday) of the 10-day period (if there was more than one weekend during the 10-day period, data for the first weekend were used). Weekend sun exposure represents the majority of the weekly sun exposure for indoor workers in Australia [19]. For all analyses, rainy days (rainfall > 0 mm) were excluded.

Daily time spent outdoors was calculated as the sum of time spent outdoors from 6 am to 6 pm Australian Eastern Standard Time (AEST), using the midpoint value of each of the five time categories (i.e., 0, 7.5, 22.5, 37.5, 52.6 min) [15].

We used the clothing on each of the body areas – upper body, lower body and head – as a separate outcome variable. We focused on clothing worn during the middle of the day (11 am to 2 pm AEST) as this is the time of peak UVR, most likely to affect both vitamin D synthesis and UV-induced skin damage. Upper body clothing was coded into three categories: no clothing on the upper body, bikini, swimsuit, crop top, or singlet; short-sleeved top; long-sleeved top. Lower body clothing was also coded into three categories: no lower body clothing, briefs, shorts or short skirt; knee-length shorts or skirt; long trousers/jeans, long skirt. Head covering was coded into two categories: no head cover or a hat without a brim; any sunhat including cap, legionnaire's cap, bucket hat or wide-brimmed hat. For regression analysis, upper body clothing