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Sun protection and vitamin D status in an Australian subtropical community

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ABSTRACT

Objective. Claims have been made that sun protection may negatively affect vitamin D status, but very few data are available about whether this applies to people in uncontrolled settings.

Method. In 1996 we measured 25(OH)-vitamin D concentrations in 1113 adults in Nambour, a subtropical community, who reported their concurrent sun protection behaviours in a skin cancer prevention trial. Estimates were adjusted for time outdoors, vitamin D intake and other factors known to affect vitamin D status.

Results. Persons who tended to stay in the shade had lower vitamin D levels than those who never stayed in the shade (62.5 vs. 68.8 nmol/L respectively, $p = 0.01$), and this association remained in persons who spent less than 50% ($p = 0.02$) but not in those who spent more than 50% of their time outdoors. Wearing a hat, long sleeves, sunglasses and use of sunscreen or umbrella were not associated with vitamin D status after adjustments, including after stratification by time outdoors.

Conclusion. Sun protection behaviour to reduce the risk of skin cancer can be maintained without affecting vitamin D serum status, although consistently seeking shade when spending less than 50% of daytime outdoors is associated with lower vitamin D levels.

Introduction

Recent evidence suggests that besides its effect on bone health, insufficient vitamin D status may have numerous negative health effects including diabetes, cardiovascular disease and several cancer types, although further evidence for this is needed (Institute of Medicine, 2011). Cutaneous formation of vitamin D following sunlight exposure is a main source of vitamin D, with the relative contributions of vitamin D intake through foods and supplements depending on behaviour, diet, and environment (Reddy and Gilchrest, 2011). Sun exposure is also the main environmental risk factor for skin cancer, and thus the possible advantages of improved vitamin D status with increased sun exposure are difficult to balance with the increased risk of skin cancer associated with exposure to ultraviolet (UV) radiation (Reddy and Gilchrest, 2010). Additionally, the dose–response relationship of UV exposure and cutaneous vitamin D synthesis is non-linear, making the prediction of safe sun exposure duration to produce vitamin D difficult (Olds et al., 2008).

Claims have been made that sun protection may negatively impact on vitamin D status. In highly controlled settings, the rise in serum vitamin D levels following UV exposure can be prevented by sunscreen application (Matsuoka et al., 1987), but it is unclear whether this is relevant to normal free-living persons (unmanaged, naturally occurring populations). In the United States, increased sun protection has been suggested as a possible explanation for the drop in 25(OH)-vitamin D levels in the National Health and Nutrition Examination Surveys (NHANES) between 1992 and 2004 (Looker et al., 2008). However, in a recent investigation sunscreen use was not associated with vitamin D status in cross-sectional analysis of NHANES participants (Linos et al., 2012).

Australia has one of the highest skin cancer incidence rates in the world (van der Pols, 2010) despite extensive prevention campaigns since the early 1980s (Shih et al., 2009), and the tension between adequate vitamin D status and skin cancer prevention is much debated in this country (Janda et al., 2007). In Queensland, Australia, UV radiation levels are high (above UV Index 3) almost all year round, and sun protection messages throughout the year are essential (Janda et al., 2010). Attitudes and behaviours towards sun protection appear to have changed already due to concerns about vitamin D status among the population (Youl et al., 2009). However, it is unclear whether sun protection negatively affects the vitamin D status of persons residing in areas of relatively high ambient sun exposure such as Australia. In a small trial in the south of Australia, there was no difference in vitamin D levels between participants who had been randomised to use daily sunscreen and those who used a placebo sunscreen for the duration of a summer season (Marks et al., 1995). Given the paucity of evidence from free-living population groups, we investigated associations between sun protection behaviours and vitamin D status in an Australian sub-tropical community,

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and whether the amount of time spent outdoors is modifying these associations.

Materials and methods

Study participants

This cross-sectional study was conducted using data compiled from self-administered questionnaires completed by participants in the Nambour Skin Cancer Study, a 20-year cohort study in a representative sample of a sub-tropical community (latitude 26°S; other cities at a similar latitude include Naples, Florida, USA; Okinawa, Japan; and Johannesburg, South Africa).

Participants were randomly selected from the Australian electoral roll in 1986 for a study of skin cancer. Between 1992 and 1996, a randomized controlled trial was carried out of daily application of a broad spectrum sunscreen and beta-carotene supplementation in the prevention of skin cancer. Full details of the study have been published previously (Green et al., 1988, 1999; van der Pols et al., 2006). At completion of the trial in August 1996 (end of winter), all study participants were invited to give a blood sample which was used for vitamin D status assessment. Participants were also asked to complete questionnaires about attitudes and behaviours regarding sun exposure and sun protection methods (see below), as well as general health and personal characteristics including smoking history (based on detailed smoking data collected in 1992 and 1996). Usual food intake was assessed using a validated food frequency questionnaire (Marks et al., 2006) from which vitamin D intake was estimated (Bonthuis et al., 2010), and total vitamin D intake was calculated by adding this to vitamin D supplement intake.

The study was approved by the Ethics Committee of the Queensland Institute of Medical Research, and all participants provided written informed consent for their ongoing study participation.

Assessment of vitamin-D status

Serum 25(OH)-vitamin D concentrations were measured by Liaison 25(OH)D Assay (Ersfeld et al., 2004) in nmol/L (divide by 2.496 to convert to ng/mL). Twelve random samples were measured in duplicate, showing high intra-assay correlation (Pearson's $r = 0.83$) and 29 random samples were compared with HPLC analysis (Pearson's $r = 0.79$).

The Institute of Medicine (IOM) in the USA has concluded recently that circulating 25(OH)-vitamin D concentrations of 50 nmol/L are sufficient to cover the requirements of at least 97.5% of the population (Ross et al., 2011). Insufficient vitamin D status was therefore defined as below 50 nmol/L.

Assessment of sun protection behaviour

Participants reported on their usual sun protection behaviours when outside in the sun in the past eight months, with five frequency options ranging from almost always to never. Six sun protection behaviours assessed were hat wearing, sunscreen application, staying in shade, use of sunglasses, umbrella use, and wearing long sleeves, following standardised and validated methodology (Glanz et al., 2008). If participants responded that they usually or almost always applied one of these behaviours, they were allocated a score of one for that behaviour. We derived a total sun protection score for each participant by summing their scores for the six behaviours. Thus the summary sun protection scores ranged between 0 and 6. For ease of analysis, sun protection scores were categorised (0–1, 2, 3, and 4–6) to achieve a fairly even distribution of participants between groups.

Statistical analysis

1992 data was used to assess differences between those included and excluded, to minimise missing values and increase statistical power. Analysis of variance (ANOVA) was used to assess group differences in serum 25(OH)-vitamin D concentration. Because serum 25(OH)D has an estimated half-life of a few weeks (Holick, 2006), general sunscreen use (response to whether participants ever apply sunscreen) immediately prior to the 1996 blood collection was considered relevant in relation to possible effects of sunscreen use on vitamin D status, and was thus included in the multivariate analysis, along with sunscreen allocation during the trial, history of skin cancer and other measured variables potentially associated with vitamin D levels, according to the literature. To assess whether the association between sun protection behaviours and vitamin D status differed by sun exposure subgroups, analyses were stratified by the amount of time spent outdoors. This was calculated from variables in which the participant reported the amount of time spent outdoors daily from sunrise to sunset, reported separately for a typical weekday and weekend day, in categories summarised as less than 50% of the time (up to 4 h per day), or more than 50% of the time (4 h or more). We then calculated a summary variable of daily average time spent outdoors that combined both weekday and weekend responses using the formula $(5 \times \text{usual weekday hours outdoors} + 2 \times \text{usual weekend hours outdoors})/7$.

Analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, North Carolina, USA), employing a significance level of $p < 0.05$.

Results

We measured 25(OH)D in 1123 participants who also provided information on sun protection behaviours. We excluded 10 participants because they lacked dietary data (5) or were not Caucasian (5), leaving 1113 participants (69% of the original 1621 persons enrolled in the Nambour trial) in the analyses. Those included were older ($p < 0.0001$), had a lower BMI ($p = 0.02$) and were more likely to have an educational qualification ($p = 0.03$). There were no differences between those included and excluded in regard to sex, occupation, or leisure type (indoors/outdoors), or smoking status.

Sun protection and vitamin D status

23% of participants had insufficient 25(OH)D levels (below 50 nmol/L). Average vitamin D status was higher in participants who were younger, male, spent more than 50% of their time outdoors and who worked outdoors, and lower in persons with a higher education level, and who were overweight or obese. Within smokers, vitamin D status was lower in persons who had smoked a larger number of pack-years, whilst participants who hadn't smoked at all also had significantly lower vitamin D status than those with 1–7 pack-years. Skin colour, sunscreen treatment during the trial and current smoking status were not associated with vitamin D levels (Table 1).

Following adjustments, shade seeking was the only sun protection behaviour that remained associated with vitamin D status, with persons who almost always stay in the shade having significantly lower vitamin D levels than those who never or almost never stay in the shade (mean adjusted vitamin D levels 62.5 vs. 68.8 nmol/L, respectively; p-value = 0.01) (Table 2). In these multivariate analyses, sex, time spent outdoors, education level, and BMI were the variables most strongly confounding the association between the summary sun protection score and vitamin D status.

Following stratification by time spent outdoors, apart from shade seeking, there were no associations between the sun protection behaviours or the summary sun protection score and vitamin D status (results not shown). Vitamin D levels decreased significantly as shade seeking behaviour increased in participants who spent less than 50% time outdoors ($p = 0.002$), whilst this association was not seen in those who spent more than 50% of their time outdoors.

Discussion

Presently there is limited information regarding the effect of specific sun protection behaviours on vitamin D status in free-living populations. Our data indicate that when other behaviours or characteristics that may affect vitamin D levels are considered, shade seeking is the only sun protection behaviour that is associated with vitamin D status in an Australian sub-tropical community. Persons who almost always stay in the shade had significantly lower vitamin D levels than those who never or almost never stay in the shade.

Burgaz and colleagues found similar results, reporting that the average vitamin D level in elderly Swedish women with a preference for