# 1_SELF ARTICLE

*by* Ngadiman Jaya

**Submission date:** 30-Nov-2020 05:49PM (UTC+0700)

**Submission ID:** 1460130808

**File name:** d_Changes_in_Sun-Protection_Behaviors_at_Different_Latitudes.pdf (178.23K)

**Word count:** 7906

**Character count:** 39534

Photochemistry and Photobiology, 2016, 92: 495–502

# Self-Reported Changes in Sun-Protection Behaviors at Different Latitudes in Australia

**Ngadiman Djaja*[1,2,3], Monika Janda[1,2,3], Robyn M. Lucas[3,4,5], Simone L. Harrison[2,3,6,7], Ingrid van der Mei[3,8], Peter R. Ebeling[3,9], Rachel E. Neale[3,10], David C. Whiteman[3,10], Madeleine Nowak[6,7] and Michael G. Kimlin[1,2,3]**

[1]School of Public Health and Social Work, Faculty of Health, Queensland University of Technology, Brisbane, Qld, Australia
[2]Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Qld, Australia
[3]National Health and Medical Research Council Centre for Research Excellence in Sun and Health, Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Qld, Australia
[4]National Centre for Epidemiology and Research School of Population Health, The Australian National University, Canberra, ACT, Australia
[5]Telethon Kids Institute, University of Western Australia, Perth, WA, Australia
[6]JCU Skin Cancer Research Group, Division of Tropical Health and Medicine, College of Public Health, Medical & Veterinary Sciences, James Cook University, Townsville, Qld, Australia
[7]Anton Breinl Centre for Health Systems Strengthening, Australian Institute of Tropical Health and Medicine (AITHM), James Cook University, Townsville, Qld, Australia
[8]Menzies Institute for Medical Research, Hobart, Tas., Australia
[9]School of Clinical Sciences, Faculty of Medicine, Nursing and Health Sciences, Monash University, Melbourne, Vic., Australia
[10]QIMR Berghofer Medical Research Institute, Brisbane, Qld, Australia

**Received 23 June 2015, accepted 3 December 2015, DOI: 10.1111/php.12582**

## ABSTRACT

**Sun exposure is the most important source of vitamin D, but is also a risk factor for skin cancer. This study investigated attitudes toward vitamin D, and changes in sun-exposure behavior due to concern about adequate vitamin D. Participants (*n* = 1002) were recruited from four regions of Australia and completed self- and interviewer-administered surveys. Chi-square tests were used to assess associations between participants' latitude of residence, vitamin D-related attitudes and changes in sun-exposure behaviors during the last summer. Multivariate logistic regression analyses were used to model the association between attitudes and behaviors. Overall, people who worried about their vitamin D status were more likely to have altered sun protection and spent more time in the sun people not concerned about vitamin D. Concern about vitamin D was also more common with increasing latitude. Use of novel item response theory analysis highlighted the potential impact of self-reported behavior change on skin cancer predisposition due concern to vitamin. This cross-sectional study shows that the strongest determinants of self-reported sun-protection behavior changes due to concerns about vitamin D were attitudes and location, with people at higher latitudes worrying more.**

## INTRODUCTION

Exposure to ultraviolet (UV) radiation from the sun causes about 90% of the global skin cancer burden (1–3). The International Agency for Research on Cancer summarized the most recent evidence for the carcinogenicity of solar radiation. While there are some differences in the patterns and timing of exposure that give rise to different types of skin cancer, overall, greater sun exposure significantly increases skin cancer risk (4). Therefore, minimizing sun exposure or protecting the skin when outdoors using clothing, shade and sunscreen is recommended when the UV Index is ≥3 (5).

Vitamin D is synthesized when the skin is exposed to sunlight, or is consumed in vitamin D-containing foods (naturally or fortified) or supplements (6). Research indicates that vitamin D deficiency may increase the risks not only of diseases of bone, but may also contribute to a wide range of other adverse outcomes such as cancer and immune-modulated diseases (7–10). This has led to interest in defining the optimal level of vitamin D and determining how to best achieve such a level (11,12). To overcome the concerns that sun-protection practices may lead to vitamin D deficiency, safe durations of unprotected sun exposure at different latitudes of Australia have been proposed and sun-protection message is not recommended when the UV Index drops below 3 (13). Exactly how much sun exposure is required to achieve sufficient levels of vitamin D is contentious, as there is little consensus on the level considered "sufficient," and vitamin D synthesis varies according to location, time of year, time of day, weather, and personal factors such as skin type and body mass index (14). In Australia, current recommendations for late autumn and winter in those parts of Australia where the UV Index is below 3, are that sun protection is not recommended (15). During these times, to support vitamin D production, it is recommended that people are outdoors in the middle of the day with some skin uncovered on most days of the week. Being physically active while outdoors will further assist with vitamin D levels.

*Corresponding author email: n.djaja@qut.edu.au (Ngadiman Djaja)

Consequently, health promotion messages for sun protection have become complicated, with different messages conveyed for different latitudes, seasons, times of day and skin types. People are confused about when they need to protect themselves, how much time they can spend outside and how to balance the risk of skin cancer *vs* those of vitamin D deficiency (16–19). Reflecting these concerns, there has been a huge increase in vitamin D testing in Australia, with costs to the health care system rising from AUS\$3.2 million in 2003 to AUS\$143 million in 2013 (20–23). It is unknown, however, whether changes in sun-exposure behavior are more common in people who are concerned about achieving optimal vitamin D, and whether this depends on where they live. The challenge now is finding the best way to balance the risks and benefits of sun exposure and how to communicate this to the general public (24).

Previous studies investigating knowledge, attitudes and behaviors related to vitamin D and sun protection have been limited by small sample sizes (16,25–27) or a focus on specific populations (28,29). In this paper, we used item response theory (IRT) to assess the potential impact that behavior change due concern to vitamin D may have on skin cancer predisposition. IRT (modern test theory) offers many advantages compared to classical test theory. It offers mathematical modeling that specifies the probability of selecting each questionnaire item's response option as a function of the target latent trait (in our case skin cancer predisposition) being measured. It therefore allows economical and precise assessment of the characteristics under study and highlights specific targets for personalized intervention. IRT is increasingly used in health research; examples include assessing activity for postacute care (30), and measures of physical functioning, health status and adolescent health risk behavior (31–33). IRT allows computation of health measures on an interval measurement scale (rather than ordinal scores provided by most classical test theory-constructed health scales) and exploration of the performance of each individual item rather than the scale as a whole. IRT encompasses any mathematical model which attempts to predict observations from locations on a latent variable. It uses logistic models including Rasch models, Generalized Rating Scale models or Samejima's Graded-Response models (34). These models are widely used in education and patient-reported outcome assessments (35–38). IRT-tested scales plot both respondent's and item's measurements calibrated onto a common latent trait such as skin cancer predisposition. IRT enables researchers to better visualize how changes in sun-protective behaviors may influence underlying skin cancer predisposition.

This study used data from a large population-based cross-sectional study (the AusD Study), designed to assess vitamin D status and determinants across a range of latitudes and seasons (39,40). We aimed to (1) assess the variation in attitudes and behaviors according to residential location; (2) identify the association between participants' attitudes about vitamin D and their self-reported changes to sun-protection or exposure behaviors; and (3) use IRT models to model the potential effect on skin cancer predisposition that may occur if sun-protection behaviors change due to concerns about vitamin D.

## MATERIALS AND METHODS

The design, recruitment and main outcome measures of the multicenter AusD Study have been described previously in detail (39). Approval was obtained from four institutional ethics committees. Potentially eligible participants were residents of four Australian cities (Hobart, Canberra, Brisbane, and Townsville) registered on the Australian Electoral Roll (a compulsory register of Australian adults aged 18+ years) and aged between 18 and 75 years. Exclusion criteria were: insufficient command of English; an impairment or illness that prevented attendance at the interview; a bleeding disorder; or positivity for hepatitis B virus, hepatitis C virus or human immunodeficiency virus. Participants completed a mailed health questionnaire followed by two personal interviews at their local study site. At the end of the second interview, a 20-mL venous blood sample was collected from each participant to measure concentrations of serum 25-hydroxyvitamin D (25OHD). The serum and buffy coat were processed using standard procedures, before storage locally in a −80°C freezer. The final study sample was representative of the underlying population based on a set of parameters (gender, age group, country of birth, perceived health status, body mass index and smoking status) available from the population-based 2007–2008 National Health Survey; most participants (80.4%) had been born in Australia, full-time workers who worked primarily indoors and considered themselves to have fair-to-medium skin color (participants were asked to self-report their skin color by a reference to a Fitzpatrick Skin Type chart (41)), brown hair, and blue or gray eyes as previously reported (39). This analysis uses data from the self-administered questionnaire (demographic characteristics and questions about the way participants protect themselves from the sun), interviewer-administered questions (phenotypic characteristics, skin cancer and vitamin D-related attitudes, use of sun protection, and changes in sun-exposure behaviors due to concern about vitamin D), and blood sample to measure concentrations of (25OHD).

*Attitudes toward vitamin D.* Three questions assessed attitudes toward vitamin D (*"I worry about getting enough vitamin D"; "I need to spend more time in the sun during summer for a healthy vitamin D level"; "It is more important to stay out of the sun than to get enough vitamin D"*), with answer categories using five-point Likert scales ranging from strongly agree to strongly disagree. An option for "can't say" was included. Participants were also asked whether they had noticed any news stories about vitamin D (yes, no, unsure).

*Change in sun-exposure or sun-protection behaviors due to concern about vitamin D.* Participants were asked if they had made changes to their personal sun-protection or sun-exposure behaviors during the previous summer in order to get enough vitamin D (*"Did you try to wear shorts more often? Did you try to wear a hat less often? Did you try to wear sunscreen less often? Did you spend more time in the sun? Any other changes?"*). Answer categories were yes, no or can't say. Fewer than 2.5% of participants answered "can't say"; these responses were combined with the "no" category. Excluding participants who answered "can't say" did not significantly change the results.

*Statistical analysis.* Prior to analysis, we grouped the response categories strongly disagree/disagree/neutral and strongly agree/agree. For the Rasch analysis, we recoded the sun-protection behavior items (items 1–6 in Table 4) so that a higher score indicated higher skin cancer predisposition as follows: strongly disagree = 4, disagree = 3, neutral = 2, agree = 1, and strongly agree = 0; and less sun-protection behavior (item 7–11 *e.g.*: try to wear a hat less often) as follows: strongly disagree = 0, disagree = 1, neutral = 2, agree = 3 and strongly agree = 4. We used chi-square tests to compare attitudes, and changes in sun-protection behaviors, stratified by participants' locations. We also used chi-square tests to determine whether reported changes in sun-protection behaviors to get more vitamin D varied according to attitudes toward vitamin D or having heard news reports about vitamin D. Bivariate logistic regression analyses were used to determine sociodemographic and skin cancer risk factors associated with changes in sun-protection behaviors. Factors that were statistically significant ($P < 0.2$) in the bivariate analyses and did not show evidence for multicollinearity were then included as adjustment factors in the multivariate logistic regression analyses. Multivariable logistic regression models were used to assess whether changes in sun-exposure or -protection behaviors (yes or no) were influenced by vitamin D-related attitudes, adjusted for age, sex, location, education, indoor or outdoor work, ability to tan and participants' measured concentrations of serum 25OHD. We repeated the models adjusting for season (data not shown), but results remained unchanged and the former more parsimonious models are reported.

*Item response theory.* The matrix of responses of 1002 participants to the attitude items was subjected to Rasch analysis using the Andrich rating scale model for polytomous data (42). Rasch models are a variant of IRT that model a relationship between the levels of that latent trait (for this study skin cancer predisposition) and the items used for measurement. In clinical assessment, the concept behind IRT is that participants respond to items in a questionnaire based on the extent of the latent trait (equivalent to person ability in Rasch analysis of a physical disability instrument). Therefore, a person with an average level of severity of skin cancer disposition will likely report that they had less sun-exposure behaviors compared to people with greater skin cancer predisposition. Severity of skin cancer predisposition is expressed in terms of log odds or "logits," and persons and items are mapped along the same scale. Logit-transformed measures represent linear measures skin cancer predisposition. For an item, a logit represents the log odds of the extent of an item relative to the position of that item within the total set of items analyzed. Logits of higher positive magnitude represent a participant who has higher skin cancer predisposition. We applied IRT models to assess the item information functions of 29 self- and interviewer-administered questions when on an underlying latent trait of skin cancer predisposition: 18 items measured phenotype and typical sun-exposure behaviors, six items measured sun-protection behaviors and five items measured changing sun-protection behaviors due to concern about getting enough vitamin D. Item information is the contribution that an individual item makes to the total information of a measured latent construct and shows where on the underlying latent construct each item measures optimally (43). In general, item information functions tend to look bell shaped. Highly discriminating items have tall, narrow information functions; they contribute greatly but over a narrow range. Less discriminating items provide less information but over a wider range. Plots of item information can be used to see how much information an item contributes and to what portion of the scale score range. Calibration into the Rasch Partial Credit Model (44) was completed using *ACER ConQuest software* (45). Calibration is the procedure of estimating a person's ability (in this case the person's skin cancer predisposition) and item difficulty (propensity to endorse an item) by converting (scaling) raw scores to logits on an underlying unidimensional measurement scale.

Unweighted and weighted fit statistics were used to check the quality of the scale from the Rasch model perspective. The mean square error (MNSQ) fit statistic is a measure of the extent to which the data match the specifications of the model. As in common practice in Rasch analysis, items that do not fit with the model are removed. Values of unweighted and weighted MNSQ can range from 0 to positive infinity with an ideal value of 1.0 indicating that the data perfectly fit the model. Values below 1.0 suggest that variation in the observed data is overpredicted by the Rasch model while values above 1.0 show that variation in the observed data is greater than that predicted by the model. Currently, there is no standard cut-off value for MNSQ; different acceptable ranges are used to indicate good-fit of the model. We used a relatively strict standard (unweighted MNSQ values between 0.75 and 1.33) as a criteria and indication of good-fit (46). Once the skin cancer predisposition scale was calibrated, we plotted each item and its response categories along this underlying latent trait logit scale which is expressed as theta, with 0 representing the mean skin cancer predisposition. To illustrate the potential effect of changing sun-protection behavior due to concern about vitamin D, we plotted a hypothetical example for a person endorsing items that confer a high or low skin cancer predisposition to show the impact on the underlying construct of skin cancer predisposition.

## RESULTS

Of 11 713 people approached, 1269 agreed to participate and 1002 provided data (overall study participation rate 9.1%). Demographic and phenotypic characteristics of the sample have been previously reported (39). The distribution of participants was approximately equally spread between the four study locations. The average age of participants was 48 years (SD 16) and 46% were male. Over 80% of participants were born in Australia and most had fair or medium skin color (90%) and green, hazel, gray or blue eyes (80%) placing them environmentally and constitutionally at risk of skin cancer (having a phenotype that confers overall higher than average risks of developing skin cancer based on accumulated epidemiologic evidence, *e.g.* skin type 1, red hair, lack of tanning ability and propensity to freckle and burn). See Table S1 for additional demographic and phenotypic characteristics. Fifty-six participants had serum 25(OH)D levels below 25 nmol $L^{-1}$; a significantly greater proportion of these participants (32.1%) were worried about not getting enough vitamin D compared to participants with level above 25 nmol $L^{-1}$ (24.0%, $P < 0.03$). Participants from Canberra were more likely than those from other locations to: work indoors (81% *vs* 68%) ($P < 0.001$); have a bachelor degree (30% *vs* 22%; $P < 0.001$); and be born outside Australia (29% *vs* 16%, $P < 0.001$). Participants from Canberra were less likely to report fair skin than other participants (50% *vs* 68%; $P < 0.001$), while participants from Hobart were more likely to report blue, gray or green eye color compared to participants from elsewhere (64% *vs* 52%; $P < 0.001$). A larger proportion of participants from Hobart entered the study in spring while a larger proportion of participants from Canberra participated during winter.

### Vitamin D-related attitudes and change in sun-protection/exposure behaviors due to concern about vitamin D, stratified by location

Concerns about vitamin D, and reported change in sun-protection or sun-exposure behavior due to those concerns, increased with increasing latitude (Table 1). For example, 18% of participants from Townsville, 21% of participants from Brisbane, 31% from Canberra and 40% from Hobart agreed with the statement "I need to spend more time in the sun during summer for a healthy vitamin D level" ($P < 0.001$). Overall, between 4 and 15% of participants reported that they had changed their sun-exposure or -protection behaviors during the previous summer to get sufficient vitamin D. People from Hobart were significantly ($P < 0.001$) more likely to report wearing shorts (24%) and spending more time in the sun due to concern about vitamin D (28%) than those from Brisbane or Townsville (8–10%). There were no significant differences in hat and sunscreen use or other sun-protective behaviors according to participants' locations (Table 1), although these behaviors also followed a latitudinal gradient.

### Associations between vitamin D-related attitudes and sun-protection behaviors

A larger proportion of people who worried about vitamin D or who felt they needed to spend more time in the sun for vitamin D production reported that they had altered their sun-exposure behaviors during the last summer (Table 2). In adjusted multivariable logistic regression analyses, those who worried about getting enough vitamin D wore sunscreen less often (adjusted OR = 3.2; 95% CI 1.6–6.2; $P = 0.001$) and shorts more often (adjusted OR = 1.6; 95% CI 1.0–2.6; $P = 0.04$) and tended to spend more time in the sun (adjusted OR = 2.4; 95% CI 1.5–3.7; $P < 0.001$). Those who agreed that they needed to spend more time in the sun in summer for a healthy vitamin D level were less likely to wear a hat (adjusted OR = 2.6; 95% CI 1.2–5.6; $P = 0.04$) or sunscreen (adjusted OR = 2.6; 95% CI

**Table 1.** Differences in vitamin D attitudes and sun-protection behaviors by location.*

| | Location | | | | |
|---|---|---|---|---|---|
| | Townsville 19.3°S $N$ = 259 (%) | Brisbane 27.5°S $N$ = 254(%) | Canberra 35.3°S $N$ = 252(%) | Hobart 42.8°S $N$ = 237(%) | $P$-value‡ |
| I worry about getting enough vitamin D | | | | | |
| Agree† $N$ = 237 (24.0%) | 30 (11.7) | 53 (21.0) | 63 (25.5) | 91 (39.1) | 0.001 |
| I need to spend more time in the sun during summer for a healthy vitamin D | | | | | |
| Agree† $N$ = 270 (27.2%) | 47 (18.3) | 53 (20.9) | 78 (31.1) | 92 (39.5) | <0.001 |
| It is more important to stay out of the sun than to get enough vitamin D | | | | | |
| Agree† $N$ = 160 (16.2%) | 60 (23.3) | 35 (13.9) | 40 (16.1) | 25 (10.8) | <0.001 |
| Have you ever heard news reports about getting vitamin D from sunlight | | | | | |
| Yes $N$ = 633 (64.7%) | 139 (55.2) | 165 (66.0) | 167 (67.6) | 162 (70.7) | 0.002 |
| Last summer did you make any changes to the way you protected yourself from the sun so you could get enough vitamin D? | | | | | |
| Wear hat less often $N$ = 41 (4.1%) | 8 (3.1) | 7 (2.8) | 11 (4.4) | 15 (6.5) | 0.46 |
| Wear sunscreen less often $N$ = 57 (5.8%) | 8 (3.1) | 13 (5.1) | 18 (7.2) | 18 (7.8) | 0.18 |
| Wear shorts more often $N$ = 136 (13.8%) | 21 (8.2) | 26 (10.3) | 33 (13.5) | 56 (24.2) | <0.001 |
| Spend more time in the sun $N$ = 153 (15.5%) | 20 (7.8) | 23 (9.2) | 44 (17.7) | 66 (28.4) | <0.001 |
| Any other changes $N$ = 81 (8.2%) | 20 (7.8) | 19 (7.5) | 21 (8.5) | 21 (9.1) | 0.29 |

*$N$ may vary slightly due to some missing values. †Agree = combined categories of strongly agree/agree. ‡$P$-value from Chi-square test.

**Table 2.** Vitamin D-related attitudes and self-reported changes in sun-protection behaviors.

Last summer did you make any changes to the way you protect yourself from the sun so you could get enough vitamin D?

| | Wear hat less often | | Wear sunscreen less often | | Wear shorts more often | | Spend more time in the sun | | Any other changes | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes $N$ (%) | No $N$ (%) | Yes $N$ (%) | No $N$ (%) | Yes $N$ (%) | No $N$ (%) | Yes $N$ (%) | No $N$ (%) | Yes $N$ (%) | No $N$ (%) |
| I worry about getting enough vitamin D | | | | | | | | | | |
| Strongly disagree/ disagree/neutral $N$ = 752 (76.0%) | 22 (55.0) | 730 (76.9) | 26 (47.3) | 726 (77.7) | 80 (59.7) | 672 (78.6) | 78 (51.3) | 674 (80.5) | 62 (77.5) | 690 (75.9) |
| Strongly agree/agree $N$ = 237 (24.0%) | 18 (45.0) $P < 0.001$ | 219 (23.1) | 29 (52.7) $P < 0.001$ | 208 (22.3) | 54 (40.3) $P < 0.001$ | 183 (21.4) | 74 (48.7) $P < 0.001$ | 163 (19.5) | 18 (22.4) $P = 0.75$ | 219 (24.1) |
| I need to spend more time in the sun during summer for a healthy vitamin D level | | | | | | | | | | |
| Strongly disagree/ disagree/neutral $N$ = 724 (72.8%) | 19 (46.3) | 705 (74.0) | 27 (47.4) | 697 (74.4) | 65 (47.8) | 659 (76.8) | 61 (39.9) | 663 (78.8) | 52 (64.2) | 672 (73.6) |
| Strongly agree/agree $N$ = 270 (27.2%) | 22 (53.7) $P < 0.001$ | 248 (26.0) | 30 (52.6) $P < 0.001$ | 240 (25.6) | 71 (52.2) $P < 0.001$ | 199 (23.2) | 92 (60.1) $P < 0.001$ | 178 (21.2) | 29 (35.8) $P = 0.07$ | 241 (26.4) |
| It is more important to stay out of the sun than to get enough vitamin D | | | | | | | | | | |
| Strongly disagree/ disagree/neutral $N$ = 829 (83.8%) | 35 (87.5) | 794 (83.7) | 49 (87.5) | 780 (83.6) | 122 (91.0) | 707 (82.7) | 135 (89.4) | 694 (82.8) | 70 (86.4) | 759 (83.6) |
| Strongly agree/agree $N$ = 160 (16.2%) | 5 (12.5) $P = 0.52$ | 155 (16.3) | 7 (12.5) $P = 0.44$ | 153 (16.4) | 12 (9.0) $P = 0.01$ | 148 (17.3) | 16 (10.6) $P = 0.04$ | 144 (17.2) | 11 (13.6) $P = 0.51$ | 149 (16.4) |
| Have you ever heard news reports about getting vitamin D from sunlight | | | | | | | | | | |
| No $N$ = 345 (35.3%) | 11 (27.5) | 334 (35.6) | 20 (35.7) | 325 (35.2) | 47 (35.6) | 298 (35.2) | 59 (39.6) | 286 (34.5) | 26 (32.1) | 319 (35.6) |
| Yes $N$ = 633 (64.7%) | 29 (72.5) $P = 0.29$ | 604 (64.4) | 36 (64.3) $P = 0.94$ | 597 (64.8) | 85 (64.4) $P = 0.93$ | 548 (64.8) | 90 (60.4) $P = 0.23$ | 543 (65.5) | 55 (67.9) $P = 0.53$ | 578 (64.4) |

$N$ may vary slightly due to some missing values.

1.3–5.0; $P = 0.004$), and more likely to wear shorts (adjusted OR = 3.0; 95% CI 1.9–4.7; $P < 0.001$) and increase the amount of time spent in the sun (adjusted OR = 4.2; 95% CI 2.8–6.4; $P < 0.001$) (Table 3).

There were no significant differences in participants' self-reported sun-protection behaviors according to whether or not they had heard any "news about vitamin D" or agreed or disagreed with the statement "it's more important to stay out of the sun than to get enough vitamin D."

### Potential effect of changes in sun-protection behavior and underlying skin cancer predisposition

For ease of interpretation, we transformed the person ability score (the skin cancer predisposition score) from a logit score into a T-Score (see Figure S1) which follows a $T$-score distribution with a mean of 50 and standard deviation of 10. Overall, the current participants were found to have skin cancer predisposition below the mean (mean = 44.10). Table 4 shows the

**Table 3.** Multivariable logistic regression models of associations between vitamin D-related attitudes and changes made during the last summer to the way people protected themselves from the sun so they can get enough vitamin D.*

| | Try to wear a hat less often? OR (95% CI); *P*-value | Try to use sunscreen less often? OR (95% CI); *P*-value | Try to wear shorts or short sleeved clothing more often? OR (95% CI); *P*-value | Try to spend more time out in the sun? OR (95% CI); *P*-value |
|---|---|---|---|---|
| I worry about getting enough vitamin D | | | | |
| Strongly disagree/disagree/neutral | 1.0 | 1.0 | 1.0 | 1.0 |
| Strongly agree/agree | 1.5 (0.7–3.4); 0.31 | 3.2 (1.6–6.2); 0.001 | 1.6 (1.0–2.6); 0.04 | 2.4 (1.5–3.7); 0.001 |
| I need to spend more time in the sun during summer for healthy vitamin D level | | | | |
| Strongly disagree/disagree/neutral | 1.0 | 1.0 | 1.0 | 1.0 |
| Strongly agree/agree | 2.6 (1.2–5.6); 0.04 | 2.6 (1.3–5.0); 0.004 | 3.0 (1.9–4.7); <0.001 | 4.2 (2.8–6.4); 0.001 |
| It is more important to stay out of the sun than to get enough vitamin D | | | | |
| Strongly disagree/disagree/neutral | 1.0 | 1.00 | 1.0 | 1.0 |
| Strongly agree/agree | 0.9 (0.3–2.7); 0.82 | 1.5 (0.6–3.8); 0.34 | 0.6 (0.3–1.1); 0.11 | 0.7 (0.4–1.3); 0.28 |
| Have you ever heard news reports about getting vitamin D from sunlight | | | | |
| No | 1.0 | 1.0 | 1.0 | 1.0 |
| Yes | 1.1 (0.5–2.3); 0.93 | 0.7 (0.4–1.3); 0.25 | 0.9 (0.6–1.4); 0.61 | 0.6 (0.4–1.0); 0.05 |

*For ease of reporting, all models are adjusted for age, sex, latitude, season, education, occupational exposure, ability to tan, measured 25OHD (continuous).

**Table 4.** Item location and fit statistics of sun-protection behavior items calibrated within a skin cancer predisposition model.

| Item no | Item | Estimated delta (standard error)* | Unweighted fit MNSQ† |
|---|---|---|---|
| 1 | Wear a broad-brimmed hat | −0.997 (0.032) | 1.01 |
| 2 | Wear a cap | −1.246 (0.039) | 1.02 |
| 3 | Wear any other head covering | −1.834 (0.070) | 1.00 |
| 4 | Wear a shirt with long sleeves | −0.634 (0.030) | 0.99 |
| 5 | Wear long trousers or clothing that covers all or most of your legs | −0.399 (0.031) | 1.01 |
| 6 | Wear sun glasses | −0.351 (0.031) | 1.00 |
| 7 | Try to wear a hat less often | 2.542 (0.155) | 1.00 |
| 8 | Try to use sunscreen less often | 2.188 (0.133) | 1.00 |
| 9 | Try to wear shorts or short sleeved clothing more often | 1.218 (0.091) | 0.99 |
| 10 | Try to spend more time out in the sun | 1.092 (0.087) | 0.99 |
| 11 | Make any other changes to the way you protect yourself from the sun | 1.802 (0.113) | |

MNSQ = mean square. *The estimate delta is the item location within a skin cancer predisposition continuum on a logit scale. The score can be from negative infinity to positive infinity. Scores below 0 (negative) represent low skin cancer predisposition score and scores above 0 (positive) represent increasingly high skin cancer predisposition score. †The fit of the items is evaluated using unweighted mean square (MNSQ). A MNSQ near 1 indicates a good fit. MNSQ <1 indicates an overfit, that is, the item discriminates more than assumed in the model. MNSQ scores >1 usually occur if the discrimination of the item is low; this is considered to be more serious violation to model fit than MNSQ <1.

item locations and the scale and fit statistics (MNSQ statistic) of selected sun-exposure behavior items within the calibrated skin cancer predisposition latent trait continuum, expressed on a logit scale. Estimates below 0 (negative) represent a low skin cancer predisposition, while those above 0 (positive) represent an increasingly high skin cancer predisposition, based on the self- and interviewer-administered questions. The overall item parameter estimates show that all 11 items fitted the skin cancer predisposition scale well, as all were located within the recommended MNSQ bounds of 0.75–1.33. Figure 1 visualizes two items assessing hat-wearing behaviors on calibrated skin cancer predisposition scale. Compared to a hypothetical person who agrees with the item "wear a hat" (*i.e.* skin cancer predisposition <0), a person who endorses the item "try to wear a hat less often" will be assigned a score well above 0. A Wilcoxon signed-ranks test indicated that the item location of concern about vitamin D were statistically significantly higher than the item location of sun-protection behavior ($Z = -2.023$, $P = 0.043$). This shows the potential effect of changing sun-protection behaviors.

## DISCUSSION

Approximately, one-quarter of the participants were concerned about their vitamin D status and believed they needed to spend more time in the sun. Although only 4% reported changing their hat-wearing behaviors, 15% reported that they tried to spend more time in the sun in the previous summer to synthesize enough vitamin D. Attitudes about vitamin D and changes in sun-protection behaviors were significantly related to each other and differed according to the latitude at which the participant lived.

The United States Preventive Services Task Force recently reviewed the evidence on the effect of vitamin D on fractures, cancers and other chronic disease prevention, and concluded that while there is some positive evidence for fracture prevention, the evidence for other chronic diseases is still inconclusive (47,48). Given the uncertainties surrounding the role of vitamin D in health, the known skin cancer-inducing effects of sun exposure, and our findings suggesting a close association between attitudes toward vitamin D and sun-exposure behavior, it is important to

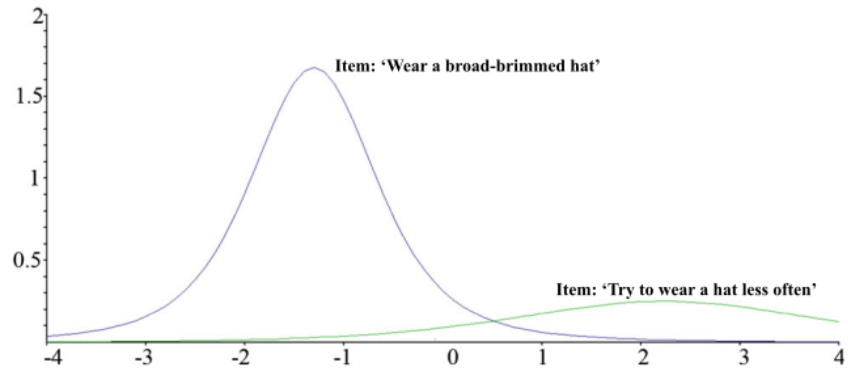


**Figure 1.** Item information functions from two items plotted along the latent trait logits of skin cancer predisposition. *Average skin cancer disposition is located at zero. **Graph indicating that if a person were to endorse the item "wear a broad-brimmed hat" their skin cancer risk is below average, whereas if they endorse the item "Last summer . . ., tried to wear a hat less often" risk is above 0 (average).

ensure that public concern about vitamin D does not jeopardize skin cancer prevention messages (28,29).

Item response theory models graphically highlight the potential impact of self-reported behavior change on skin cancer predisposition. Cancer Council Australia's Skin Cancer Committee has updated their skin cancer prevention messages to accommodate the balance between the risks and benefits of sun exposure; for example, they have contributed to a position statement which recommends sun protection if the UV Index is ≥3 but also "exposing the face, arms and hands or the equivalent area of skin to a few minutes of sunlight on either side of the peak UV periods on most days of the week" (49). A previous study (50) found that sun exposure to the arms and legs as little as two exposures per week of 5 min duration may be sufficient to main adequate vitamin D > 30 nmol $L^{-1}$ (depending on time of day, season, etc.). One of the concerns with changing the sun-protection messages provided by preventive health authorities is that people may be confused. For example, should they discard hats and sunscreen in order to optimize vitamin D regardless of where they live? Our finding that vitamin D-related attitudes and self-reported changes in sun-protective behaviors increased with increasing latitude is reassuring and is consistent with the messages and position statements issued by health authorities which recommend, for example, to discard use of hats only in the southern states of Australia in winter (51). Once adjusted for relevant confounders, latitude and 25OHD level, only people who worried about vitamin D, and those who specifically thought that they needed to spend more time in the sun for vitamin D production, had higher odds of having changed their sun-exposure behaviors. These findings suggest that people make choices about their sun exposure based on their attitudes and environment (latitude), and more research on these interactions is needed to determine what influences these attitudes. We previously found that people obtained information through the media (19,28), but in this study, we did not observe a strong association between having heard about vitamin D on the news and change in either attitudes or behaviors. Future work needs to explore this in more detail and should address important issues such as adding some questions about participants' knowledge of sun protection and vitamin D.

### Study limitations

The main limitation of this study was its cross-sectional design. Further research incorporating longitudinal assessment of 25OHD is needed to determine whether people who are worried about vitamin D status actually have lower 25OHD levels, and if so, whether additional sun exposure helps to increase these levels.

While the AusD Study recruited participants from a population-based register of all Australian voting adults, the participation rate was low, and only through its sampling requirements achieved a similar proportion of men and women. Results from this study may not be generalizable to general adult Australian population due to low response rate (9.1%). Participants were more likely than nonparticipants to be female (54.2% *vs* 47.2% ($P < 0.001$) and older than age 39 years ($P < 0.001$) (39).

Overall, this study attracted a higher proportion of women and older, indoor-working, well-educated participants compared with the underlying population. It is possible that these participants may have been more motivated to participate because they were more concerned about vitamin D than nonparticipants.

## CONCLUSION

We found that the strongest and most consistent determinant of self-reported sun-protection behavior changes due to concerns about vitamin D were attitudes and location, with those at higher latitudes worrying more. Further research is needed to understand what drives people's vitamin D-related attitudes. This information may be useful to inform public health strategies or to help people to make behavioral choices that are consistent with their values.

*Acknowledgements*—The authors thank the AusD investigators who provided the data extract used in this study. Ngadiman Djaja is supported by the National Health and Medical Research Council of Australia (NHMRC) CRESH PhD scholarship. Rachel E. Neale is funded by a NHMRC Senior Research Fellowship. Robyn M Lucas is supported by a NHMRC Career Development Fellowship.

## SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Demographic and phenotypic characteristics of the participants ($n$ = 1002).

**Figure S1.** The distribution of skin cancer predisposition (scores converted to *T* score). The *x*-axis shows the participants' skin cancer predisposition (converted to *T* score with mean = 50, SD = 10).

## REFERENCES


1. Armstrong, B. K., A. Kricker and D. R. English (1997) Sun exposure and skin cancer. *Australas. J. Dermatol.* **38**(Suppl. 1), S1–S6.
2. International Agency for Research on Cancer (1992) *Solar and Ultraviolet Radiation, Vol. 55* (Edited by I. A. f. R. o. Cancer). World Health Organization, Lyon.
3. Armstrong, B. K. and A. Kricker (1993) How much melanoma is caused by sun exposure? *Melanoma Res.* **3**, 395–401.
4. The International Agency for Research on Cancer (2009) Radiation: a review of human carcinogens. In *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Vol. 100 D.* Lyon.
5. World Health Organization, World Meteorological Organization, United Nations Environment Programme and International Commission on Non-Ionizing Radiation Protection (2002) *Global Solar UV Index: A Practical Guide* (Edited by WHO). World Health Organization, Geneva, Switzerland.
6. Ross, A. C., J. E. Manson, S. A. Abrams, J. F. Aloia, P. M. Brannon, S. K. Clinton, R. A. Durazo-Arvizu, J. C. Gallagher, R. L. Gallo, G. Jones, C. S. Kovacs, S. T. Mayne, C. J. Rosen and S. A. Shapses (2011) The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *J. Clin. Endocrinol. Metab.* **96**, 53–58.
7. Barnard, K. and C. Colon-Emeric (2010) Extraskeletal effects of vitamin D in older adults: cardiovascular disease, mortality, mood, and cognition. *Am. J. Geriatr. Pharmacother.* **8**, 4–33.
8. Ginde, A. A., R. Scragg, R. S. Schwartz and C. A. Camargo Jr (2009) Prospective study of serum 25-hydroxyvitamin D level, cardiovascular disease mortality, and all-cause mortality in older U.S. adults. *J. Am. Geriatr. Soc.* **57**, 1595–1603.
9. Tomson, J., J. Emberson, M. Hill, A. Gordon, J. Armitage, M. Shipley, R. Collins and R. Clarke (2013) Vitamin D and risk of death from vascular and non-vascular causes in the Whitehall study and meta-analyses of 12,000 deaths. *Eur. Heart J.* **34**, 1365–1374.
10. Bischoff-Ferrari, H. A., E. Giovannucci, W. C. Willett, T. Dietrich and B. Dawson-Hughes (2006) Estimation of optimal serum concentrations of 25-hydroxyvitamin D for multiple health outcomes. *Am. J. Clin. Nutr.* **84**, 18–28.
11. Ben-Shoshan, M. (2012) Vitamin D deficiency/insufficiency and challenges in developing global vitamin D fortification and supplementation policy in adults. *Int. J. Vitam. Nutr. Res.* **82**, 237–259.
12. Holick, M. F. (2013) Vitamin D, sunlight and cancer connection. *Anticancer Agents Med. Chem.* **13**, 70–82.
13. The Australia and New Zealand Bone and Mineral Society, Osteoporosis Australia, Australasian College of Dermatologists and The Cancer Council Australia (2007) Risks and benefits of sun exposure: position statement. Available at: http://www.cancer.org.au/policy-and-advocacy/position-statements/sun-smart/. Accessed on 20 July 2015.
14. Samanek, A. J., E. J. Croager, P. Gies, E. Milne, R. Prince, A. J. McMichael, R. M. Lucas and T. Slevin (2006) Estimates of beneficial and harmful sun exposure times during the year for major Australian population centres. *Med. J. Aust.* **184**, 338–341.
15. The Australian and New Zealand Bone and Mineral Society, Osteoporosis Australia, The Australian College of Dermatologists and The Cancer Council Australia (2007) *Risks and Benefits of Sun Exposure Position Statement*. Cancer Council Australia, Sydney, Australia. http://www.cancer.org.au/content/pdf/CancerControlPolicy/Position Statements/PSRisksBenefitsSunExposure03May07.pdf. Accessed on 22 November 2015.
16. Janda, M., M. Kimlin, D. Whiteman, J. Aitken and R. Neale (2007) Sun protection and low levels of vitamin D: are people concerned? *Cancer Causes Control* **18**, 1015–1019.
17. Scully, M., M. Wakefield and H. Dixon (2008) Trends in news coverage about skin cancer prevention, 1993–2006: increasingly mixed messages for the public. *Aust. N. Z. J. Public Health* **32**, 461–466.
18. Dixon, H., C. Warne, M. Scully, S. Dobbinson and M. Wakefield (2014) Agenda-setting effects of sun-related news coverage on public attitudes and beliefs about tanning and skin cancer. *Health Commun.* **29**, 173–181.
19. Langbecker, D., P. Youl, M. Kimlin, K. Remm and M. Janda (2011) Factors associated with recall of media reports about vitamin D and sun protection. *Aust. N. Z. J. Public Health* **35**, 159–162.
20. Bilinski, K. and S. Boyages (2012) The rise and rise of vitamin D testing. *BMJ* **345**, e4743.
21. Bilinski, K. and S. Boyages (2013) Evidence of overtesting for vitamin D in Australia: an analysis of 4.5 years of Medicare Benefits Schedule (MBS) data. *BMJ Open* **3**, 1–7.
22. The Department of Human Services (2014) Medicare Benefits Schedule (MBS). Available at: http://www.medicareaustralia.gov.au/provider/medicare/mbs.jsp. Accessed on 25 July 2015.
23. Bilinski, K. L. and S. C. Boyages (2012) The rising cost of vitamin D testing in Australia: time to establish guidelines for testing. *Med. J. Aust.* **197**, 90.
24. Glanz, K., B. K. Rimer and F. M. Lewis (2002) *Health Behavior and Health Education: Theory, Research, and Practice*, 3rd edn. Jossey-Bass, San Francisco, CA.
25. Vu, L. H., J. C. van der Pols, D. C. Whiteman, M. G. Kimlin and R. E. Neale (2010) Knowledge and attitudes about Vitamin D and impact on sun protection practices among urban office workers in Brisbane, Australia. *Cancer Epidemiol. Biomarkers Prev.* **19**, 1784–1789.
26. Youl, P. H., M. Janda and M. Kimlin (2009) Vitamin D and sun protection: the impact of mixed public health messages in Australia. *Int. J. Cancer* **124**, 1963–1970.
27. Janda, M., P. Youl, K. Bolz, C. Niland and M. Kimlin (2010) Knowledge about health benefits of vitamin D in Queensland Australia. *Prev. Med.* **50**, 215–216.
28. Nowak, M., S. L. Harrison, P. G. Buettner, M. Kimlin, D. Porter, L. Kennedy and R. Speare (2011) Vitamin D status of adults from tropical australia determined using two different laboratory assays: implications for public health messages. *Photochem. Photobiol.* **87**, 935–943.
29. Harrison, S., P. Büttner and M. Nowak (2005) Maternal beliefs about the reputed therapeutic uses of sun exposure in infancy and the postpartum period. *Australian Midwifery* **18**, 22–28.
30. Reid, C. A., S. A. Kolakowsky-Hayner, A. N. Lewis and A. J. Armstrong (2007) Modern psychometric methodology: applications of item response theory. *Rehabil. Couns. Bull.* **50**, 177–188.
31. Cella, D. and C.-H. Chang (2000) A discussion of item response theory and its applications in health status assessment. *Med. Care* **38**, II66–II72.
32. Hays, R. D., L. S. Morales and S. P. Reise (2000) Item response theory and health outcomes measurement in the 21st century. *Med. Care* **38**, II28–II42.
33. Warne, R. T., E. J. L. McKyer and M. L. Smith (2012) An introduction to item response theory for health behavior researchers. *Am. J. Health Behav.* **36**, 31–43.
34. Linacre, J. M. (2014) What is item response theory, IRT? A tentative taxonomy. *Rasch Meas Trans* **17**, 926–927.
35. da Rocha, N. S., E. Chachamovich, M. P. de Almeida Fleck and A. Tennant (2013) An introduction to Rasch analysis for Psychiatric practice and research. *J. Psychiatr. Res.* **47**, 141–148.
36. Leung, Y. Y., M. E. Png, P. Conaghan and A. Tennant (2014) A systematic literature review on the application of Rasch analysis in musculoskeletal disease – a special interest group report of OMERACT 11. *J. Rheumatol.* **41**, 159–164.
37. Lundgren-Nilsson, A., I. H. Jonsdottir, G. Ahlborg Jr and A. Tennant (2013) Construct validity of the Psychological General Well Being Index (PGWBI) in a sample of patients undergoing treatment for stress-related exhaustion: a Rasch analysis. *Health Qual. Life Outcomes* **11**, 2.
38. Waller, J., R. Ostini, L. A. Marlow, K. McCaffery and G. Zimet (2013) Validation of a measure of knowledge about human papillomavirus (HPV) using item response theory and classical test theory. *Prev. Med.* **56**, 35–40.
39. Brodie, A. M., R. M. Lucas, S. L. Harrison, I. A. F. van der Mei, B. Armstrong, A. Kricker, R. S. Mason, A. J. McMichael, M. Nowak, D. C. Whiteman and M. G. Kimlin (2013) The AusD Study: a population-based study of the determinants of serum 25-hydroxyvitamin

D concentration across a broad latitude range. *Am. J. Epidemiol.* **177**, 894–903.
40. Kimlin, M. G., R. M. Lucas, S. L. Harrison, I. van der Mei, B. K. Armstrong, D. C. Whiteman, A. Kricker, M. Nowak, A. M. Brodie and J. Sun (2014) The contributions of solar ultraviolet radiation exposure and other determinants to serum 25-hydroxyvitamin D concentrations in Australian adults: the AusD Study. *Am. J. Epidemiol.* **179**, 864–874.
41. Fitzpatrick, T. B. (1975) Soleil et peau. *J. Med. Esthet.* **2**, 33–34.
42. Andrich, D. (1978) A rating scale formulation for ordered response categories. *Psychometrika* **32**, 561–573.
43. De Ayala, R. J. (2009) *The Theory and Practice of Item Response Theory*. Guilford Press, New York.
44. Masters, G. N. (1982) A Rasch model for partial credit scoring. *Psychometrika* **47**, 149–174.
45. Adams, R., M. Wu and M. Wilson (2013) *ACER ConQuest 3.0.1*. ACER, Melbourne, Vic.
46. Wilson, M. (2005) *Constructing Measures: An Item Response Modeling Approach*. Lawrence Erlbaum Associates, Mahwah, NJ.
47. Chung, M., J. Lee, T. Terasawa, J. Lau and T. A. Trikalinos (2011) Vitamin D with or without calcium supplementation for prevention of cancer and fractures: an updated meta-analysis for the U.S. Preventive Services Task Force. *Ann. Intern. Med.* **155**, 827–838.
48. Lips, P., E. Gielen and N. M. van Schoor (2014) Vitamin D supplements with or without calcium to prevent fractures. *BoneKEy Rep.* **3**, 1–6.
49. Cancer Council Australia (2007) *Position Statement: Screening and Early Detection of Skin Cancer*. Cancer Council Australia, Sydney, Australia.
50. Holick, M. F. (2007) Vitamin D deficiency. *N. Engl. J. Med.* **357**, 266–281.
51. Nowson, C. A., J. J. McGrath, P. R. Ebeling, A. Haikerwal, R. M. Daly, K. M. Sanders, M. J. Seibel and R. S. Mason; Working Group of Australian and New Zealand Bone and Mineral Society, Endocrine Society of Australia and Osteoporosis Australia (2012) Vitamin D and health in adults in Australia and New Zealand: a position statement. *Med. J. Aust.* **196**, 686–687.

# 1_SELF ARTICLE

ORIGINALITY REPORT

| 8% | 8% | 1% | 0% |
| --- | --- | --- | --- |
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | | |
| --- | --- | --- | --- |
| 1 | qdoc.tips | Internet Source | 1% |
| 2 | www.sinclairdermatology.com.au | Internet Source | 1% |
| 3 | www.neps-data.de | Internet Source | 1% |
| 4 | uece.br | Internet Source | 1% |
| 5 | watermark.silverchair.com | Internet Source | 1% |
| 6 | protocolexchange.researchsquare.com | Internet Source | <1% |
| 7 | journal.frontiersin.org | Internet Source | <1% |
| 8 | docs.niwa.co.nz | Internet Source | <1% |
| 9 | www.jmir.org | Internet Source | <1% |

| | | |
|---|---|---|
| 10 | pesquisa.bvsalud.org<br>Internet Source | <1% |
| 11 | jissn.biomedcentral.com<br>Internet Source | <1% |
| 12 | pilarmartinescudero.com<br>Internet Source | <1% |
| 13 | www.dhhs.tas.gov.au<br>Internet Source | <1% |
| 14 | www.hindawi.com<br>Internet Source | <1% |
| 15 | www.nice.org.uk<br>Internet Source | <1% |
| 16 | www.fecpl.ca<br>Internet Source | <1% |
| 17 | www.aph.gov.au<br>Internet Source | <1% |
| 18 | multiple-sclerosis-research.blogspot.co.il<br>Internet Source | <1% |
| 19 | rasch.org<br>Internet Source | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | < 15 words |
| Exclude bibliography | On | | |