**Title: Vitamin D and Sun Protection: The impact of mixed public health messages in Australia**

Authors: Philippa H Youl,[1,2] Monika Janda,[3] Michael Kimlin[3]

[1] Viertel Centre for Research in Cancer Control, Cancer Council Queensland, Queensland Australia.
[2] Faculty of Population Health, University of Queensland, Australia
[3] Australian Sun and Health Research Laboratory, School of Public Health, Institute of Biomedical Innovation, Queensland University of Technology, Queensland Australia

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**Abbreviations:** UV, ultraviolet radiation; CATI, computer-assisted telephone interview; MED, Minimal Erythemal Dose; OR, odds ratio; CI, confidence interval.

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Balancing the possible benefits and known harms associated with UV exposure represents a challenge not only for health experts but also for the general public. This study shows a shift within the population towards increasing sun exposure for vitamin D. There is an urgent need to re-focus health messages regarding sun exposure and the need for continued sun protection practices particularly in areas with high levels of UV.

**Corresponding Author**
Philippa Youl
Viertel Centre for Research in Cancer Control
Cancer Council Queensland
PO Box 201
Spring Hill QLD
Australia
Tel: + 61 7 3258 2301
Fax: + 61 7 3258 2310
Email: pipyoul@cancerqld.org.au

**Abstract**

Exposure of the skin to sunlight can cause skin cancer and is also necessary for cutaneous vitamin D production. Media reports have highlighted the purported health benefits of vitamin D. Our aim was to examine attitudes and behaviours related to sun protection and vitamin D. A cross-sectional study of 2,001 residents in Queensland, Australia aged 20-70 years was undertaken. Information collected included: skin cancer risk factors; perceptions about levels of sun exposure required to maintain vitamin D; belief that sun protection increases risk of vitamin D deficiency; intention, and actual change in sun protection practices for adults and children. Multivariate models examined predictors of attitudinal and behavioural change. One-third (32%) believed a fair-skinned adult, and 31% thought a child required at least 30 minutes per day in summer sun to maintain vitamin D levels. Reductions in sun protection were reported by 21% of adults and 14% of children. Factors associated with belief that sun protection may result in not obtaining enough vitamin D included aged ≥ 60 years (OR=1.35, 95% CI 1.09-1.66) and having skin that tanned easily (OR=1.96, 95% CI 1.38-2.78). Participants from low income households, and those who frequently used sun protective clothing were more likely to have reduced sun protection practices (OR=1.33, 95% CI 1.10-1.73 and OR=1.73, 95% CI 1.36-2.20, respectively). This study provides evidence of reductions in sun protection practices in a population living in a high UV environment. There is an urgent need to re-focus messages regarding sun exposure and for continued sun protection practices.

## Introduction

Vitamin D, commonly referred to as the 'sunshine vitamin' is required for the preservation of calcium and phosphate blood levels and hence the maintenance of bone health. [1] While there are dietary sources of vitamin D, the main source (over 95%) is through exposure of 7-dehydrocholesteraol in the skin to ultraviolet radiation (UV) followed by two hydroxylation steps. [2] It has been estimated that Vitamin D production is maximised following exposure to one-third of a MED (Minimal Erythemal Dose). [2] Increasing the surface of the skin exposed to UV radiation also decreases the amount of time taken to synthesise vitamin D. It is known that UV induced DNA damage increases linearly with total exposure to sunlight. However the concentration of pre-vitamin D reaches a threshold after one MED. Thus increasing exposure of the skin to the sun does not necessary result in increased vitamin D production. [3]

Epidemiological studies have suggested that low vitamin D status may be associated with an increased risk of cancer. [4-6] Results from a US survey found no association between overall cancer mortality and serum vitamin D levels, but reported an approximate 70% reduction in risk of death from colorectal cancer.[7] Additionally, other studies have shown small survival benefits for melanoma, lung cancer and Non-Hodgkin lymphoma associated with sun exposure. [8-11] However, as most of these studies have been of an ecological or case-control design, and therefore subject to several biases, their results should be interpreted with caution.

It is well known that UV exposure is the primary cause of the vast majority of non-heritable skin cancers. [12] For squamous cell carcinoma (SCC) in particular the risk

increases linearly with total sun exposure. [13-16] In Australia, the lifetime risk of developing melanoma or non-melanoma skin cancer (NMSC) is 1 in 30 [17]and 1 in 2 [18] respectively, testimony to the mismatch between skin pigmentation and UV exposure. [19, 20] Therefore weighing up the health benefits and harms associated with UV exposure is challenging and continues to be debated.

The amount of UV exposure required to maintain adequate levels of vitamin D depends on several factors including latitude, ozone depletion, skin colour, sensitivity of skin to UV, and age, and research is ongoing to understand these complex relationships. [21] While a small study by Kimlin et al found [22] 10% of a sample of 127 healthy adults in South-East Queensland had serum 25 (OH) D levels below 25 nmol/l (considered deficient) and a further 32% had levels between 25 nmol/l and 50 nmol/l (considered insufficient), it is not known if this reflects the Queensland population at large. While sunscreen has been suggested to reduce vitamin D synthesis, [23] several studies have failed to show any evidence that regular use of sunscreen results in vitamin D deficiency. [24-26]

In a position statement released in 2007, the Cancer Council Australia in collaboration with leading medical bodies indicated that in summer anywhere in Australia a person with fair skin is able to achieve adequate levels of vitamin D (> 50 nmol/L) by exposing their face, arms and hands to sunlight for only a few minutes either side of the peak UV times on most days of the week. In winter, in areas at higher latitudes where UV is lower, individuals may require two to three hours exposure over a week. [27] It is now recommended that sun protection practices be reduced during winter

months for those living at higher latitudes, [28] while no such policy change has as yet been made by health authorities in lower latitude areas such as Queensland.

In 2004, we conducted a population-based survey to assess cancer risk factors and cancer screening behaviours. At that time we obtained information on attitudes towards sun protection and vitamin D and found that 15% agreed, and 39% were unsure, with the statement that ""if I regularly protect my skin from the sun I am in danger of not getting enough vitamin D". [29] Since that survey was conducted a significant amount of media attention has focussed on the issue of vitamin D deficiency, sun protection and cancer. A recent study in Australia examined trends in media coverage about skin cancer prevention, and found a significant increase in coverage of issues surrounding vitamin D. Further, this research highlighted that articles were more likely to report a "negative" effect of sun protection where they referred to vitamin D. [30] Given the recent increased media attention on the issue of vitamin D and health, and the level of population uncertainty, [31-33] we wanted to monitor attitudes and possible changes in sun protection behaviour due to concerns about healthy levels of vitamin D over time.

The aims of this project were to examine whether the prevalence of those who agree that sun protection may result in not getting enough vitamin D has changed since 2004, to assess if in consequence the population has changed their sun protective behaviour, and that of their children, due to concerns about vitamin D and to examine factors associated with these attitudes and behaviours in a high UV environment.

## Material and Methods

This cross-sectional study was conducted in the state of Queensland Australia, which spans from approximately 12°S to 27°S latitude and has a population of approximately 4 million with more than 50% living outside its capital city, Brisbane. Queensland residents aged 18 to 70, who spoke English, and who were not cognitively impaired were eligible to participate. Random digit dialling was used to ascertain households at equivalent quotas based on location (50% from Brisbane/metropolitan and 50% from rural and regional areas), sex (50% male and 50% female) and age group (18-49 years and 50-70 years). Based on Australian Bureau of Statistics (ABS) Population Census figures [34] we anticipated that approximately 30% of households would contain children under 13 years of age.

Data were obtained using computer-assisted telephone interviews (CATI) utilising a structured questionnaire. We collected information on:

*Skin cancer risk factors*: hair, eye and skin colour; sensitivity of skin to the sun, ability to tan, previous history of skin cancer.

*Knowledge about vitamin D*: "have you ever heard about vitamin D (yes, no, don't know); "Can you tell me what aspects of your health vitamin D is important for?" (unprompted response). Participants were then asked a series of prompted questions to elicit their knowledge about potential health benefits of vitamin D, including healthy bones and prevention of cancer (full list provided in Figure 1). Participants were also asked where they think the body gets vitamin D from, and their source of information (doctor, other health professional, media [print, TV, radio], internet and other sources), and whether they were ever prescribed a vitamin D supplement by their doctor or took over the counter supplements.

*Time spent in the sun to maintain healthy vitamin D level*: Participants were asked to estimate the amount of time in summer and in winter a fair-skinned person needs to spend in the sun in Queensland during the hours of 10am to 3pm in order to maintain a healthy vitamin D level (none, 5-10 minutes, 15-20 minutes, 30-60 minutes, more than one hour) and what parts of the body need to be exposed.

*Attitudes and behaviours*: was assessed by asking participants the identical question used in the 2004 survey [29]: "If I regularly protect my skin from the sun, I am in danger of not getting enough vitamin D" (strongly disagree, disagree, unsure, agree, strongly agree). We also examined participants' intention to change sun protection behaviours and actual change in sun protection behaviours due to concerns about maintaining healthy vitamin D levels.

*Current sun protection practices:* including the use of protective clothing, hats, sunscreen and sunglasses.

*Participants with children under 13 years*: we obtained information on the amount of sun exposure required to maintain healthy vitamin D levels, concern about vitamin D levels and current sun protection practices for their children under the age of 13 years.

*Media reports*: the interview also obtained information regarding perceptions of media messages about vitamin D and if the messages impacted on sun protection behaviours.

## Statistical Analysis

Descriptive statistical analyses were used to summarise participants' characteristics and proportions were compared using Chi-Square tests. For questions asking participants' level of agreement or disagreement with certain statements, we collapsed five categories into three due to small numbers in some categories. Multivariate

logistic regression models were fitted to examine predictors of 1) attitudes and 2) predictors of sun protection behaviour change. All variables with significant ($p<0.05$) bivariate associations as well as variables of a-priori interest (age, sex, skin colouring) were entered into the multivariate models. All analyses were weighted by age, gender and geographic location so that the actual results reflected the Queensland population 20 to 70 years. As there were no significant differences between rural and urban participants for any variables of interest, results are not reported further. All data were analysed using SAS version 9.1. [35]

Ultraviolet radiation exposures, presented as MED were extracted from data collected via an outdoor UV detector based at the Queensland University of Technology in Brisbane, Queensland. Total irradiances were calculated from this data for 10, 20 and 60 minute exposure times at 9am, 12pm and 3pm respectively. Figures 2 and 3 plot the exposure times participants estimated (y-axes on the left hand side) and also presents the associated measured UV exposure levels in Queensland (Brisbane) for summer and winter which a person with type 2 skin would be exposed to if they were to remain in the sun for 10, 20 or 60 minutes at 10am, 12pm and 3 pm (y-axes on the right hand side).

Ethics approval for this study was obtained from the Behavioural and Social Sciences Ethics Review Committee of University of Queensland. Informed consent was obtained at the time of interview.

**Results**

Of a total of 4,468 eligible households, 2,001 completed the survey (response rate=45%). Table 1 provides a description of the study group. Mean age was 45 years (similar for men and women). Approximately one-third had children under the age of 13 years and 25% had obtained a university degree. In relation to skin cancer risk factors nearly two-thirds (60%) had fair skin and around one-quarter (24%) indicated their skin tended to burn and not tan after exposure to the sun (Table 1).

*Knowledge about vitamin D*

The majority of participants (84%) had heard about vitamin D. Women, and those over the age of 60 years were significantly more likely to have heard about vitamin D ($\chi^2$ 57.9, p <0.001 and $\chi^2$ 9.8, p=0.04, respectively). The most frequently cited sources for obtaining information about vitamin D included the media (48%), doctors (12%) or pharmacists (8%).

In unprompted responses, participants indicated that vitamin D was beneficial for general health (22%), protecting the skin (20%), good for the bones (14%), good for eyesight (4%). When prompted, there were significant differences in knowledge about known or purported health benefits of vitamin D between men and women. Over half of women (59%) identified that vitamin D is beneficial for healthy bones compared to 40% of men ($\chi^2$ 114.3, p <0.001). Compared to men, women were also significantly more likely to identify that vitamin D is beneficial for the prevention of rickets ($\chi^2$ 184.1, p <0.001). However compared to women, more men indicated they thought vitamin D helped prevent skin cancer ($\chi^2$ 27.1, p <0.001) (Figure 1).

Approximately one-third of the group identified fatty fish as a source of vitamin D. More women than men identified milk as a source of vitamin D (36% and 28%

respectively) ($\chi^2$ 21.3, p <0.001). The majority of participants (82% of men and 90% of women) identified that vitamin D can be obtained by exposing the skin to the sun.

*How much sun (UV exposure) do you need to maintain a healthy vitamin D level?*

Nearly one-third of participants (32%) thought a fair-skinned person needed at least 30 minutes in the sun per day between the hours of 10am and 3pm in summer to maintain a healthy vitamin D level and for winter, 47% indicated 30 minutes or more was required on a daily basis (Figures 2 and 3).

*Attitudes and behaviors*

When asked "If I regularly protect my skin from the sun, I am in danger of not getting enough vitamin D" 32% agreed or strongly agreed and 16% were unsure.

Approximately 16% of participants intended to, and 21% indicated they already had, reduced their sun protective behaviours due to concerns about vitamin D levels. No significant differences were observed between men and women, or according to age. Of those who indicated they had changed their sun protective behaviours, approximately 20% did so on the advice of a health professional, and this was significantly more common for men ($\chi^2$ 9.5, p=0.002), and for those 60 years or older ($\chi^2$ 6.0, p=0.05) (Table 2).

*Who is concerned about Vitamin D?*

In the multivariate model (Table 3) factors associated with an increased likelihood of believing sun protection may result in not getting enough vitamin D included aged 60 years or older (OR=1.35, 95% CI 1.09-1.68) and having children under the age of 13 years (OR=1.38, 95% CI 1.15-1.56). Other factors positively associated included having skin that

tanned easily, belief that high levels of sun exposure are required to maintain healthy vitamin D levels, and participants who tried to tan in the past 12 months. Factors associated with a decreased likelihood of believing that sun protection may result in not getting enough vitamin D, included a high gross household income (OR=0.57, 95% CI 0.43-0.76), a history of skin cancer (OR=0.72, 95% CI 0.59-0.88), and frequent use of sunscreen (OR=0.79, 95% CI 0.63-0.98) (Table 3).

*Who has changed their sun protection behaviour due to Vitamin D concerns?*

Participants showing an increased likelihood of reducing their sun protection behaviours included those with a gross annual household income of less than $60,000 (OR=1.33, 95% CI 1.09-1.73), and a tendency to tan and not burn (OR=1.34, 95% CI 1.09-2.01). Participants indicating they covered up outdoors some of the time were nearly 80% more likely to have changed their sun protection behaviours. There were no variables within the fully adjusted model associated with a decreased likelihood of reduced sun protective behaviours (Table 4).

*Vitamin D, sun (UV) exposure and sun protection for children*

Approximately one third (31%) of parents said they thought their child needed at least 30 minutes a day in the sun in summer, and 43% indicated they required at least 30 minutes in winter (Figures 2 and 3). Over three-quarters (77%) thought their child was maintaining a healthy level of vitamin D. However, 12% were concerned their child was not maintaining a healthy vitamin D level, and nearly 14% had actually changed the sun protection behaviours for their child (Table 2).

In a logistic regression analysis factors associated with an increased likelihood of having reduced the sun protective behaviours for their children included parents with a high school

education and low income households (OR=1.65, 95% CI 1.12-2.41, and OR=1.56, 95% CI 1.10-2.27 respectively), parents with dark or olive skin (OR=2.04, 95% CI 1.31-2.99), and parents who indicated they thought their child required at least 30 minutes of exposure to the sun in summer to maintain a healthy vitamin D level (OR=2.13, 95% CI 1.46-3.09).

**Discussion**

Within the past 4 years, since our last cross-sectional survey [29] in the Queensland population, the percentage of people agreeing with the statement that sun protection could lead to not having enough vitamin D has increased by about 15 percentage points or 100% to a current figure of 32%. While both surveys were cross-sectional and did not interview the same people at both time periods, the surveys were conducted in the same population. The percentage changes are consistent with what we could expect under a dissemination of innovations model. In 2004, we may have observed the early adopters changing their sun protection attitudes based on scientific and subsequent media reports about beneficial effects of sun exposure for vitamin D, while now the early majority is following their lead. [36] The attitudinal effect is occurring at a faster rate than the actual behavioural change, where 21% of our participants reported a reduction in their own, and 14% a reduction in their children's (≤ 12 years), sun protection behaviour out of concern about vitamin D levels.

After adjustment for age, sex, skin colour and skin type, participants who usually undertook some sun protective behaviours, such as covering up when outdoors and using sunscreen, represented the group most likely to have changed their sun protective behaviours with respect to vitamin D. This finding may indicate that those who have earlier followed sun protection messages are now so concerned about their vitamin D levels they

are electing to reduce their sun protection practices, again consistent with dissemination theory.

Recent work by Samanek et al [37] indicated the times of UV exposure required to produce current recommended intakes of Vitamin D. For Brisbane, they suggested that in summer 2 to 6 minutes of solar UV exposure was required whilst in winter 4 to 17 minutes of exposure was required. This data varies significantly from the UV exposure times that the general public reported in this work. Data obtained in this study provides strong evidence that the public is confused about how much sun exposure is required to maintain healthy levels of vitamin D. A large proportion of the population estimated long time-periods of 15 minutes or more per day. Some reports in the US have recommended exposing hands, face & arms to a third to one half an MED in summer is required to maintain adequate levels of vitamin D, equivalent to about 5 minutes for those with type 2 skin. [38, 39] In Australia, current recommendations have been designed to reduce the confusion surrounding sun exposure and vitamin D (as outlined in the introduction). [27] However the results from this current study indicate that this strategy does not seem to have been successful. If a significant proportion of the Queensland population were to follow their current belief and expose themselves for up to 30 minutes or longer, this may result in them receiving high levels of UV radiation (as shown in Figures 2 and 3), a well established risk factor for skin cancer.

Due to the complexity of the vitamin D issue and the variety of factors people need to take into account when calculating sun exposure, such as their skin type, occupation, location of residence, cloud coverage and so on, a more individualised approach of information provision must be taken. This is not uncommon in health. For example, a similarly

complicated picture of potential benefits and risks exists with regards to information provision around screening for prostate cancer using prostate specific antigen (PSA). The current recommendation in Australia is to provide men with decision aids to make an informed choice. [40] In this study we found that approximately half those surveyed had heard about vitamin D through the media and only a minority through a doctor or other health professional. Thus given the complexity of this issue it maybe necessary for health professionals to take a more active educative role.

Around one-third of those surveyed thought that vitamin D helped prevent cancer. A number of studies have reported inverse relationships between vitamin D and incidence or mortality for some cancers (primarily prostate, colorectal and breast cancer), [5, 6, 41-43] and these studies have tended to feature prominently in the popular press. It should be noted however that a number of these studies have examined the effect of vitamin D supplementation in their intervention and not increased sun exposure. Other studies failing to find a relationship between vitamin D levels and the prevention of cancers [44-48] have received less press. The conflicting results of these studies highlight the uncertainty surrounding the possible cancer preventive benefits of vitamin D. Meanwhile evidence that excessive sun exposure is the main cause of skin cancer has been available for decades. [13, 49-52] Skin cancer is associated with significant morbidity, and associated health care costs. [53, 54] Additionally, it is estimated that melanoma will account for 8,420 deaths in the USA in 2008 and has accounted for over 1,200 deaths in Australia in 2003. [17, 55] Some evidence now suggests a stabilisation in the incidence of melanoma in younger cohorts, which has been attributed to two decades of public health messages.[56] Recent media reports could be responsible for our observation of an attitude and behaviour change with regards to sun protection.

In this study participants who agreed that they may be in danger of not obtaining enough vitamin D if they regularly protect their skin displayed a tendency towards increased levels of sun exposure, e.g. believed that a suntanned person looked healthier and thought that more than 10 minutes of daily sun exposure were required for a healthy vitamin D level. It is therefore possible that those who usually display less sun protective behaviours now feel they can "legitimately" go unprotected. There has been strong evidence to suggest that those who purposely attempt to tan are likely to be young adults and teenagers who have sun sensitive skin. [57] However this is also the group who is least likely to have low levels of vitamin D. [3] It would be beneficial therefore for media reports to also feature the potential harms associated with increasing sun exposure or reducing sun protection.

Strengths of this study are its large sample size and population-based design. Limitations include the response rate of approximately 45%. While this could be considered low, it is in line with many studies where ascertainment is by random digit dialling. Some recent methodological studies have failed to show associations between response rates and bias. [58, 59] We compared our study sample to ABS Population Census figures and found it broadly representative of the Queensland population with the exception that our participants were slightly more educated, married, and in full-time work. [34] An additional limitation is that the cross-sectional nature of the survey prohibits the establishment of causality.

This study has provided evidence regarding the level of population uncertainty and concern about vitamin D and sun exposure, leading to reduced sun protection practices in up to 20% of the population. This is of great concern, as this part of Australia has the highest rates of skin cancer in the world, with high levels of year round UV radiation. There is also

evidence that the current tailoring of public health messages regarding sun exposure and vitamin D, are causing confusion in the population. There is an urgent need to re-focus health messages regarding sun exposure and the need for continued sun protection practices. If not potentially we may witness an increase in rates of skin cancer in the future.

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**References**


1. Holick MF. Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. Am J Clin Nutr 2004;80:1678S-88S.
2. Holick MF, MacLaughlin JA, Clark MB, Holick SA, Potts JT Jr, Anderson RR, Blank IH, Parrish JA, Elias P. Photosynthesis of previtamin D3 in human skin and the physiologic consequences. Science 1980;210:203-5.
3. Wolpowitz D, Gilchrest BA. The vitamin D questions: how much do you need and how should you get it? J Am Acad Dermatol 2006;54:301-17.
4. Holick MF. Vitamin D: its role in cancer prevention and treatment. Prog Biophys Mol Biol 2006;92:49-59.
5. Grau MV, Baron JA, Sandler RS, Haile RW, Beach ML, Church TR, Heber D. Vitamin D, calcium supplementation, and colorectal adenomas: results of a randomized trial. J Natl Cancer Inst 2003;95:1765-71.
6. Garland CF, Garland FC, Gorham ED, Lipkin M, Newmark H, Mohr SB, Holick MF. The role of vitamin D in cancer prevention. Am J Public Health 2006;96:252-61.
7. Freedman DM, Looker AC, Chang SC, Graubard BI. Prospective study of serum vitamin D and cancer mortality in the United States. J Natl Cancer Inst 2007;99:1594-602.
8. Berwick M, Armstrong BK, Ben-Porat L, Fine J, Kricker A, Eberle C, Barnhill R. Sun exposure and mortality from melanoma. J Natl Cancer Inst 2005;97:195-9.
9. Giovannucci E, Liu Y, Rimm EB, Hollis BW, Fuchs CS, Stampfer MJ, Willett WC. Prospective study of predictors of vitamin D status and cancer incidence and mortality in men. J Natl Cancer Inst 2006;98:451-9.
10. Hughes AM, Armstrong BK, Vajdic CM, Turner J, Grulich AE, Fritschi L, Milliken S, Kaldor J, Benke G, Kricker A. Sun exposure may protect against non-Hodgkin lymphoma: a case-control study. Int J Cancer 2004;112:865-71.
11. Zhou W, Suk R, Liu G, Park S, Neuberg DS, Wain JC, Lynch TJ, Giovannucci E, Christiani DC. Vitamin D is associated with improved survival in early-stage non-small cell lung cancer patients. Cancer Epidemiol Biomarkers Prev 2005;14:2303-9.
12. Lucas R, McMichael T, Smith R, Armstrong BK, Global burden of disease from solar ultraviolet radiation. World Health Organisation, 2006.
13. Armstrong BK, Kricker A. Epidemiology of sun exposure and skin cancer. Cancer Surv 1996;26:133-53.
14. English DR, Armstrong BK, Kricker A, Winter MG, Heenan PJ, Randell PL. Case-control study of sun exposure and squamous cell carcinoma of the skin. Int J Cancer 1998;77:347-53.
15. Rosso S, Zanetti R, Martinez C, Tormo MJ, Schraub S, Sancho-Garnier H, Franceschi S, Gafa L, Perea E, Navarro C, Laurent R, Schrameck C, et al. The multicentre south European study 'Helios'. II: Different sun exposure patterns in the aetiology of basal cell and squamous cell carcinomas of the skin. Br J Cancer 1996;73:1447-54.
16. Zanetti R, Rosso S, Martinez C, Nieto A, Miranda A, Mercier M, Loria DI, Osterlind A, Greinert R, Navarro C, Fabbrocini G, Barbera C, et al. Comparison of risk patterns in carcinoma and melanoma of the skin in men: a multi-centre case-case-control study. Br J Cancer 2006;94:743-51.

17. Australian Institute of Health and Welfare (AIHW) & Australasian Associations of Cancer Registries (AACR), Cancer in Australia, An overview 2006. AIHW 2007.
18. Staples MP, Elwood M, Burton RC, Williams JL, Marks R, Giles GG. Non-melanoma skin cancer in Australia: the 2002 national survey and trends since 1985. Med J Aust 2006;184:6-10.
19. Diamond J. Evolutionary biology: geography and skin colour. Nature 2005;435:283-4.
20. Jablonski NG, Chaplin G. The evolution of human skin coloration. J Hum Evol 2000;39:57-106.
21. Olds WJ, McKinley AR, Moore MR, Kimlin MG. In vitro model of vitamin D(3) (Cholecalciferol) synthesis by UV radiation: Dose-response relationships. J Photochem Photobiol B 2008.
22. Kimlin M, Harrison S, Nowak M, Moore M, Brodie A, Lang C. Does a high UV environment ensure adequate vitamin D status? J Photochem Photobiol B 2007;89:139-47.
23. Matsuoka LY, Ide L, Wortsman J, MacLaughlin JA, Holick MF. Sunscreens suppress cutaneous vitamin D3 synthesis. J Clin Endocrinol Metab 1987;64:1165-8.
24. Matsuoka LY, Wortsman J, Hanifan N, Holick MF. Chronic sunscreen use decreases circulating concentrations of 25-hydroxyvitamin D. A preliminary study. Arch Dermatol 1988;124:1802-4.
25. Marks R, Foley PA, Jolley D, Knight KR, Harrison J, Thompson SC. The effect of regular sunscreen use on vitamin D levels in an Australian population. Results of a randomized controlled trial. Arch Dermatol 1995;131:415-21.
26. Farrerons J, Barnadas M, Rodriguez J, Renau A, Yoldi B, Lopez-Navidad A, Moragas J. Clinically prescribed sunscreen (sun protection factor 15) does not decrease serum vitamin D concentration sufficiently either to induce changes in parathyroid function or in metabolic markers. Br J Dermatol 1998;139:422-7.
27. The Cancer Council Australia. The risks and benefits of sun exposure, 2007.
28. The Cancer Council Victoria. It's May, so put hats away, 2008.
29. Janda M, Kimlin M, Whiteman D, Aitken J, Neale R. Sun protection and low levels of vitamin D: are people concerned? Cancer Causes Control 2007;18:1015-9.
30. Scully M, Wakefield M, Dixon H. Trends in news coverage about skin cancer prevention, 1993-2006: increasingly mixed messages for the public. Aust N Z J Public Health 2008;32:461-6.
31. Cairns Post. Daily dose of sun cuts cancer risk by half The Cairns Post Cairns, 2006.
32. The Gold Coast Bulletin. Lack of sun a hazard to health The Gold Coast Bulletin Brisbane, 2006.
33. Townsville Bulletin. Sunburnt land lacks vitamin D Townsville, 2006.
34. Australian Bureau of Statistics. 2006 Census of Population and Housing, 2007.
35. SAS Institute. SAS Computer Software, ed. 9.1 Carey, N.C., 2001.
36. Berwick DM. Disseminating innovations in health care. JAMA 2003;289:1969-75.
37. Samanek AJ, Croager EJ, Giesfor P, Milne E, Prince R, McMichael AJ, Lucas RM, Slevin T. Estimates of beneficial and harmful sun exposure times during the year for major Australian population centres. Med J Aust 2006;184:338-41.

38. Reichrath J. The challenge resulting from positive and negative effects of sunlight: how much solar UV exposure is appropriate to balance between risks of vitamin D deficiency and skin cancer? Prog Biophys Mol Biol 2006;92:9-16.
39. Webb AR, Kline L, Holick MF. Influence of season and latitude on the cutaneous synthesis of vitamin D3: exposure to winter sunlight in Boston and Edmonton will not promote vitamin D3 synthesis in human skin. J Clin Endocrinol Metab 1988;67:373-8.
40. Baade PD, Steginga SK, Pinnock CB, Aitken JF. Communicating prostate cancer risk: what should we be telling our patients? Med J Aust 2005;182:472-5.
41. Holick MF. Vitamin D: importance in the prevention of cancers, type 1 diabetes, heart disease, and osteoporosis. Am J Clin Nutr 2004;79:362-71.
42. Garland CF, Garland FC, Gorham ED. Can colon cancer incidence and death rates be reduced with calcium and vitamin D? Am J Clin Nutr 1991;54:193S-201S.
43. Grant WB, Garland CF. Evidence supporting the role of vitamin D in reducing the risk of cancer. J Intern Med 2002;252:178-9; author reply 9-80.
44. Tamimi RM, Lagiou P, Adami HO, Trichopoulos D. Prospects for chemoprevention of cancer. J Intern Med 2002;251:286-300.
45. Hartman TJ, Albert PS, Snyder K, Slattery ML, Caan B, Paskett E, Iber F, Kikendall JW, Marshall J, Shike M, Weissfeld J, Brewer B, et al. The association of calcium and vitamin D with risk of colorectal adenomas. J Nutr 2005;135:252-9.
46. Gross MD. Vitamin D and calcium in the prevention of prostate and colon cancer: new approaches for the identification of needs. J Nutr 2005;135:326-31.
47. Tuohimaa P, Tenkanen L, Ahonen M, Lumme S, Jellum E, Hallmans G, Stattin P, Harvei S, Hakulinen T, Luostarinen T, Dillner J, Lehtinen M, et al. Both high and low levels of blood vitamin D are associated with a higher prostate cancer risk: a longitudinal, nested case-control study in the Nordic countries. Int J Cancer 2004;108:104-8.
48. Wactawski-Wende J, Kotchen JM, Anderson GL, Assaf AR, Brunner RL, O'Sullivan MJ, Margolis KL, Ockene JK, Phillips L, Pottern L, Prentice RL, Robbins J, et al. Calcium plus vitamin D supplementation and the risk of colorectal cancer. N Engl J Med 2006;354:684-96.
49. Armstrong BK, Kricker A, English DR. Sun exposure and skin cancer. Australas J Dermatol 1997;38 Suppl 1:S1-6.
50. Elwood JM, Jopson J. Melanoma and sun exposure: an overview of published studies. Int J Cancer 1997;73:198-203.
51. Kricker A, Armstrong BK, English DR. Sun exposure and non-melanocytic skin cancer. Cancer Causes Control 1994;5:367-92.
52. Kricker A, Armstrong BK, English DR, Heenan PJ. Does intermittent sun exposure cause basal cell carcinoma? a case-control study in Western Australia. Int J Cancer 1995;60:489-94.
53. Australian Institute of Health and Welfare, Health system expenditure on cancer and other neoplasms in Australia, 2000-01. AIHW (Health and Welfare Expenditure Series no. 22). 2005.
54. Housman TS, Feldman SR, Williford PM, Fleischer AB, Goldman ND, Acostamadiedo JM, Chen GJ. Skin cancer is among the most costly of all cancers to treat for the Medicare population. J Am Acad Dermatol 2003;48:425-9.
55. American Cancer Society. Cancer Facts and Figures 2008 2008.

56. Coory M, Baade P, Aitken J, Smithers M, McLeod GR, Ring I. Trends for in situ and invasive melanoma in Queensland, Australia, 1982-2002. Cancer Causes Control 2006;17:21-7.
57. Geller AC, Brooks DR, Colditz GA, Koh HK, Frazier AL. Sun protection practices among offspring of women with personal or family history of skin cancer. Pediatrics 2006;117:e688-94.
58. Keeter S, Miller C, Kohut A, Groves RM, Presser S. Consequences of reducing nonresponse in a national telephone survey. Public Opin Q 2000;64:125-48.
59. Curtin R, Presser S, Singer E. The effects of response rate changes on the index of consumer sentiment. Public Opin Q 2000;64:413-28.

**Table I**: SOCIO-DEMOGRAPHIC AND SKIN CANCER RISK CHARACTERISTICS OF 2,001 STUDY PARTICIPANTS

| | N[1] | %[2] |
|---|---|---|
| **Sex** | | |
| Male | 1001 | 50.1 |
| Female | 1000 | 49.9 |
| **Age group** | | |
| 20 – 29 years | 252 | 7.1 |
| 30 – 39 years | 430 | 18.3 |
| 40 – 49 years | 526 | 26.5 |
| 50 – 59 years | 513 | 29.9 |
| 60+ years | 280 | 18.2 |
| **Location** | | |
| Brisbane/Metropolitan region | 1000 | 34.0 |
| Outer regional / rural | 1001 | 66.1 |
| **Marital status** | | |
| Married/living together | 1,444 | 74.5 |
| Divorced/separated/widowed | 243 | 12.6 |
| Never married | 310 | 12.9 |
| **Education** | | |
| Primary/no formal schooling | 26 | 1.8 |
| Some high school | 541 | 30.7 |
| Completed high school | 526 | 24.6 |
| Trade/technical certificate | 373 | 17.8 |
| University/college | 526 | 25.1 |
| **Employment** | | |
| Full-time | 1113 | 54.0 |
| Part-time/casual | 417 | 21.6 |
| Home duties/home carer | 145 | 7.1 |
| Unemployed | 55 | 2.4 |
| Retired | 188 | 11.0 |
| Other | 79 | 3.9 |
| **Gross annual household income** | | |
| Less than $20,000 | 154 | 8.7 |
| $20,000 to less than $60,000 | 689 | 34.9 |
| $60,000 to less than $100,000 | 513 | 24.5 |
| ≥ $100,000 | 352 | 17.0 |
| Unwilling to answer | 173 | 8.8 |
| Don't know | 120 | 6.1 |
| **Private health insurance** | | |
| Yes | 1147 | 59.1 |
| No | 844 | 40.9 |
| **Households with children ≤ 12 years** | | |
| None | 1340 | 70.6 |
| One child | 250 | 11.1 |
| Two or more | 411 | 18.3 |
| **Skin colour** | | |
| Fair | 1191 | 60.3 |
| Medium | 502 | 25.0 |
| Olive/brown/black | 307 | 14.7 |
| **Skin sensitivity** [3] | | |
| Burn and not tan afterwards | 467 | 23.6 |
| Burn then tan | 936 | 46.9 |
| Tan slightly without burning | 456 | 23.0 |
| Tan a lot without burning | 131 | 6.5 |
| **History of any type of skin cancer** | | |
| Yes | 429 | 23.8 |
| No | 1563 | 76.2 |

[1] total may vary due to missing values, [2] Percentages weighted to the Queensland population, [3] Skin sensitivity assessed by asking "If you were exposed to strong sun for 30 minutes at the beginning of summer, would your skin..."

**Table II:** ATTITUDES AND BEHAVIORS ABOUT SUN PROTECTION AND VITAMIN D LEVELS

| | n | % [1] |
|---|---|---|
| **Do you think you are maintaining a healthy vitamin D level?** | | |
| Yes | 1190 | 59.5 |
| No | 142 | 6.5 |
| Don't know | 669 | 34.0 |
| **Are you concerned about not maintaining a health vitamin D level?** | | |
| Yes | 235 | 11.7 |
| No | 1623 | 81.0 |
| Don't know | 143 | 7.3 |
| **Intend to change sun protective behaviours because of vitamin D levels** | | |
| Yes | 320 | 15.8 |
| No | 1577 | 81.1 |
| Don't know | 81 | 3.8 |
| **Changed sun protective behaviours due to concern about vitamin D levels** | | |
| Yes | 412 | 20.5 |
| No | 1542 | 77.2 |
| Don't know | 47 | 2.3 |
| **Believe that sun protection may result in not getting enough vitamin D** | | |
| Strongly disagree/disagree | 1059 | 52.2 |
| Agree/strongly agree | 647 | 32.2 |
| Unsure | 295 | 15.5 |
| **Do you think your child/children are maintaining a healthy vitamin D level? [2]** | | |
| Yes | 507 | 77.0 |
| No | 16 | 2.1 |
| Don't know | 138 | 20.9 |
| **Are you concerned your child/children are not maintaining a healthy vitamin D level?** | | |
| Yes | 75 | 11.9 |
| No | 552 | 83.0 |
| Don't know | 34 | 5.1 |
| **Changed sun protective behaviours for child/children due to concern about vitamin D levels** | | |
| Yes | 98 | 13.9 |
| No | 527 | 80.2 |
| Don't know | 36 | 5.9 |

[1] percentages weighted to the Queensland population, [2] figures based on 661 participants who indicated they had children under the age of 13 years

**Table III:** FACTORS ASSOCIATED WITH BELIEF THAT IF YOU REGULARLY PROTECT SKIN FROM THE SUN YOU ARE IN DANGER OF VITAMIN D DEFICIENCY: AGREE/STRONGLY AGREE VERSUS DISAGREE/STRONGLY DISAGREE/UNSURE

| | If I regularly protect my skin from the sun I am in danger of not getting enough vitamin D | | | | Adjusted[1] Odds Ratio (95% CI) | |
|---|---|---|---|---|---|---|
| | 32.2% Agree | 15.5% Unsure | 52.2% Disagree | $\chi^2$, p value | Agree versus unsure or disagree | |
| **Sex** | | | | 32.3, < 0.001 | | |
| Female | 31.2 | 12.7 | 56.1 | | 1.00 | |
| Male | 33.3 | 18.4 | 48.4 | | 1.10 | 0.93-1.30 |
| **Age** | | | | 30.9, < 0.001 | | |
| 20 – 39 years | 32.1 | 14.1 | 53.7 | | 1.00 | |
| 40 – 59 years | 30.7 | 14.8 | 54.5 | | 1.05 | 0.86-1.27 |
| 60 – 75 years | 37.1 | 19.8 | 43.1 | | 1.35 | 1.09-1.66 |
| **Education** | | | | 58.7, < 0.001 | | |
| Primary/junior high | 33.7 | 19.2 | 47.1 | | 1.00 | |
| Completed high school | 36.5 | 14.1 | 49.4 | | 1.35 | 1.12-1.62 |
| Trade/technical/diploma | 32.6 | 14.1 | 53.2 | | 1.02 | 0.82-1.26 |
| University | 26.0 | 12.7 | 61.3 | | 0.96 | 0.78-1.19 |
| **Gross household income** | | | | 36.7, < 0.001 | | |
| Less than $20,000 | 39.4 | 18.2 | 42.4 | | 1.00 | |
| $20,000 - $59,999 | 34.8 | 14.7 | 50.6 | | 0.83 | 0.64-1.08 |
| $60,000 – 79,999 | 30.8 | 13.2 | 56.0 | | 0.75 | 0.55-1.02 |
| $80,000+ | 26.6 | 15.8 | 57.6 | | 0.57 | 0.43-0.76 |
| **Children under the age of 13 yrs** | | | | 3.1, 0.21 | | |
| No | 31.4 | 15.5 | 53.1 | | 1.00 | |
| Yes | 34.1 | 15.7 | 50.2 | | 1.38 | 1.15-1.67 |
| **Skin colour** | | | | 32.3, < 0.001 | | |
| Fair | 29.1 | 16.4 | 54.5 | | 1.00 | |
| Medium | 35.2 | 13.8 | 51.1 | | 1.13 | 0.93-1.37 |
| Olive/dark | 40.2 | 15.1 | 44.8 | | 1.37 | 1.08-1.74 |
| **Tendency to burn after 30 mins of unprotected sun exposure** | | | | 25.6, 0.003 | | |
| Burn and not tan afterwards | 28.9 | 15.1 | 56.0 | | 1.00 | |
| Burn then tan | 31.0 | 15.1 | 53.9 | | 1.07 | 0.87-1.31 |
| Tan slightly without burning | 35.3 | 16.7 | 48.0 | | 1.15 | 0.90-1.48 |
| Tan a lot without burning | 41.8 | 15.5 | 42.7 | | 1.96 | 1.38-2.78 |
| **History of skin cancer** | | | | 22.6, < 0.001 | | |
| No | 34.2 | 15.6 | 50.2 | | 1.00 | |
| Yes | 26.2 | 15.4 | 58.4 | | 0.72 | 0.59-0.89 |
| **Believe suntanned person looks healthy** | | | | 58.9, < 0.001 | | |
| Strongly disagree/disagree | 27.7 | 16.2 | 56.1 | | 1.00 | |
| Agree/strongly agree | 39.6 | 13.7 | 46.7 | | 1.77 | 1.51-2.07 |
| **Sun exposure required to maintain vitamin D level** [2] | | | | 356.2, < 0.001 | | |
| Nil to less than 10 minutes | 26.5 | 10.4 | 63.1 | | 1.00 | |
| 15 to 20 minutes | 35.1 | 10.4 | 54.5 | | 1.59 | 1.27-1.98 |
| 30 minutes or more | 38.7 | 12.4 | 48.9 | | 1.58 | 1.29-1.93 |
| Don't know | 27.1 | 38.5 | 34.4 | | 1.01 | 0.78-1.31 |
| **Use sunscreen when outdoors in the sun** | | | | 51.6, < 0.001 | | |
| Never/little of the time | 37.9 | 17.5 | 44.6 | | 1.00 | |
| Some of the time | 29.8 | 12.0 | 58.2 | | 0.78 | 0.63-0.98 |
| Most of the time/always | 29.3 | 15.7 | 55.0 | | 0.88 | 0.73-1.06 |

[1] Model is fully adjusted for all factors in the table; [2] "Between the hours of 10am and 3pm in Queensland in summer approximately how much time do you think a fair skinned person needs in the sun per day to maintain a healthy Vitamin D level?"

**TABLE IV:** FACTORS ASSOCIATED WITH A REDUCTION IN SUN PROTECTION BEHAVIOR DUE TO CONCERN ABOUT NOT MAINTAINING HEALTHY LEVELS OF VITAMIN D – RESULTS OF FULLY ADJUSTED MODEL

| | Adjusted [1] Odds Ratio (95% CI) | |
|---|---|---|
| **Sex** | | |
| Female | 1.00 | |
| Male | 0.96 | 0.80-1.16 |
| **Age** | | |
| 20 – 39 years | 1.00 | |
| 40 – 59 years | 0.94 | 0.76-1.16 |
| 60 – 75 years | 1.13 | 0.84-1.51 |
| **Education** | | |
| Primary school/junior high | 1.00 | |
| Completed high school | 0.95 | 0.77-1.18 |
| Trade/technical/diploma | 1.13 | 0.89-1.42 |
| University | 0.91 | 0.72-1.15 |
| **Gross household income** | | |
| Less than $20,000 | 1.00 | |
| $20,000 - $59,999 | 1.33 | 1.10-1.73 |
| $60,000 - $79,000 | 1.21 | 0.84-1.74 |
| $80,000+ | 1.06 | 0.76-1.50 |
| **Skin colour** | | |
| Fair | 1.00 | |
| Medium | 1.07 | 0.86-1.32 |
| Olive/dark | 1.24 | 1.00-1.45 |
| **History of skin cancer** | | |
| No | 1.00 | |
| Yes | 1.26 | 1.02-1.56 |
| **Sun exposure required to maintain vitamin D level** [2] | | |
| Nil to less than 10 minutes | 1.00 | |
| 15 to 20 minutes | 1.05 | 0.81-1.34 |
| 30 minutes or more | 1.25 | 1.05-1.56 |
| Don't know | 0.84 | 0.62-1.13 |
| **Cover up when outdoors in the sun** | | |
| Never/little of the time | 1.00 | |
| Some of the time | 1.73 | 1.36-2.20 |
| Most of the time/always | 1.55 | 1.24-1.93 |
| **Use sunscreen when outdoors in the sun** | | |
| Never/little of the time | 1.00 | |
| Some of the time | 1.00 | 0.78-1.29 |
| Most of the time/always | 1.32 | 1.06-1.63 |

[1] Model is fully adjusted for all above factors, [2] Between the hours of 10am and 3pm in Queensland in summer approximately how much time do you think a fair skinned person needs in the sun per day to maintain a healthy Vitamin D level?"

**FIGURE I:** PERCENTAGE REPORTING KNOWLEDGE ABOUT PURPORTED HEALTH BENEFITS OF VITAMIN D

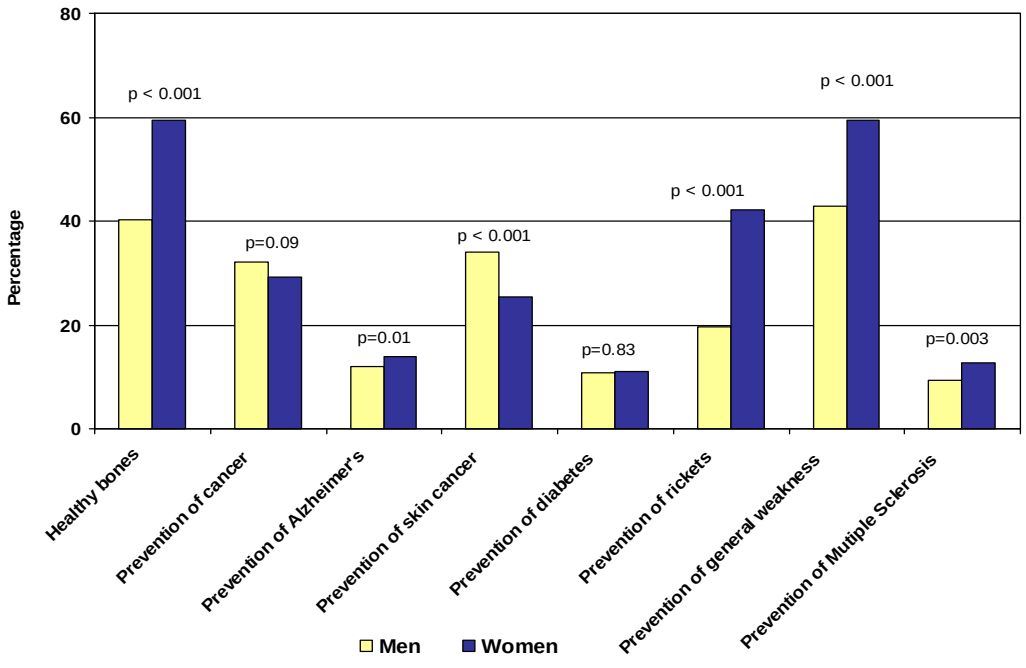

**FIGURE II:** PERCENTAGE REPORTING WHERE THE BODY CAN OBTAIN VITAMIN D FROM

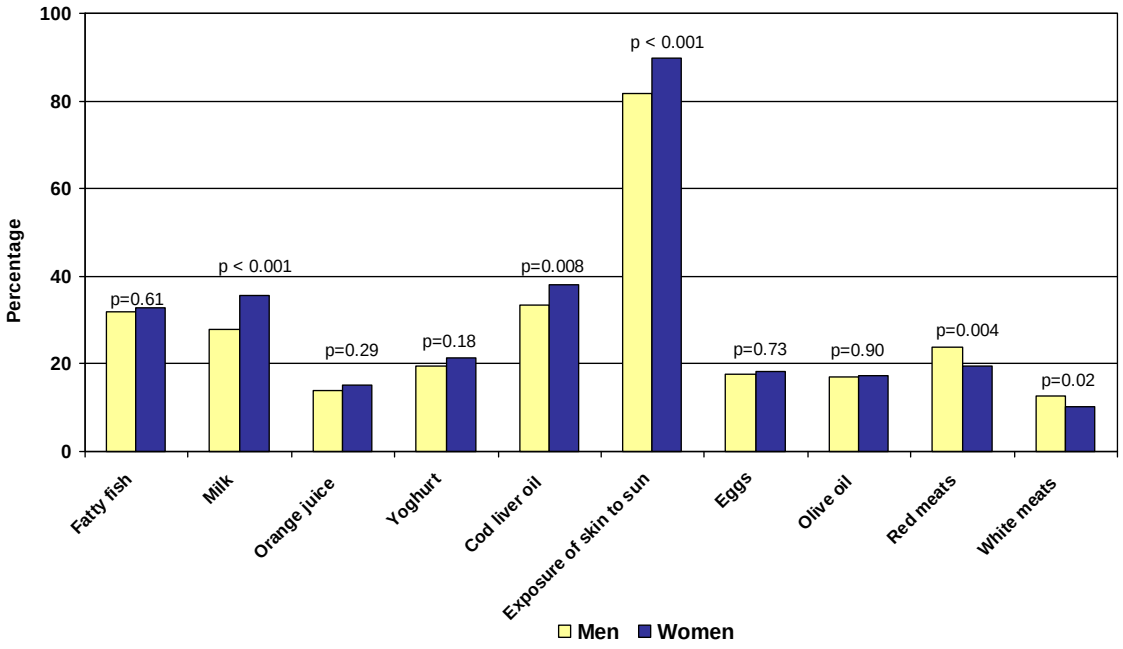

**FIGURE III:** AMOUNT OF TIME FAIR-SKINNED PERSON NEEDS TO SPEND IN THE SUN TO MAINTAIN VITAMIN D LEVELS