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# Sunbed use during adolescence and early adulthood is associated with increased risk of early-onset melanoma

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## Abstract

Sunbed use is associated with increased risk of melanoma. Younger people might be more susceptible to the carcinogenic effects of ultraviolet radiation. We investigated the association between sunbed use and risk of early-onset cutaneous malignant melanoma. From the Australian Melanoma Family Study, a multi-centre, population-based, case-control-family study, we analysed data for 604 cases diagnosed between ages 18 and 39 years and 479 controls. Data were collected by interview. Associations were estimated as odds ratios (ORs) using unconditional logistic regression, adjusting for age, sex, city, education, family history, skin colour, usual skin response to sunlight, and sun exposure. Compared with having never used a sunbed, the OR for melanoma associated with ever-use was 1.41 (95% confidence interval (CI) 1.01-1.96), and 2.01 (95% CI 1.22-3.31) for more than 10 lifetime sessions ($P_{trend}$ 0.01 with cumulative use). The association was stronger for earlier age at first use ($P_{trend}$ 0.02). The association was also stronger for melanoma diagnosed when aged 18-29 years (OR for more than 10 lifetime sessions = 6.57, 95% CI 1.41-30.49) than for melanoma diagnosed when 30-39 years (OR 1.60, 95% CI 0.92-2.77; $P_{interaction}$ 0.01). Among those who had ever used a sunbed and were diagnosed between 18-29 years of age, three quarters (76%) of melanomas were attributable to sunbed use. Sunbed use is associated with increased risk of early-onset melanoma, with risk increasing with greater use, an earlier age at first use and for earlier onset disease.

### Keywords

sunbed; artificial tanning; melanoma; risk factor; early-onset

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**Brief statement**:
This is the first study of sunbed use with risk of early-onset melanoma. Our findings indicate that sunbed use is associated with increased risk of early-onset melanoma, with risk increasing with greater use, an earlier age at first use and for earlier onset disease.

## INTRODUCTION

There is mounting evidence that use of sunbeds (indoor tanning) is associated with an increased risk of melanoma at any age. However, younger people might have greater susceptibility to the carcinogenic effects of artificial ultraviolet (UV) radiation.[1] A meta-analysis of 19 studies reported that ever-use of sunbeds was associated with 15% increased risk of melanoma (95% confidence interval (CI) 1.00-1.31) compared with never having used a sunbed, although there was no consistent evidence of a dose-response relation. The relative risk of melanoma was greater for those who first used a sunbed before 35 years of age (summary relative risk based on 7 studies: 1.75, 95% CI 1.35-2.26).[1]

Adolescents and young adults have the highest prevalence of sunbed use, estimated at about 20-40% in the United States and Sweden,[2-6] yet little is known about the association of sunbed use with melanoma diagnosed in young adults since most previous studies have recruited people with melanoma diagnosed at any age. Although the median age of diagnosis of melanoma is about 60 years,[7,8] melanoma is one of the most common cancers and leading causes of cancer death in young adults.[7-9] It is of public health importance to determine the risks of melanoma associated with sunbed use in younger people because this risk behaviour is increasingly prevalent in developed countries including the United States and Australia.[2,4,10,11] and melanoma incidence rates continue to increase in populations of European origin.[9,12,13] No studies have been published with adequate power to determine the risk of early-onset melanoma associated with sunbed use.

The Australian Melanoma Family Study is a population-based case-control-family study of early-onset melanoma (diagnosed between 18 and 39 years) conducted in three major cities located at different latitudes, and with detailed data collected on natural and artificial UV radiation exposures and skin phenotype. We present the associations between sunbed use during adolescence and early adulthood, and risk of early-onset cutaneous malignant melanoma.

## METHODS

### Study design and population-based sampling

Details of the study design, population, recruitment and data collection methods have been previously published.[14] We recruited cases and controls from Sydney, Melbourne and Brisbane, which are the three largest urban populations in Australia comprising about 50% of the Australian population and accounting for a similar proportion of melanoma incidence. These cities differ substantially in latitude, ambient UV irradiance and melanoma incidence, but have similar ethnic and demographic composition.[14] Ascertainment was population-based. Participants were cases and controls residing in these cities' greater metropolitan areas at the time of diagnosis or selection who could complete an interview in English. Approval for the study was obtained from the ethics committees of the three coordinating centres and the cancer registries. All participants provided written informed consent.

**Cases—**Eligible cases were men and women diagnosed between 1st July 2000 and 31st December 2002 with a histopathologically confirmed first primary invasive cutaneous melanoma, and who were aged between 18 and 39 years at diagnosis. Cases with a previous history of *in situ* melanoma were not excluded. Cases were identified through population-based state cancer registries, where notification of cancer is mandatory and registration is considered to be virtually complete. A total of 629 cases participated. The main reasons for non-participation by eligible cases were inability to contact (21%), refusal (17%), and doctors not giving permission to contact them (6%). Participation was 54% when calculated as a proportion of those eligible and 76% as a proportion of those contactable. The median

interval between diagnosis of melanoma and interview for participating cases was 10.0 months ($25^{th}$-$75^{th}$ centile: 6.8-14.1 months).

**Controls—**Population controls were selected from the electoral roll (registration to vote is compulsory for Australian citizens 18 years and over) and were frequency-matched to cases by city, age (within 5 years) and sex using proportional random sampling. Population controls were eligible if they were aged between 18 and 39 years at the time of approach and had no history of melanoma including *in situ* melanoma. In addition, each case was asked to nominate a spouse, partner, or friend as a potential control subject. Spouse/friend controls were eligible if they were at least 18 years of age and had no history of melanoma including *in situ* melanoma; there were no other age, sex or residency restrictions. A total of 240 population controls and 295 spouse/friend controls participated. The main reason for non-participation by eligible population controls was inability to contact (43% of those selected). Participation by population controls was 23% when calculated as a proportion of all apparently eligible controls selected and 42% as a proportion of those contactable. A spouse or friend was nominated as a potential control subject by 59% of cases; participation was 80% of those nominated.

## Data collection

Data were collected between January 2001 and December 2005. Recruitment and interviews were managed by the local study centre for each city, and study materials and procedures were standardised across study centres. Data were entered centrally. Demographic information, ethnicity and details of melanoma diagnoses for participants and their relatives were collected by questionnaire. Reports of family cancer were checked with relatives where possible, and verification of all reported cancers was sought from cancer registries, hospital and pathology records, treating clinicians, general practitioners and death certificates, when participant or next-of-kin (if participant deceased) consent had been obtained. All histopathology reports were reviewed by the Sydney study team to determine whether or not the diagnosis was as reported by the participant.

A trained interviewer administered a structured questionnaire to each participant by telephone. Data were collected on ever use of a sunbed or sunlamp, ages at first use and last use, total number of lifetime sessions, and locations in which sunbeds or sunlamps were used. ‘Sunbed’ throughout this paper refers to use of either sunbeds or sunlamps. Cases and controls were also asked how often the specific anatomical site of the melanoma was exposed to the light from the lamps; for these questions controls were assigned a specific site, frequency-matched based on the expected site distribution in the cases. To estimate sunbed exposure to the specific anatomical site of the melanoma, we multiplied exposure estimates by a weighting factor based on the reported amount of time that the site was exposed (1.0 = always, 0.75 = more than half, 0.5 = about half, 0.25 = less than half, 0.0 = never).

During the 45-minute telephone interview, participants were also asked to recall their sun exposure at 10, 15, 20, 30 and 40 years of age. To improve recall, cases and controls were asked to complete before the interview a lifetime calendar in which they indicated, for each year of life, their place of residence, place of work or study, number of days spent at work or study each week in warmer months and in cooler months, and holiday locations. A summary of the completed residence calendar was sent to participants to refer to during the telephone interview. Participants also reported their skin, eye colour, natural hair colour at age 18 years, usual tanning and sunburn response to prolonged or repeated exposure of skin to sunlight, the number of moles (nevi) covering the body (described pictorially as none, few,

some, many), freckling, and were asked to have someone count the number of all moles on their back.

Estimates of lifetime total sun exposure were derived by assigning recalled data from age 10 years to each year from ages 5 to 12, from age 15 to each year from ages 13 to 17, from age 20 to years 18 to 24, from age 30 to years 25 to 34, and from age 40 to years 35 to 44. Childhood estimates included exposure up to and including 17 years of age. Estimates of lifetime and age-specific ambient UV irradiation exposure were obtained by combining information on annual place of residence with an objective measure of cloud-adjusted, monthly mean ambient erythemal UV in $kJ/m^2$ at each residential location, derived from published satellite observations.[15,16]

## Statistical analysis

A total of 604 cases and 479 controls (232 population-controls and 247 spouse/friend controls) were included in this analysis. We excluded any participant who did not complete a questionnaire (1 case, 1 population-control and 6 spouse/friend controls), 33 spouse/friend controls who were ≥ 45 years at interview, and participants with missing data for sunbed exposure (ever-use) or any of the covariates included in the regression models (24 cases, 7 population-controls and 9 spouse/friend controls). Population-controls and spouse/friend-controls were combined into one control group for this analysis, as we have previously shown that associations for standard risk factors were similar when either control group or both control groups were used.[14]

To examine correlates of sunbed use we used Pearson chi-square tests for comparing proportions, t-tests for comparing means, and rank-sum tests for comparing median values. Relative risks of melanoma associated with sunbed use were estimated as odds ratios (OR) for melanoma and 95% CIs, using unconditional logistic regression. Sun exposure-related variables were categorised using quartiles of the distribution for controls. We adjusted for age (continuous), sex, city of recruitment, usual skin response to sun exposure (in general, how does your skin react to the sun: never burns always tans, sometimes burns usually tans, usually burns sometimes tans, always burns never tans); confirmed family history in 1st degree relatives (none, any), skin colour (very fair, fair, olive/brown/Asian/black), cumulative lifetime total sun exposure (quartiles), and education (junior high school, senior high school, vocational, university).

We tested whether the associations between sunbed exposure and melanoma differed by sex, age, usual skin response to sun exposure, anatomical site, number of nevi, ambient UV irradiance and lifetime total sun exposure. For stratification of the sunbed-melanoma association by age at diagnosis we divided the age range at its middle (18-29 years, ≥ 30 years); and for age of first or last use of sunbeds we initially used the median age of first use in controls as a cut-point, and then further examined younger ages. Interactions with covariates were tested by adding to the model a product term between each covariate and sunbed categories none, 1-10 sessions and >10 sessions fitted as a one degree-of-freedom ordinal variable to test for interaction in the trend effect. We used multinomial models for analyses of different anatomical sites.

We estimated the attributable risk percent and the population attributable fraction using established methods,[17-19] and used adjusted relative risks and the proportion of cases exposed to sunbeds for estimating the population attributable fraction.[18,19] Data were analysed using SAS version 9.2 (SAS Institute, Cary NC) and statistical significance was inferred at two-sided $P<0.05$.

## RESULTS

Demographic characteristics of cases and controls are shown in Table 1. Gender, country of birth and socioeconomic status were similar for cases and controls. Cases were more likely to have Caucasian ethnicity and only school-level education.

Ever-use of a sunbed or sunlamp was reported by 18% of controls and 23% of cases and was more prevalent among females than males (8% of male and 24% of female controls; 14% of male and 28% of female cases). The median age at first use of a sunbed was 22 years (interquartile range (IQR) 19-26) for cases and 24 years (IQR 20-30) for controls, and the earliest reported age at first use was 14 years for cases and 16 years for controls. Of those who reported sunbed use, the median number of lifetime sunbed sessions was 10 (IQR 4-20) for cases and 9 (IQR 4-18) for controls, and the median time between first exposure to sunbeds and diagnosis (cases) or interview (controls) was 9 years for both cases and controls. The most common locations where sunbeds were used were tanning salons (83%), gyms (72%), private home use (60%) and beauty salons (55%).

We examined whether age at first use of sunbeds, cumulative number of sessions and age at diagnosis of melanoma were related in participants who reported sunbed use. The median number of lifetime sunbed sessions was the same regardless of whether first use of a sunbed was before age 20 years (median 10, IQR 5-20), between ages 20-24 years (median 10, IQR 3-20) or at 25 years or older (median 10, IQR 4-15) ($P$=0.43). The age at first use of a sunbed and the total number of sunbed sessions was also similar for participants aged 18-29 years at diagnosis or interview and those aged more than 30 years at diagnosis or interview: the median ages at first use of a sunbed were 22 years (IQR 20-25) and 23 years (IQR 19-29), respectively ($P$=0.27), and the median number of sunbed sessions was 10 (IQR 4-20) in both age-groups ($P$=0.90).

We explored whether sunbed use was associated with demographic factors and different measures of sun sensitivity and sun exposure. Compared to cases and controls who had never used a sunbed, participants who reported ever-use were more likely to be female ($P$<0.0001), to usually or always tan in response to sun exposure ($P$ =0.02), to have higher lifetime sun exposure during summer holidays ($P$ =0.01), and lower lifetime ambient UV exposure ($P$ <0.0001). Sunbed use was modestly associated with country of birth other than Australia ($P$ =0.07), higher socioeconomic index based on residential postcode at the time of recruitment ($P$ =0.09), lower total childhood sun exposure ($P$ =0.09) and more lifetime sunburns causing blisters ($P$ =0.06). Skin colour, family history, education level, leisure-time sun exposure, and weekend and weekday sun exposure were not associated with ever use of a sunbed.

Compared with participants who had never used a sunbed, those who reported ever-use were 41% more likely to develop melanoma (Table 2). There was evidence that an earlier age at first use of sunbeds was associated with greater risk of melanoma: compared to never-users, the OR was 1.64 (95% CI 1.07-2.51) for first use before age 25 years (Table 2), and when we examined a younger age cut-point the OR was 1.50 (95% CI 0.88-2.55) for first use between ages 20-24 years and 1.88 (95% CI 0.99-3.57) before age 20 years ($P_{trend}$ 0.02). Risk increased with cumulative use ($P_{trend}$ 0.01). Participants who reported more than 10 sunbed sessions (3% of male controls and 7% of female controls; 6% of male cases and 13% of female cases) had about twice the risk of melanoma than those with no sessions (Table 2), and the OR was similar (2.09, 95% CI 1.25-3.48; $P_{trend}$ 0.007) when estimates were weighted by the reported proportion of time that the melanoma ‘site’ was exposed to light from the lamps. We further teased out the associations between age at first use and cumulative exposure to sunbeds by stratification (Table 2), and by mutual adjustment of

these variables in an analysis restricted to those who reported ever using a sunbed (Table 3). After mutual adjustment, the association of earlier age at first use of sunbeds with melanoma was attenuated by about 50%, but there was negligible change to the association of number of sessions.

Stratified results for interactions between the number of lifetime sunbed sessions and covariates are presented in Table 4. The increased risk associated with more than 10 sunbed sessions was over four times greater for melanoma diagnosed when aged 18-29 years (6.57, 95% CI 1.41-30.49) than for melanoma diagnosed when aged 30-39 years (1.60, 95% CI 0.92-2.77). The OR associated with ever-use compared with never-use was 4.12 (95% CI 1.57-10.81) for melanoma diagnosed when aged 18-29 years and 1.15 (95% CI 0.79-1.65) for melanoma diagnosed when aged 30-39 years. We estimate that for cases in our study who had ever used a sunbed and were diagnosed between 18 and 29 years of age, 76% of melanomas were attributable to sunbed use; and for those diagnosed between 30 and 39 years of age the attributable risk percent was 13%.[17]

More than 10 lifetime sunbed sessions was associated with a 5-fold higher risk of melanoma for participants whose lifetime total sun exposure was below the median value, but the same sunbed exposure did not increase risk for those with higher levels of total sun exposure ($P_{\text{interaction}}$ 0.02). There was marginal evidence that sunbed use was more strongly associated with melanoma on the trunk than on the limbs or head and neck ($P_{\text{interaction}}$ 0.09). There were no statistically significant differences between ORs when stratified by usual skin response to sun exposure, number of nevi covering the body, ambient UV irradiance, or sex, although the number of sessions required to increase risk appeared higher for women than for men.

The risk estimates were similar in analyses that compared cases separately with each control group. We tested the effect of including different measures of lifetime and childhood sun exposure that were correlated with sunbed use as potential confounders in the regression models. Adjustment for total sun exposure, ambient UV exposure, sunburns and summer holiday exposure changed the ORs for the sunbed-melanoma association by less than 10% and thus were not included in the final models. Lifetime total sun exposure was included *a priori*. Other potential confounders, including an age-sex interaction term, socio-economic index, and number of nevi covering the body also had minimal effect on ORs so none was included in the final models. We did not include hair and eye colour in the regression models because they are strongly correlated with skin colour and their inclusion had a smaller impact on the OR than inclusion of skin colour; nor did we include ethnicity because it was correlated with skin type.

## DISCUSSION

This is the first published study of sunbed use with risk of early-onset melanoma. Our findings indicate that sunbed use is a risk factor for early-onset melanoma, with evidence of a dose-response relation between the number of lifetime sessions and melanoma risk. Compared with participants who had never used a sunbed, the risk of melanoma was 41% higher for those who had ever used a sunbed, and was approximately doubled for those who reported more than 10 lifetime sessions. We also found that the risk of melanoma was greater with earlier age at first use of sunbeds and for earlier onset disease. Those who reported more than 10 lifetime sessions appeared some six times more likely to be diagnosed with melanoma before 30 years of age compared with never-users, but the same exposure was associated with less than two-fold increased risk of melanoma diagnosed after 30 years of age.

The weaker association of sunbeds with later age at onset of melanoma suggests addition of risk from sunbed use to accumulating risk from sun exposure, with the relative effect of sunbeds becoming smaller when superimposed on increasing, accumulated sun exposure. This would indicate that sun exposure and sunbed use increase melanoma risk through the same mechanism. This additivity of risk with sun exposure is supported by our observation that sunbed use was associated with an increased risk of melanoma for those with lower but not higher levels of lifetime total sun exposure, although this difference was only evident with more than 10 lifetime sunbed sessions. We observed a similar pattern when stratified by ambient UV irradiance, although the interaction was not statistically significant.

Another explanation for the age at diagnosis interaction and the increasing risk associated with earlier age at first use could be that younger people might be more biologically susceptible to the carcinogenic effects of artificial UV radiation. This rationale is consistent with the hypothesis that UV radiation exposures during childhood are important contributors to the initiation and promotion of biological events involved in the development of adult melanoma.[20-24] Similarly, risks of ionizing radiation-related cancers have been shown to be greatest for those exposed early in life.[25,26] However, a recent study suggested that early age at first use of a sunbed is most likely a marker for cumulative sunbed exposure, and not an indication of increased susceptibility for younger people.[27] In our study, mutual adjustment of these variables did indicate that cumulative sunbed exposure is probably more important than age at first use, although cumulative exposure did not fully account for the association of earlier age at first use with melanoma risk. Moreover, age at first use was not related to the number of lifetime sessions. The difference in risk by age at diagnosis was also unlikely to be explained by differences in sunbed exposure between these two age-groups because the number of sunbed sessions and age at first use were similar for both age-groups at diagnosis.

Our findings are broadly consistent with a systematic review[1] that reported relative risks for melanoma diagnosed at any age of 1.15 (95% CI 1.00-1.31) for ever-use of a sunbed and 1.75 (95% CI 1.35-2.26) when first use of sunbeds was before 35 years of age. However, in contrast to our study, the review found no evidence of a dose-response relation. A dose-response relation was found in some,[27-29] but not all,[30,31] more recent studies. A recent prospective analysis of a Norwegian-Swedish cohort of women reported a relative risk of melanoma of 1.31 (95% CI 1.03-1.66) associated with ever-use of sunbeds at ages 10 to 39 years, and a clear positive trend with cumulative sunbed use; however, they did not observe a higher relative risk associated with an earlier age at first use.[29]

Previous studies that have performed subgroup analyses to examine the association of sunbeds with melanoma diagnosed at different ages have been limited by small numbers of younger cases, but similar to our findings, most have observed stronger associations for those diagnosed at younger ages (defined as younger than age 30 years,[32] 36 years[33] or 45 years[28,34]). However, two recent studies[27,31] found no indication of heterogeneity by age-group.

We found that sunbed use was more associated with melanoma on the trunk than on the limbs or head and neck. Although these differences could easily have been due to chance, other studies have also found that melanoma risk at different body sites reflects different patterns of sun exposure; in particular that more continuous exposures are associated with melanomas on the head and neck and more intermittent exposures, such as sunbed use, with melanomas on the trunk and limbs.[32,35-37]

Our findings that sunbed use was more prevalent among females and those with good tanning ability are similar to previous studies.[4] Our data suggest that individuals are more

likely to use sunbeds if they lived in cooler climates and had high levels of sun exposure during summer holidays, which is consistent with a large survey in Germany that found tanning and preparation for sunny holidays were the main reasons for sunbed use.[38] Similarly, studies in the US have observed lower prevalence of sunbed use in warmer regions.[3,5] Several studies have found sunbed use to be positively correlated with sun-seeking behaviours,[3,30,33] although associations with sun exposure were not always consistent.[4,31] Similar to previous studies,[1,29-31] we found that adjustment for different measures of sun exposure or skin type had minimal effect on the association of sunbeds with melanoma.

Strengths of this study include the multi-centre, population-based design and a large sample of young cases and controls. A young study population is likely to have better recall of sunbed use and early-life sun exposure, which appears to be of particular etiological importance to melanoma. Our cases and controls were of similar socioeconomic status, cases' melanoma characteristics were representative of the population, and demographic characteristics of controls were generally similar to the population.[14] Our study also has several limitations. We cannot exclude the possibility of recall bias in our study, as the accuracy of reporting past sunbed exposures might differ between cases and controls. However, previous studies of sunbeds and melanoma have found minimal evidence of recall bias[27,39] and good reliability for cases and controls when reporting sunbed use.[40,41] Selection bias might also be a problem due to poor participation by cases and controls, if participation of cases and controls was influenced by their past or current sunbed use. However, collection of data on sunbed use was part of a larger study examining genetic and environmental risk factors for melanoma and thus sunbed use might be less likely to have influenced participation. Data collection was also completed well before local news media coverage of cases of melanoma in young people who had used sunbeds.[42]

We did not collect information on the specific type of indoor tanning device that was used, nor were we able to collect data on the duration of each sunbed session. Before 1980, indoor tanning devices emitted greater amounts of UVB radiation, whereas devices after 1980 emitted mainly UVA, however, there is little evidence that the association between artificial UV exposure and melanoma differs by the type of indoor tanning appliance used.[1,27] In our young study population, it is likely that most participants used more modern UVA-emitting devices. Due to the high UV intensity of indoor tanning devices, it is estimated that the annual UVA doses received by frequent indoor tanners may be 1.2–4.7 times those received from the sun, in addition to sun exposure.[1]

Our findings indicate that UV radiation exposure from sunbeds is a risk factor for early-onset melanoma, particularly melanoma diagnosed between ages 18 and 29 years. The increasing risk associated with an earlier age at first use adds further support to efforts to restrict minors and discourage young adults from using sunbeds.[1,43-45] Sunbed use is a completely avoidable but increasingly prevalent risk behaviour[2,4] and, on the evidence of this study, causes some 76% of melanomas occurring in people 18-29 years of age who have ever used a sunbed. At the population level, we estimate that 16% of melanoma cases aged 18-29 years at diagnosis and 3% of melanoma cases aged 30-39 years at diagnosis would be prevented in Australia by avoiding sunbed exposure.[18,19] Since Australia is reported to have the lowest frequency of sunbed use of developed countries[4] and perhaps the highest sun exposure, the proportion of all cases of early-onset melanoma attributable to sunbed use is almost certainly higher in other developed countries.

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## Abbreviations

| | |
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| **UV** | ultraviolet |
| **CI** | confidence interval |
| **OR** | odds ratio |

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**Table 1**

Demographic characteristics of cases and controls in the Australian Melanoma Family Study

| Demographic variable | Cases (n=604)[a] | | Controls (n=479)[a,b] | | *P* value[c] |
|---|---|---|---|---|---|
| | N | % | N | % | |
| Sex | | | | | |
| Male | 228 | 38 | 204 | 43 | |
| Female | 376 | 62 | 275 | 57 | 0.11 |
| Age at diagnosis/interview (years)[d] | | | | | |
| Median (range) | 33 (18-39) | | 35 (19-44) | | |
| 18-24 | 73 | 12 | 34 | 7 | |
| 25-29 | 117 | 19 | 61 | 13 | |
| 30-34 | 185 | 31 | 139 | 29 | |
| 34-39 | 229 | 38 | 166 | 35 | |
| ≥ 40 | 0 | 0 | 79 | 16 | <0.001 |
| Place of recruitment | | | | | |
| Brisbane | 228 | 38 | 212 | 44 | |
| Sydney | 161 | 27 | 123 | 26 | |
| Melbourne | 215 | 36 | 144 | 30 | 0.07 |
| Country of Birth | | | | | |
| Australia | 523 | 87 | 418 | 87 | |
| New Zealand | 20 | 3 | 8 | 2 | |
| United Kingdom, Ireland | 30 | 5 | 21 | 4 | |
| Other | 31 | 5 | 31 | 6 | 0.28 |
| Ethnicity | | | | | |
| Caucasian | 597 | 99 | 457 | 96 | |
| Other | 6 | 1 | 20 | 4 | <0.001 |
| Index of relative socioeconomic disadvantage[e], mean (SD) | 1,027 (68) | | 1,025 (65) | | 0.73 |
| Highest level of education | | | | | |
| Junior secondary school or below | 93 | 15 | 55 | 11 | |
| Senior secondary school | 181 | 30 | 132 | 28 | |
| Vocational | 118 | 20 | 130 | 27 | |

| Demographic variable | Cases (n=604)[a] | | Controls (n=479)[a,b] | | *P* value[c] |
|---|---|---|---|---|---|
| | N | % | N | % | |
| University | 212 | 35 | 162 | 34 | 0.02 |

Missing or unknown data are excluded from percentage calculations: country of birth missing for 1 control; ethnicity missing for 1 case and 2 controls.

[a] Excludes participants who gave a blood sample but did not complete a questionnaire (1 case, 7 controls), those with missing values for sunbed exposure (ever-use) or any of the covariates included in the regression models (24 cases, 16 controls), and 33 spouse/friend controls who were ≥ 45 years at interview.

[b] Includes 232 population-controls and 247 spouse/friend controls.

[c] $\chi^2$ test for association comparing the distribution of categorical variables and two-sample t-test for comparing mean values between case and control subjects. *P* values are two-sided.

[d] All cases were < 40 years at diagnosis and all controls were < 40 years when ascertained. Cases and controls could be up to age 44 years at interview.

[e] Based on data from the Socio-Economic Indexes for Areas (SEIFA 2001), Australian Bureau of Statistics (www.abs.gov.au). The Index ranks areas on the level of social and economic well-being, and index scores have been standardized to have a mean of 1000 and a standard deviation of 100 at the Collection District Level. A higher index value indicates less disadvantage. The mean SEIFA Index for study participants was derived from residential postcode at recruitment.

**Table 2**

ORs for melanoma in relation to sunbed use

| Sunbed use | Cases[b] | Controls[b] | OR & 95% CI[a] |
|---|---|---|---|
| Ever-use | | | |
| Never | 467 | 395 | 1.00 |
| Ever | 137 | 84 | 1.41 (1.01-1.96) |
| $P_{diff}$ | | | 0.04 |
| Age at first use | | | |
| Never | 467 | 395 | 1.00 |
| < 25 years | 83 | 41 | 1.64 (1.07-2.51) |
| ≥ 25 years | 46 | 39 | 1.06 (0.66-1.72) |
| $P_{het}$ | | | 0.07 |
| Age at last use | | | |
| Never | 467 | 395 | 1.00 |
| < 25 years | 59 | 35 | 1.32 (0.82-2.11) |
| ≥ 25 years | 72 | 47 | 1.39 (0.91-2.11) |
| $P_{het}$ | | | 0.20 |
| Number of lifetime sessions | | | |
| None | 467 | 395 | 1.00 |
| 1-10 | 72 | 57 | 1.08 (0.72-1.61) |
| >10 | 62 | 27 | 2.01 (1.22-3.31) |
| $P_{trend}$ [c] | | | 0.01 |
| Age at first use/lifetime sessions | | | |
| Never | 467 | 395 | 1.00 |
| < 25 / 1-10 | 42 | 26 | 1.30 (0.75-2.24) |
| < 25 / >10 | 39 | 15 | 2.13 (1.13-4.03) |
| ≥ 25 / 1-10 | 25 | 29 | 0.79 (0.45-1.41) |
| ≥ 25 / >10 | 21 | 10 | 1.88 (0.85-4.19) |
| $P_{het}$ | | | 0.06 |
| Years since first use | | | |
| Never | 467 | 395 | 1.00 |
| 1-4 | 48 | 24 | 1.35 (0.78-2.33) |
| 5-14 | 45 | 28 | 1.33 (0.79-2.23) |
| 15+ | 36 | 28 | 1.43 (0.83-2.46) |
| $P_{trend}$ | | | 0.09 |

[a] Adjusted for age, sex, city of recruitment, education, family history of melanoma, skin color, usual skin response to sun exposure, and cumulative lifetime total sun exposure. $P_{diff}$ is the *P* value for the OR for ever-use compared to never-use, $P_{het}$ is the *P* value testing for heterogeneity of the ORs between groups, $P_{trend}$ is the *P* value for trend calculated across categories.

[b] Numbers do not always total 604 cases and 479 controls due to missing data for number of lifetime sessions (3 cases), age at first use (8 cases, 4 controls) and age at last use (6 cases, 2 controls).

[c] The *P* value for trend for number of lifetime sessions was 0.01 both when calculated across categories and when treated as a continuous variable

## Table 3

Effect of mutual adjustment of age at first use of sunbeds and number of lifetime sessions on ORs for melanoma, in participants who reported ever using a sunbed

| | | | OR & 95% CI[a] | |
|---|---|---|---|---|
| | | | Adjusted for lifetime sunbed sessions[b]? | |
| **Age at first use of sunbeds** | **Cases[c]** | **Controls[c]** | **No** | **Yes** |
| ≥ 25 years | 46 | 39 | 1.00 | 1.00 |
| < 25 years | 81 | 41 | 1.32 (0.70-2.48) | 1.18 (0.62-2.25) |
| $P_{diff}$ | | | 0.39 | 0.61 |
| ≥ 25 | 46 | 39 | 1.00 | 1.00 |
| 20-24 | 45 | 26 | 1.14 (0.55-2.35) | 1.07 (0.51-2.22) |
| < 20 | 36 | 15 | 1.63 (0.72-3.70) | 1.39 (0.59-3.23) |
| $P_{trend}$ | | | 0.26 | 0.48 |
| | | | **Adjusted for age at first use[b]?** | |
| **Lifetime sunbed sessions** | **Cases** | **Controls** | **No** | **Yes** |
| 1-10 | 67 | 55 | 1.00 | 1.00 |
| >10 | 60 | 25 | 2.07 (1.08-4.00) | 2.01 (1.04-3.89) |
| $P_{diff}$ | | | 0.03 | 0.04 |

[a] All models were adjusted for age, sex, city of recruitment, education, family history of melanoma, skin colour, usual skin response to sun exposure, and cumulative lifetime total sun exposure.

[b] Adjustment for number of lifetime sunbed sessions as a continuous variable and age at first use in categories (<20, 20-24, ≥ 25).

[c] Excludes cases and controls who had never used a sunbed (467 cases, 395 controls), or who had missing data for number of lifetime sessions or age at first use (8 cases, 4 controls).

## Table 4

ORs for melanoma in relation to number of lifetime sunbed sessions, stratified by sex, age, usual skin response to sun exposure, nevi, total sun exposure, ambient UV irradiance and anatomical site

| Number of lifetime sunbed sessions | | Cases[b] | Controls[b] | OR & 95% CI[a] |
|---|---|---|---|---|
| Sex | | | | |
| Males | None | 195 | 187 | 1.00 |
| | 1-10 sessions | 17 | 10 | 2.46 (1.02-5.91) |
| | >10 sessions | 14 | 7 | 2.56 (0.97-6.76) |
| | $P_{trend}$ | | | 0.01 |
| Females | None | 272 | 208 | 1.00 |
| | 1-10 sessions | 55 | 47 | 0.83 (0.52-1.31) |
| | >10 sessions | 48 | 20 | 1.77 (0.98-3.21) |
| | $P_{trend}$ | | | 0.20 |
| | $P_{interaction}$ | | | 0.25 |
| Age at diagnosis/interview[c] | | | | |
| 18-29 years | None | 150 | 89 | 1.00 |
| | 1-10 sessions | 20 | 4 | 2.94 (0.91-9.44) |
| | >10 sessions | 20 | 2 | 6.57 (1.41-30.49) |
| | $P_{trend}$ | | | 0.005 |
| 30-39 years | None | 317 | 306 | 1.00 |
| | 1-10 sessions | 52 | 53 | 0.88 (0.57-1.38) |
| | >10 sessions | 42 | 25 | 1.60 (0.92-2.77) |
| | $P_{trend}$ | | | 0.23 |
| | $P_{interaction}$ | | | 0.01 |
| Usual skin response to sun exposure | | | | |
| Sometimes or never tans | None | 259 | 167 | 1.00 |
| | 1-10 sessions | 34 | 22 | 1.07 (0.58-1.96) |
| | >10 sessions | 26 | 5 | 3.18 (1.16-8.75) |
| | $P_{trend}$ | | | 0.05 |
| Usually or always tans | None | 208 | 228 | 1.00 |
| | 1-10 sessions | 38 | 35 | 1.09 (0.63-1.87) |
| | >10 sessions | 36 | 22 | 1.64 (0.90-2.99) |
| | $P_{trend}$ | | | 0.13 |
| | $P_{interaction}$ | | | 0.36 |
| Number of nevi covering the body | | | | |
| None or few | None | 149 | 230 | 1.00 |
| | 1-10 sessions | 24 | 31 | 1.28 (0.67-2.44) |
| | >10 sessions | 21 | 13 | 3.26 (1.49-7.11) |
| | $P_{trend}$ | | | 0.004 |
| Some or many | None | 208 | 228 | 1.00 |
| | 1-10 sessions | 48 | 26 | 0.97 (0.56-1.68) |

| Number of lifetime sunbed sessions | | Cases[b] | Controls[b] | OR & 95% CI[a] |
|---|---|---|---|---|
| | >10 sessions | 41 | 13 | 1.50 (0.76-2.99) |
| | $P_{trend}$ | | | 0.34 |
| | $P_{interaction}$ | | | 0.19 |
| Lifetime total sun exposure | | | | |
| ≤ median (27,208 hrs) | None | 260 | 203 | 1.00 |
| | 1-10 sessions | 41 | 31 | 1.03 (0.60-1.76) |
| | >10 sessions | 37 | 6 | 5.06 (2.02-12.65) |
| | $P_{trend}$ | | | 0.002 |
| > median | None | 207 | 192 | 1.00 |
| | 1-10 sessions | 31 | 26 | 1.14 (0.61-2.15) |
| | >10 sessions | 25 | 21 | 0.95 (0.49-1.85) |
| | $P_{trend}$ | | | 0.98 |
| | $P_{interaction}$ | | | 0.02 |
| Lifetime ambient UV irradiance | | | | |
| ≤ median (42,004 kJ/m$^2$) | None | 304 | 189 | 1.00 |
| | 1-10 sessions | 53 | 37 | 1.01 (0.61-1.66) |
| | >10 sessions | 48 | 14 | 2.53 (1.31-4.90) |
| | $P_{trend}$ | | | 0.02 |
| > median | None | 162 | 206 | 1.00 |
| | 1-10 sessions | 19 | 20 | 1.12 (0.55-2.30) |
| | >10 sessions | 14 | 13 | 1.21 (0.52-2.78) |
| | $P_{trend}$ | | | 0.61 |
| | $P_{interaction}$ | | | 0.29 |
| Anatomical site of melanoma | | | | |
| Head and neck | None | 69 | 395 | 1.00 |
| | 1-10 sessions | 8 | 57 | 0.89 (0.39-2.00) |
| | >10 sessions | 5 | 27 | 1.16 (0.42-3.23) |
| | $P_{trend}$ | | | 0.93 |
| Trunk | None | 156 | 395 | 1.00 |
| | 1-10 sessions | 21 | 57 | 1.12 (0.63-1.97) |
| | >10 sessions | 28 | 27 | 3.19 (1.75-5.80) |
| | $P_{trend}$ | | | <0.001 |
| Limbs | None | 237 | 395 | 1.00 |
| | 1-10 sessions | 43 | 57 | 1.11 (0.71-1.76) |
| | >10 sessions | 29 | 27 | 1.67 (0.94-2.97) |
| | $P_{trend}$ | | | 0.10 |
| | $P_{interaction}$ | | | 0.09 |

[a] Adjusted for age, sex, city of recruitment, education, family history of melanoma, skin colour, usual skin response to sun exposure, and cumulative lifetime total sun exposure (quartiles); the stratification variable is also excluded from the model.

[b] Numbers do not always total 604 cases and 479 controls due to missing data for some variables.

[c] Based on age at diagnosis for cases and age at interview for controls. All cases were < 40 years at diagnosis and all controls were < 40 years when ascertained. Cases and controls could be up to age 44 years at interview.