Can ultraviolet radiation act as a survival enhancer for cutaneous melanoma?

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Some studies have suggested that sun exposure plays a protective role in melanoma survival. This created a paradox as the known carcinogen can act as a cancer promoter and also as a survival enhancer. The aim of this study was to investigate the effect of sun exposure on melanoma mortality using both ambient sun exposure and individual data. A 10-year cohort study was carried out on primary cutaneous melanoma cases ($n = 972$). Residential data were coupled with levels of ultraviolet radiation (UV) to provide a measure of individual exposure. Demographic, histological and clinical data were obtained for all participants. In a subsample, information on pigmentary characteristics, diet, medical history, phenotype and self-reported sun exposure was also collected. Survival analysis and Cox proportional hazards models were used to examine associations. No protective effect was found for UVB or individual sun exposure variables on melanoma mortality. However, an increased risk of mortality was found among patients with cutaneous melanoma located on the lower limbs and in the highest decile of UVB exposure ($\geq$3.298 J/cm^2) after controlling for sex, age and Breslow thickness (relative risk: 4.78; 95% confidence interval: 1.30–17.5). The increased risk of mortality for the highest decile of UVB was also confirmed in the subsample after controlling for sex, age, education, use of sun lamps, pigmentary characteristics and diet. The results of the study suggested no protective effect of sun exposure for melanoma mortality and showed that high sun exposure increases the risk of melanoma mortality among patients with melanomas located on the lower limbs. ***European Journal of Cancer Prevention*** **25:34–40**

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Background

Cutaneous melanoma (CM) has been one of the most rapidly increasing cancers in White populations over the past several decades and it is still increasing, in particular, among men and in Northern and Western Europe and Australia. The global incidence of CM among men has increased in 6 years from 2.8 to 3.1 per 100 000 inhabitants, whereas among women, the incidence has remained fairly constant (Ferlay *et al.*, 2004, 2008). There were 232 130 new melanoma cases in 2012 worldwide. However, there is a striking variation in the risk of CM according to geographic location. Among white populations, an important difference in the incidence of melanoma exists between populations, with rates ranging from 35.1 new cases per 100 000 inhabitants in Australia/New Zealand to 8.1 new cases per 100 000 inhabitants in Southern Europe (Ferlay *et al.*, 2012). These differences can be attributed to differences in the intensity of environmental exposure to ultraviolet radiation (UV), with residents of Australia receiving more than twice the intensity of UV radiation as in Europe under clear sky conditions (Gallagher and Elwood, 1994). There is no doubt that sun exposure plays a predominant role in the genesis of melanoma (*http://www.skincancer.org*). However, evidence suggests that sun exposure may also exert a protective effect on melanoma survival, probably because of vitamin D (Holick, 2004; Berwick *et al.*, 2005; Rosso *et al.*, 2008). This created a paradox as the known carcinogen can act as a cancer promoter and also as a survival enhancer.

Ambient UV exposures, which vary markedly throughout the year (Boniol *et al.*, 2006) and according to geographic location, may be highly informative in exploring the sun exposure phenomenon on melanoma survival. The sources of vitamin D are sunlight exposure and diet, with sunlight (UVB) being a major source for most individuals. Nevertheless, the potential protective effect of UV because of vitamin D on melanoma survival may also depend on other factors, such as the host susceptibility characteristics (e.g. skin pigmentation, phenotype), use

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of sun lamps, and diet (Calvo *et al.*, 2005; Burke and Wei, 2009; Narayanan *et al.*, 2010). However, using a semi-ecologic design that combines ambient UV exposures with individual-level data, we may disentangle the paradox described previously. Clearly, we cannot apply this study design to a large number of individuals, but having individual data, even on a small subsample, can provide valuable additional information. It may help to improve exposure estimation and modelling, which in turn should lead to improved assessment of risk (Jackson *et al.*, 2006, 2008).

Few studies have examined the role of individual sun exposure (Berwick *et al.*, 2005; Rosso *et al.*, 2008) or ambient UV (Fears and Tucker, 2005) in melanoma mortality. To our knowledge, none has examined both individual and ambient sun exposure. As the effect of sun exposure on CM survival is still controversial (Fears and Tucker, 2005; Jayasekara *et al.*, 2009), it was considered that further investigation of this factor would be important to improve exposure estimation and future recommendations.

Therefore, the aim of this study was to investigate the effect of history of sun exposure on melanoma survival using both ambient and individual sun exposure data.

Methods

Data were merged from the clinical Melanoma Registry of the Istituto Dermopatico dell'Immacolata (IDI). From January 2001 to December 2003, 972 patients with newly diagnosed CM and living in the Lazio region were registered at IDI. Demographic, histological, residential and clinical data were collected for all participants. Data on pigmentary characteristics, diet and sun exposure history were also available for 256 out of 972 patients from a previous case–control study. The details of this study have been described previously (Fortes *et al.*, 2008). In brief, information on sociodemographic characteristics, personal medical history, diet, phenotypic traits (skin type, skin, hair and eye colour) and family history of skin cancer, lifetime sunlight exposure, sunburn history and sun bed exposure was obtained. We combined medical and environmental data to improve risk assessment and control for potential confounding factors. The IDI-IRCCS ethical committee approved the study and written informed consent was obtained from the participants.

The histological type, tumour thickness, ulceration, regression and cellular types were recorded and followed the guidelines described elsewhere (Clark *et al.*, 1969, 1989; Breslow, 1970; Barnhill, 1995). The International Classification of Diseases (ICD-9) was used to classify the anatomic site and cause of death.

After giving informed consent, study participants were interviewed by two trained dermatologists and were examined clinically to look for the presence of pigmented lesions. Pigmented lesions were identified by dermatologists and recorded according to the IARC protocol (English and Mac Lennan, 1990).

The Fitzpatrick system was used to classify skin phototype (burning and tanning tendency) (Freedberg *et al.*, 1999). Three hair colour categories were created (red, blonde; light brown; dark brown, black). Three eye colour categories were created (blue, grey, green; light brown; dark brown and black).

Indicators of intermittent exposure were time spent outdoors during vacation, sunburn episodes and use of sun beds. Indicators of chronic exposure were time spent outdoors in recreational activities, occupational sun exposure and lifetime sun exposure. Occupational sunlight exposure was classified as indoors and outdoors. Information on sunburn episodes (number of sunburns causing pain and erythema and/or blisters for more than 24 h) was collected. Sunburn episodes were classified into two categories (no/yes).

Consumption of foods rich in vitamin D was classified into low and high consumption. The following categories were used: milk (more than daily vs. weekly consumption), cheese ($\geq$3 times weekly vs. $\leq$ 2 times weekly) and fatty fish (less than weekly vs. weekly and more).

Ambient UV radiation

UV ambient radiation information was extracted from databases of the EuroSun project (2012). It provided an estimation of the daily average of UVA and UVB irradiation in Europe on the basis of satellite measurements for every 1' of arc-angle. Data were reported as the 5-year average of monthly means of UV daily doses (1988–1992; 1993–1997; 1998–2002; 2003–2007) selected for counties in the Lazio region. The last 10 years of residential UV exposure before melanoma diagnosis (2001–2003) were considered for all participants. Individual UV exposure was calculated for each participant in the study as weighted mean by providing different weights on the basis of the numbers of years covered in the different 5-year periods (*http://www.eurosun-project.org*). Deciles were calculated and the reference category was defined as the lowest ninth.

In our study, the following UV variables were considered: UVA mean daily irradiation premelanoma diagnosis, UVB mean premelanoma diagnosis, UVA peak in daily irradiation premelanoma diagnosis and UVB peak premelanoma diagnosis.

All UV variables were highly correlated. For example, the correlation between UVA mean and UVB mean was $\rho = 1.0$; $P < 0.0001$; the correlation between UVA peak and UVB peak was $\rho = 1.0$; $P < 0.0001$; and the correlation between UVB peak and UVB mean was $\rho = 0.95$; $P < 0.0001$. The UV measurements were expressed in J/cm^2. Then, we restricted the analysis to UVB exposure because it is the main source of vitamin D.

Table 1 Demographic, histological and clinical characteristics of the participants: percentage melanoma survival and crude hazard ratio for mortality and 95% confidence intervals

	Participants		Deaths	Survival		
	N	%	*N*	%	*P*-value[a]	Hazard ratio (95% CI)[b]
Sex						
Females	508	52.3	23	95.2	0.05	1
Males	464	47.7	34	92.3		1.68 (0.99–2.86)
Age groups (years)						
<30	58	6.0	2	96.6	<0.001[c]	1
30–44	210	21.6	11	94.3		1.52 (0.34–6.86)
45–59	285	29.3	11	96.1		1.13 (0.25–5.06)
60–69	202	20.8	9	95.4		1.35 (0.29–6.23)
70–79	159	16.4	15	90.1		3.11 (0.71–13.6)
≥80	58	6.0	9	81.9		6.58 (1.42–30.5)
Residence						
City of Rome	582	59.9	30	94.7	0.24	1
Outside Rome	390	40.1	27	92.5		1.36 (0.81–2.29)
Anatomic site						
Head/neck	126	13.0	6	94.8	0.89	1
Trunk	354	36.4	19	94.3		1.02 (0.41–2.55)
Upper limb	214	22.0	13	93.8		1.20 (0.46–3.17)
Lower limb	274	28.2	18	93.1		1.28 (0.51–3.24)
Unclassified	4	0.4	1	0		–
Histological type						
SSM	710	73.0	31	95.3	<0.0001	1
Nodular	79	8.1	20	72.3		7.43 (4.23–13.1)
Other[d]	14	1.4	4	71.4		7.38 (2.60–20.9)
In-situ and LM	154	15.8	0	100.0		–
Unclassified	15	1.5	2	84.9		3.03 (0.73–12.7)
Pre-existing naevus						
No	829	85.3	53	93.2	0.08	1
Yes	143	14.7	4	97.2		0.42 (0.15–1.16)
Breslow thickness (mm)[e]						
0.01–1.00	572	69.9	10	98.0	<0.0001[c]	1
1.01–2.00	103	12.6	11	89.0		6.55 (2.78–15.4)
2.01–4.00	81	9.9	20	73.9		17.3 (8.10–37.0)
>4.00	44	5.4	14	61.6		28.6 (12.7–64.4)
Unclassified	18	2.2	2	81.5		2.39 (0.74–7.70)
Cell type[e]						
Epithelioid	613	74.9	45	92.3	0.26	1
Spindle	42	5.1	5	87.5		1.95 (0.77–4.91)
Mixed	46	5.6	4	90.7		1.23 (0.44–3.41)
Lentiginous	44	5.4	1	97.7		0.30 (0.04–2.18)
Unclassified	73	8.9	2	97.0		0.24 (0.03–1.71)
Mitotic rate[e]						
Low (<1 mitosis/mm^2)	353	43.2	20	93.8	<0.0001	1
High (≥1 mitoses/mm^2)	72	8.8	18	73.5		5.42 (2.87–10.3)
Unclassified	393	48.0	19	94.9		0.86 (0.46–1.61)
Presence of ulceration[e]						
No	754	92.2	41	94.2	<0.0001	1
Yes	64	7.8	16	72.9		5.87 (3.29–10.5)
Regression[e]						
No	719	87.9	53	92.2	0.20	1
Yes	99	12.1	4	95.9		0.52 (0.19–1.44)

CI, confidence interval; HR, hazard ratio; LM, lentigo maligna; SSM, superficial spreading melanoma.
[a]Log-rank test.
[b]Evaluated by Cox's proportional model.
[c]Log-rank test trend.
[d]Acral and desmoplastic melanoma.
[e]Excluding in-situ and lentigo maligna melanoma.

Vital status

Files from the Registry Office of the Department of Epidemiology of the Lazio region were examined to obtain information on vital status and cause-specific mortality. The length of follow-up for each participant was the number of days from the diagnosis of primary melanoma to the date of death or to 31 December 2009, whichever came first. Patients who were alive, or dead because of other causes, were considered censored.

Statistical methods

The outcome of interest was death from melanoma. The Kaplan–Meier method and the Cox proportional hazards model were the methods chosen for the statistical

analysis. UVB radiation was categorized into deciles of exposure. Using upper decile versus lower ninth deciles, the relative risk and 95% confidence intervals (CIs) were calculated. The potential for violation of the proportional hazards assumption was assessed graphically by comparing survival curves for each variable level. Scaled Schoenfeld and Martingale residuals were also used. The following variables were considered in the models as potential confounders: sex, age, Breslow's thickness, presence of ulceration, histological type, mitotic rate, anatomic site, pre-existing naevus, latitude of residence, Rome/outside Rome, elastosis and self-reported sun exposure.

The likelihood ratio test was used to decide whether to retain each covariate in the model. Only the variables that made statistically significant contributions to the model were included ($P < 0.05$). Effect modification by sex, age, Breslow, residence (Rome/outside Rome), pre-existing naevus, histological type, anatomic site of melanoma and UV radiation was considered. A stratified analysis by anatomic site was carried out. Data were analysed using STATA software (Stata 11.0; StataCorp LP, College Station, Texas, USA). Missing data were recorded as unclassified and risk estimates were calculated when possible.

Table 2 Demographic and clinical characteristics of the participants in the study base population and in the subsample.

	n (%)		
	All ($N = 972$)	Subsample ($N = 256$)	*P*-value[a]
Sex			
Females	508 (52.3)	142 (55.5)	0.36
Males	464 (47.7)	114 (44.5)	
Age [mean (SD)]	55.8 (16.3)	52.4 (15.1)	0.003
Residence			
City of Rome	582 (59.9)	166 (64.8)	0.15
Outside Rome	390 (40.1)	90 (35.2)	
UVB radiation			
Low (≤ 9th decile, ≤ 3.297 J/cm^2)	876 (90.1)	230 (89.8)	0.89
High (10th decile, ≥ 3.298 J/cm^2)	96 (9.9)	26 (10.2)	
Anatomic site			
Head/neck	126 (13.0)	19 (7.4)	0.13[b]
Trunk	354 (36.4)	96 (37.5)	
Upper limb	214 (22.0)	65 (25.4)	
Lower limb	274 (28.2)	75 (29.3)	
Unclassified	4 (0.4)	1 (0.4)	
Breslow thickness (mm)[c]			
0.01–1.00	572 (69.9)	165 (67.9)	0.79[b]
1.01–2.00	103 (12.6)	36 (14.8)	
2.01–4.00	81 (9.9)	25 (10.3)	
> 4.00	44 (5.4)	14 (5.8)	
Unclassified	18 (2.2)	3 (1.2)	
Mitotic rate[c]			
Low (< 1 mitosis/mm^2)	353 (43.2)	107 (44.0)	0.70
High (≥1 mitoses/mm^2)	72 (8.8)	25 (10.3)	
Unclassified	393 (48.0)	111 (45.7)	
Presence of ulceration[c]			
No	754 (92.2)	226 (93.0)	0.68
Yes	64 (7.8)	17 (7.0)	

[a]*P*-value for χ^2-test analysis between the study base population and the subsample.
[b]*P*-value for Fisher's exact test analysis between the study base population and the subsample.
[c]Excluding in-situ and lentigo maligna melanoma.

Results

In the study population, there were 150 deaths, 57 of which were because of melanoma. The median follow-up time was 7.4 years (ranging from 1.2 months to 9.0 years). The mean age of the participants was 55.8 years (SD = 16.3), and 52.3% of the population were women. Overall survival for melanoma was 93.8%, but when divided into four primary tumour thickness categories – equal and under 1.00 mm, 1.01–2.00 mm, 2.01–4.0 mm and over 4.0 mm – 10-year figures were 98.4, 89.0, 73.9 and 61.6% ($P_{trend} < 0.0001$), respectively. Women had a better survival rate than men (95.2 vs. 92.3%). Survival decreased with increasing age ($P_{trend} < 0.001$) (Table 1). The most powerful predictor of mortality after thickness was ulceration [hazard ratio (HR): 5.87; 95% CI: 3.29–10.5], followed by mitotic rate (HR: 5.42; 95% CI: 2.87–10.3). Nodular (HR: 7.43; 95% CI: 4.23–13.1) and 'other' types of melanoma (HR: 7.38; 95% CI: 2.60–20.9) were also associated with an increased risk. The presence of regression, the presence of pre-existing naevus, cell type and anatomical site were not associated with mortality.

Table 2 shows the characteristics of the entire sample of patients with CM, excluding in-situ and lentigo maligna melanoma, and the subsample. No significant differences were found for all variables studied, except for age. Patients were slightly younger in the subsample than in the total sample.

Table 3 shows no differences in survival between high (≥3.298) and low UVB exposure (≤3.297). The results show no effect of UVB radiation on melanoma mortality after controlling for sex, age and Breslow thickness (HR for highest decile: 1.01; 95% CI: 0.43–2.38). The effect of UVB radiation on mortality did not change after excluding melanoma in-situ and lentigo maligna (HR: 1.02; 95% CI: 0.43–2.41). We also did not find an association between UVB and overall survival or all-cause mortality (Supplementary Table 1). As an interaction was suggested between UVB ambient exposure and lower limbs (HR: 6.71; 95% CI: 1.02–44.3; $P = 0.048$), we carried out a stratified analysis. An increased risk of both melanoma mortality (HR: 4.78; 95% CI: 1.30–17.5) and all-cause mortality (HR: 2.80; 95% CI: 0.96–8.14) was found among patients with CM located on the lower limbs and in the highest decile of UVB exposure, in comparison with patients with CM located on the lower limbs and with lower UVB exposure, after controlling for sex, age and Breslow. The effect of both melanoma mortality (HR: 5.09; 95% CI: 1.39–18.6) and all-cause mortality (HR: 3.03; 95% CI: 1.04–8.83) increased slightly after excluding melanoma in-situ and lentigo maligna and after introducing ulceration, mitotic rate and histological type

Table 3 Percentage survival and hazard ratio for mortality and 95% confidence intervals for high UV radiation: univariate and multivariate analysis

	Participants		Deaths	Survival		Any anatomic sites		Lower limbs	Other sites combined
	N	%	*N*	%	*P*-value[a]	HR (95% CI)	HR (95% CI)[b]	HR (95% CI)[b]	HR (95% CI)[b]
All ($N=972$)									
UVB radiation									
Low (≤ 9th decile, ≤ 3.297)	876	90.1	51	93.8	0.87	1	1	1	1
High (10th decile, ≥ 3.298)	96	9.9	6	93.7		1.07 (0.46–2.50)	1.01 (0.43–2.38)	4.78 (1.30–17.5)	0.36 (0.08–1.51)
Excluding in-situ and lentigo maligna melanoma ($N=818$)									
UVB radiation									
Low (≤ 9th decile, ≤ 3.297 J/cm^2)	738	90.2	51	92.7	0.84	1	1	1	1
High (10th decile, ≥ 3.298 J/cm^2)	80	9.8	6	92.4		1.09 (0.47–2.54)	1.02 (0.43–2.41)	5.09 (1.39–18.6)	0.36 (0.08–1.51)

CI, confidence interval; HR, hazard ratio.
[a]Log-rank test.
[b]HR adjusted for sex, age and Breslow thickness.
[c]Head/neck, trunk and upper limbs.

Table 4 Subsample analysis – multivariate analysis for high UV radiation in melanoma of the lower limbs

	HR (95% CI)	
	All melanoma	Excluding in-situ and lentigo maligna melanoma
Model 0: UV radiance, sex, age and Breslow thickness	11.7 (1.94–71.1)	11.6 (1.91–70.3)
Model 1: Model 0 + education	11.9 (1.73–82.0)	11.8 (1.71–81.0)
Model 2: Model 1 + time spent outdoors during vacation in adulthood	11.3 (1.53–83.6)	11.2 (1.51–82.6)
Model 3: Model 1 + use of sun bed and/or sunlamp	9.68 (1.39–67.4)	9.49 (1.36–66.2)
Model 4: Model 1 + sunburns in total life	18.6 (1.30–265.8)	18.2 (1.28–260.0)
Model 5: Model 1 + time spent outdoors during recreational activities in childhood	15.5 (1.97–122.6)	15.3 (1.94–120.0)
Model 6: Model 1 + solar elastosis	10.1 (1.33–76.2)	9.98 (1.32–75.6)

CI, confidence interval; HR, hazard ratio.

in the model. No increased risk of mortality was found for patients with invasive CM located in other anatomic sites (trunk, HR: 0.48; 95% CI: 0.06–3.64; upper limbs, HR: 0.69; 95% CI: 0.08–6.01). Risk estimates could not have been calculated for head and neck alone. Most cases located on the head and neck were in-situ melanomas and no death was observed in the highest decile of UVB exposure. No increased risk of mortality was found for patients with CM located in other anatomic sites combined (trunk, head and neck and upper limbs) (HR: 0.36; 95% CI: 0.08–1.51).

Table 4 presents the adjusted hazard ratios predicting the risk of death due to melanoma among the subsample by UVB radiation. The increased risk of mortality associated with high UVB exposure among patients with melanoma on the lower limbs was confirmed in the subsample (HR: 9.68; 95% CI: 1.39–67.4) after controlling for sex, age, education, Breslow thickness and sun bed use. We also controlled, one at a time, in the model for other potential confounders such as clinical solar elastosis, chronic and intermittent sun exposure variables, skin phototype, 'red hair/fair skin' phenotype, occupational sun exposure, family history of skin cancer, and foods rich in vitamin D, and the effect remained. No differences in age, Breslow thickness, mitotic rate and the presence of ulceration were found between melanomas located on the lower limbs and other anatomical sites ($P=0.53$) (Supplementary Table 2).

Discussion

Although some studies have evaluated associations between latitude (Crocetti *et al.*, 2012) or ambient UV radiation and melanoma mortality (Fears and Tucker, 2005), only a few studies have examined individual-level data (Berwick *et al.*, 2005; Rosso *et al.*, 2008). This is the first study to elucidate the contribution of sun exposure to melanoma mortality using both ambient and individual sun exposure data. No increased risk of mortality was associated with UVB or sun exposure variables. However, patients with CM located on the lower limbs and exposed to high levels of ambient UVB had a four-fold increased risk of mortality after controlling for all possible risk factors for mortality.

The results of our study did not confirm the results of two studies that suggested a protective role for sun exposure in melanoma survival after taking into consideration UVA and UVB radiation data and individual chronic and intermittent sun exposure, and after controlling for all possible confounding factors such as pigmentary characteristics, phenotype and diet. In a 5-year follow-up study of 528 melanoma patients who participated in a US case–control study in the 1990s, Berwick and colleagues

observed that mortality from melanoma was approximately half among those with signs of elastosis in comparison with those without solar elastosis. In our study, elastosis was not associated with a protective effect on mortality. In the study by Rosso *et al.* (2008) with 260 melanoma cases, intermittent sun exposure, measured by number of weeks over a lifetime on the beach, was protective for melanoma mortality. In our study, time spent outdoors during vacations was not associated with melanoma mortality.

Fears and Tucker (2005) considered 24 888 melanoma patients and studied UVB flux and survival, and found no evidence for an association between melanoma survival and UVB flux. We also did not find an association between UVB and melanoma mortality. However, we observed that patients with CM located on the lower limbs and exposed to high levels of ambient UVB had a four-fold increased risk of mortality after controlling for all possible risk factors for mortality. In addition, our results were fairly stable even after adjustment for pigmentary characteristics, sun exposure variables and high intake of foods rich in vitamin D.

Ambient UVB radiation at diagnosis may not be the best measure of individuals' sun exposure, but within the subsample, we also had individual sun exposure data. However, misclassification of sun exposure could also be a limitation of our study. To overcome the problem, we validated our questionnaire using two independent measures as suggested elsewhere (Fortes, 2002). It has been suggested that total sun exposure is associated with elastosis, and sunburns and intermittent sun exposure predict the number of naevi (Bernstein *et al.*, 1996; Lee *et al.*, 2006; Dodd *et al.*, 2007; Gefeller *et al.*, 2007). We compared sun exposure variables assessed by the questionnaire with skin damage variables assessed by a dermatologist following the IARC protocol (English and Mac Lennan, 1990). We found that total sun exposure and occupational sun exposure were highly associated with elastosis, sunburns in childhood with number of naevi in adults and time spent in the sun during holidays in childhood with number of naevi (Fortes *et al.*, 2011).

From our results, we cannot confirm the hypothesis suggested elsewhere (Berwick *et al.*, 2005) that melanomas induced by chronic sun exposure have a less aggressive phenotype than tumours that are not induced by chronic sun exposure. It is likely that high UV exposure causes a more aggressive melanoma in small groups with a certain phenotype and/or genotype. In our study, patients with melanomas located on the lower limbs were more likely to have the phenotype 'red hair and fair skin colour' (12 vs. 5%) than patients with melanomas located in other anatomic sites. It has been suggested that the NRAS mutation, in contrast to the BRAF mutation, is associated with chronic sun exposure and with tumour locations such as the extremities (Lee *et al.*, 2011). However, we do not have data on genetics to confirm these findings. Our findings suggest that UV exposure plays a limited role as a risk factor for melanoma mortality. High sun exposure should not be recommended for patients diagnosed with melanoma to enhance survival. Sun-protection behaviour is necessary and is unlikely to place patients at risk of vitamin D deficiency.

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Conflicts of interest

There are no conflicts of interest.

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