RESEARCH ARTICLE

Ultraviolet radiation and risk of cutaneous melanoma and squamous cell carcinoma in males and females in the Norwegian Offshore Petroleum Workers cohort

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Abstract

Background: Increased risk of cutaneous melanoma and squamous cell carcinoma (SCC) has been reported among petroleum workers, but few studies include females, exposure data on ultraviolet radiation (UVR), and potential confounding factors. We aimed to examine UVR exposure in relation to risk of melanoma and SCC among male and female offshore petroleum workers. We also examined the association between UVR exposure and melanoma (Breslow) thickness.

Methods: The Norwegian Offshore Petroleum Workers (NOPW) cohort (n = 27,917) holds information on sunbathing, indoor tanning, sunburns, sunscreen use, and other lifestyle factors recorded in 1998. Linkage to the Cancer Registry of Norway gave information on cancer diagnosis through 2017. We used Cox and logistic regression to estimate hazard ratios (HRs) of skin cancer and odds ratios (OR) of thick (≥1 mm) melanomas, respectively, with 95% confidence intervals (CIs).

Results: Melanoma risk increased with increasing frequency of sunbathing after age 20 (p_trend = 0.031), sunburn average intensity (p_trend = 0.028), and sunscreen use (HR = 2.16; 95% CI: 1.42 - 3.27 for almost always vs. never/rarely). The risk of thick melanoma was inversely associated with sunbathing frequency after age 20 (OR = 0.38; 95% CI: 0.16 - 0.90 for ≥4 weeks/year vs. 1 week/year). SCC risk increased with increasing frequency of indoor tanning after age 20 (HR = 2.72; 95% CI: 1.22 - 6.05 for ≥3 times/months vs. never), sunburn average intensity (p_trend < 0.001), and sunscreen use (p_trend < 0.001).

Conclusions: Our results support associations between UVR exposure and skin cancer risk in male and female offshore petroleum workers. This occupational group may be especially relevant for targeted sun protection advice.

KEYWORDS
cohort, melanoma, occupation, petroleum workers, squamous cell carcinoma, ultraviolet exposure

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INTRODUCTION

Cutaneous melanoma (hereafter melanoma) and squamous cell carcinoma (SCC) are among the most common types of cancer in many Western populations. In Norway, the melanoma incidence rate increased by 22% in men and 17% in women from 2009–2013 to 2014–2018. The non-melanoma skin cancer rate increased by more than 20% in both genders during the same period. Melanoma and SCC are multifactorial diseases involving a combination of environmental exposure, host factors, and occupational exposures. Ultraviolet radiation (UVR) exposure is the leading environmental risk factor for these skin cancers, and they share host risk factors such as light skin, hair and eye color, while nevi and freckling are specific to melanoma.

Excesses in skin cancer incidence and mortality among petroleum workers have previously been reported from Australia, Canada, Norway, and the United Kingdom, and skin cancer in relation to occupational UVR exposure has recently received increased attention from both the World Health Organization (WHO) and the International Labour Organization (ILO). We have previously shown that the majority of the skin cancers in Norwegian male offshore petroleum workers was related to UVR exposure and that associations with hydrocarbon exposure were restricted to the hands and forearms. Due to a harsh climate and mandatory use of personal protective equipment (PPE), including helmet, glasses, gloves, coverall, and boots, workers are likely to experience little UVR exposure when on-duty in the offshore work environment, with the exception of the pioneer era in the late 1960s and early 1970s. In this occupational group, UVR exposure has most likely occurred during off-duty activities such as during sunbathing holidays or during the use of indoor tanning devices, the latter also provided as a free welfare service by the companies on many offshore accommodation.

Indoor tanning exposure plays a role in the development of both melanoma and SCC and has been associated with melanoma diagnosed at a younger age. Offshore workers in Norway have an extreme work schedule with 2 weeks on-duty and 2 weeks off-duty. Offshore workers also receive twice the income compared with their onshore peers. The combination of long off-duty periods and high salary allows offshore workers to travel to sunny destinations all year round. Additionally, association studies on occupational UVR exposure and skin cancer have been somewhat conflicting. In a pooled analysis of two multicentre case–control studies, increased occupational sun exposure was associated with decreased melanoma risk, while the most recent meta-analysis on occupational sun exposure and keratinocyte cancer reported an increased risk of SCC among outdoor workers.

The excess melanoma incidence in the petroleum industry has been partly attributed to frequent health examination and thereby early detection. Early melanoma detection would result in a high proportion of thin melanomas, having low Breslow thickness (i.e., vertical tumor thickness), which also is the most important prognostic factor of localized primary melanoma. Prediagnostic sun exposure has been inversely associated with Breslow thickness, but to our knowledge, this association has not been examined in an occupational setting. It would be of interest to address this question and the proportion of thin melanoma in an occupational cohort with frequent health exams.

Melanoma and SCC risk has previously been examined according to UVR exposure in male offshore workers. In the present study, we prospectively examined a comprehensive set of UVR exposure variables in relation to melanoma and SCC risk among 2570 females and 25,347 males in the Norwegian Offshore Petroleum Workers (NOPW) cohort with extended follow-up. In addition, we examined the association between UVR exposure and Breslow thickness.

MATERIALS AND METHODS

Study population and study design

The NOPW cohort was established in 1998 by the Cancer Registry of Norway (CRN). In 1998, a questionnaire was sent to current or former male and female offshore petroleum workers with a minimum of 20 days of work on the Norwegian continental shelf between 1965 and 1998 (inclusion criterion). In total, 27,917 workers were included (estimated response rate, 69%) in the NOPW cohort. Details on the cohort have been published. All workers filled in an informed consent for participation in the study. Necessary legal and ethical approvals have been obtained from the Norwegian Data Inspectorate, the Regional Committee for Medical Research Ethics, and the Norwegian Directorate of Health.

Identification of cancer cases

The NOPW cohort was linked to the CRN and the National Population Register for information on cancer diagnoses, death, and emigration, by using the unique personal identification numbers assigned to all Norwegian citizens. The start of follow-up was set to July 1, 1999, and the end of follow-up to December 31, 2017. Individuals who died or emigrated before the start of follow-up were excluded (n = 68).

Reporting of incident cancers to the CRN is mandatory in Norway, and the degree of completeness and validity is high, with morphology verified for 99.5% and 99.8% of the melanomas and SCCs, respectively. Skin cancer cases were defined according to the International Classification of Diseases, Tenth Revision (ICD-10), C43 for melanoma (ICD-Oncology third revision codes: 80003, 87203, 87213, 87233, 87303, 87423, 87433, 87443, 87453, 87703, and 87723) and C44 for SCC (ICD-O-3: 80703, 80713, 80763, 80953, 80513, 80723, and 80743). Melanoma and SCC cases were included if they were the first-ever diagnosed skin cancer in each individual and diagnosed during the follow-up period (prospectively). The CRN does not routinely record information on basal cell carcinoma (BCC) of the skin, and therefore, BCC cases were omitted. Out of 27,849 participants, we excluded 77 individuals who had melanoma or SCC diagnosed before the start of follow-up (Figure 1).
2.3 | Assessment of exposure

2.3.1 | UVR exposure and sunscreen use

The questionnaire asked for information on UVR exposure before and after the age of 20 specifically; sunbathing frequency per year (never, 1 week, 2–3 weeks, 4–5 weeks, and ≥7 weeks [4–5 and ≥7 weeks collapsed into ≥4 weeks]), number of sessions of indoor tanning per month (never, rarely, 1–2 times, 3–4 times, and >4 times [3–4 times and >4 times collapsed into ≥3 times]), and sunburn frequency per year (never, once, 2–3 times, 4–5 times, and ≥6 times [4–5 times and ≥6 times collapsed into ≥4 times]). Sunscreen use was recorded as used in 1998 (never/rarely, often, and almost always).

2.3.2 | UVR exposure pattern before and after age 20

To study the UVR exposure pattern before and after age 20, we categorized sunbathing, indoor tanning, and sunburns as low (<2 weeks/year for sunbathing, <1 time/month for indoor tanning, and <2 times/year for sunburn) or high (≥2 weeks/year, ≥1 time/month, and ≥2 times/year, respectively) separately for the time before and after age 20. We then categorized the workers as (1) low-low (consistently low; low before and after age 20), (2) low-high (increased exposure; low before age 20 and high after age 20), (3) high-low (reduced exposure; high before age 20 and low after age 20), and (4) high-high (consistently high; high before and after age 20).

2.3.3 | UVR average intensity

The average intensity of sunbathing, indoor tanning, and sunburns was defined as (frequency × duration)/age in 1998. Frequency was redefined by transforming response categories into the following values: sunbathing as weeks/year: never = 0, 1 = 1, 2–3 = 2.5, 4–5 = 4.5, and ≥7 = 8; Indoor tanning as times/year: never = 0, rarely = 2, 1–2 times/month = 18, 3–4 times/month = 42, and ≥4 times/month = 60; and sunburns as times/year: never = 0, 1 = 1, 2–3 = 2.5, 4–5 = 4.5, and ≥6 = 7. Duration was defined as 10 years for exposures before age 20, and age in 1998 minus 20 for exposures after age 20.

2.3.4 | Ambient UVR of residence and average intensity of ambient UVB

Ambient UVR of residence was categorized by county of residence at baseline (in 1998) into north-middle, southwest, southeast inland, and southeast coast, in the increasing order of UVR intensity from north to south, with the latter category representing the highest ambient UVR. The average intensity of ambient UVB was constructed by accruing the yearly UVB doses from the year of birth to 1998 for each worker divided by age in 1998. Data on annual UVB doses were derived from modeled values and from the UV measurement stations. For counties without a measurement station, we used UVB data from the nearest station.

2.3.5 | Other variables

Height (cm) and weight (kg) were recorded in the questionnaire, and body mass index was calculated as kg/m². Body surface area (m²) was calculated using the DuBois and DuBois equation (weight^{0.4253} × height^{0.7253} × 0.07184). Main offshore activity in each worker’s last position was recorded as production and process, drilling and well maintenance, maintenance/inspection/deck construction, catering and health/office/administration, and miscellaneous. Education was recorded as compulsory, vocational, folk high school, upper secondary (folk high school and upper secondary were collapsed into upper secondary), and university/college.

2.4 | Data analysis

The associations between UVR exposure variables and risk of melanoma and SCC were estimated by hazard ratios (HRs) and 95% confidence intervals (CIs) using Cox regression with age as the time scale. Person-years were calculated from the start of follow-up to the date of diagnosis of either melanoma or SCC, emigration, death, or the end of follow-up, whichever occurred first. For analyses with melanoma as the outcome, individuals with SCC diagnosed before melanoma were censored at the date of the SCC diagnosis and vice
| Variables | Males \( (n = 25,215) \) | Females \( (n = 2557) \) | Total \( (n = 27,772) \) |
|-----------|-------------------|-----------------|------------------|
| Age at baseline in 1998 (years), mean (range) | 43 (18–80) | 39 (19–74) | 43 (18–80) |
| Main occupational activity in last position, \( n \) (%) | | | |
| Production and process | 1797 (7) | 149 (6) | 1946 (7) |
| Drilling and well maintenance | 3623 (14) | 145 (6) | 3768 (14) |
| Maintenance/inspection/deck construction | 12,603 (50) | 270 (11) | 12,873 (46) |
| Catering and health/office/administration | 2933 (12) | 1726 (67) | 4659 (17) |
| Miscellaneous | 4007 (16) | 231 (9) | 4238 (15) |
| Missing | 252 (1) | 36 (1) | 288 (1) |
| Height (cm), mean (range) | 180.1 (125–205) | 167.4 (149–188) | 178.9 (125–205) |
| Weight (kg), mean (range) | 83.4 (40–204) | 66.1 (42–170) | 81.8 (40–204) |
| BMI (kg/m²), mean (range) | 25.7 (12.1–65.5) | 23.6 (15.9–63.7) | 24.5 (12.1–65.5) |
| BSA (m²), mean (range) | 2.0 (1.4–3.1) | 1.7 (1.3–2.7) | 2.0 (1.3–3.1) |
| Education, \( n \) (%) | | | |
| Compulsory | 2996 (12) | 381 (15) | 3377 (12) |
| Vocational | 10,349 (41) | 557 (22) | 10,906 (39) |
| Upper secondary\(^{a}\) | 5985 (24) | 850 (33) | 6835 (25) |
| University/college | 5700 (22) | 742 (29) | 6442 (23) |
| Missing | 185 (1) | 27 (1) | 212 (1) |
| Sunbathing before age 20, \( n \) (%) | | | |
| Never | 2124 (9) | 74 (3) | 2198 (8) |
| 1 week/year | 6376 (25) | 354 (14) | 6730 (24) |
| 2–3 weeks/year | 9100 (36) | 1056 (41) | 10,156 (37) |
| ≥4 weeks/year | 6319 (25) | 933 (37) | 7252 (26) |
| Missing | 1296 (5) | 27 (1) | 1436 (5) |
| Indoor tanning before age 20, \( n \) (%) | | | |
| Never | 19,721 (78) | 1456 (57) | 21,177 (76) |
| Rarely | 3591 (14) | 702 (27) | 4293 (16) |
| 1–2 times/month | 459 (2) | 150 (6) | 609 (2) |
| ≥3 times/month | 230 (1) | 108 (4) | 338 (1) |
| Missing | 1214 (5) | 27 (1) | 1355 (5) |
| Sunburn before age 20, \( n \) (%) | | | |
| Never | 3870 (15) | 526 (21) | 4396 (16) |
| 1 time/year | 14,843 (59) | 1347 (53) | 16,190 (58) |
| 2–3 times/year | 4758 (19) | 480 (19) | 5238 (19) |
| ≥4 times/year | 613 (3) | 86 (3) | 699 (3) |
| Missing | 1131 (4) | 118 (4) | 1249 (4) |
| Sunbathing after age 20, \( n \) (%) | | | |
| Never | 1946 (8) | 60 (3) | 2006 (7) |
| 1 week/year | 7169 (28) | 430 (17) | 7599 (27) |
| 2–3 weeks/year | 9763 (39) | 1183 (46) | 10,946 (40) |
| ≥4 weeks/year | 5464 (22) | 802 (31) | 6266 (23) |
| Missing | 873 (3) | 82 (3) | 955 (3) |
| Indoor tanning after age 20, \( n \) (%) | | | |
| Never | 11,679 (46) | 329 (13) | 12,008 (43) |
| Rarely | 10,361 (41) | 1514 (59) | 11,875 (43) |
| 1–2 times/month | 1722 (7) | 398 (16) | 2120 (8) |

(Continues)
| Variables                              | Males             | Females          | Total             |
|----------------------------------------|-------------------|-------------------|-------------------|
|                                        | (n = 25,215)      | (n = 2557)        | (n = 27,772)      |
| ≥3 times/month                         | 886 (4)           | 263 (10)          | 1149 (4)          |
| Missing                                | 567 (2)           | 53 (2)            | 620 (2)           |
| Sunburn after age 20, n (%)            |                   |                   |                   |
| Never                                  | 5501 (22)         | 837 (33)          | 6338 (23)         |
| 1 time/year                            | 16,134 (64)       | 1420 (56)         | 17,554 (63)       |
| 2–3 times/year                         | 2548 (10)         | 203 (8)           | 2751 (10)         |
| ≥4 times/year                          | 304 (1)           | 31 (1)            | 335 (1)           |
| Missing                                | 728 (3)           | 66 (2)            | 794 (3)           |
| Sunscreen use in 1998, n (%)           |                   |                   |                   |
| Never/rarely                           | 10,077 (40)       | 491 (19)          | 10,568 (38)       |
| Often                                  | 8395 (33)         | 734 (29)          | 9129 (33)         |
| Almost always                          | 6427 (26)         | 1302 (51)         | 7729 (28)         |
| Missing                                | 316 (1)           | 30 (1)            | 346 (1)           |
| Sunbathing pattern before and after age 20, n (%) |                   |                   |                   |
| Low-low (always <2 weeks/year)         | 6469 (26)         | 232 (9)           | 6701 (24)         |
| Low-high (<2 weeks/year, ≥2 weeks/year)| 1890 (8)          | 188 (7)           | 2078 (8)          |
| High-low (≥2 weeks/year, <2 weeks/year)| 2330 (9)          | 237 (9)           | 2567 (9)          |
| High-high (always ≥2 weeks/year)       | 12,833 (51)       | 1726 (68)         | 14,559 (53)       |
| Missing                                | 1693 (6)          | 174 (7)           | 1867 (6)          |
| Indoor tanning pattern before and after age 20, n (%) |                   |                   |                   |
| Low-low (always <1 time/month)         | 21,072 (83)       | 1653 (65)         | 22,725 (82)       |
| Low-high (<1 time/month, ≥1 time/month)| 1944 (8)          | 485 (19)          | 2429 (9)          |
| High-low (≥1 time/month, <1 time/month)| 226 (1)           | 119 (5)           | 345 (1)           |
| High-high (always ≥1 time/month)       | 429 (2)           | 130 (5)           | 559 (2)           |
| Missing                                | 1544 (6)          | 170 (6)           | 1714 (6)          |
| Sunburn pattern before and after age 20, n (%) |                   |                   |                   |
| Low-low (always <2 times/year)         | 17,744 (70)       | 1788 (70)         | 19,532 (70)       |
| Low-high (<2 times/year, ≥2 times/year)| 609 (2)           | 50 (2)            | 659 (2)           |
| High-low (≥2 times/year, <2 times/year)| 3143 (13)         | 385 (15)          | 3528 (13)         |
| High-high (always ≥2 times/year)       | 2169 (9)          | 177 (7)           | 2346 (9)          |
| Missing                                | 1550 (6)          | 157 (6)           | 1707 (6)          |
| Sunbathing average intensity (cumulative sum = (frq × dur)/year), median (25th-75th percentile) | 1.8 (0.8–2.4) | 2.0 (1.6–3.1) | 1.8 (0.8–2.4) |
| Indoor tanning average intensity (frq/year), median (25th-75th percentile) | 0.7 (0–1.2) | 1.3 (0.9–7.1) | 0.8 (0–1.3) |
| Sunburn average intensity (frq/year), median (25th-75th percentile) | 0.8 (0.6–0.8) | 0.7 (0.3–0.8) | 0.8 (0.5–0.8) |
| Ambient UVR of residence in 1998, n (%) |                   |                   |                   |
| North-middle                           | 3231 (13)         | 219 (9)           | 3450 (12)         |
| Southwest                              | 14,143 (56)       | 1694 (66)         | 15,837 (57)       |
| Southeast inland                       | 2929 (12)         | 297 (12)          | 3226 (12)         |
versa. The proportional-hazards assumption was evaluated by Schoenfeld residuals and found satisfactory. Likelihood ratio tests were used to test for the interaction between UVR exposures and sex, main occupational activity in the last position, and ambient UVR of residence.

To explore the shape of the associations between UVR average intensity and melanoma as well as SCC, restricted cubic splines were incorporated into the Cox models, using the Stata modules -partpred- and -rcsgen-. We used likelihood ratio tests to determine whether linear or spline models gave the better fit. Population attributable fractions (PAFs) of melanoma and SCC using the -punafcc- module in Stata. PAFs were estimated in relation to dichotomized versions of the UVR average intensity variables (never = 0, ever > 0). These variables were also renamed “Sunbathing before and after age 2,” “Indoor tanning before and after age 20,” and “Sunburn before and after age 20” to reflect that they were not continuous variables.

To examine the relationship between UVR exposure variables and Breslow thickness, we defined thin melanomas as ≤1 mm (T1) and thick melanomas as >1 mm (T2–T4) and used logistic regression to estimate odds ratios (ORs) with 95% CIs. In a supplemental analysis, we also examined Breslow thickness as a continuous outcome by linear regression with loge-transformed Breslow thickness as the outcome and all exposures and adjustment variables. We imputed 15 data sets, and the estimates and computations with chained equations, assuming missing at random. The imputation model included the outcome and all exposures and adjustment variables. We imputed 15 data sets, and the estimates and standard errors were combined using Rubin’s rule (Supporting Information Material).

To assess the influence of missing values, we used multiple imputations with chained equations, assuming missing at random. The imputation model included the outcome and all exposures and adjustment variables. We imputed 15 data sets, and the estimates and standard errors were combined using Rubin’s rule (Supporting Information Material).

All models were adjusted for age (as the time scale for Cox, and at diagnosis for linear and logistic regression). Depending on the UVR exposure in question, covariates included in the models were sex, height, ambient UVR of residence, education, main occupational activity in the last position, sunbathing after age 20, sunbathing pattern before and after age 20, sunbathing average intensity, and sunburn after age 20. The variables entering each model are specified in the footnotes of each result table and displayed in directed acyclic graphs in the Supporting Information Material. We chose not to report results for the “UVR exposure before age 20 variables” alone as they were presumably less accurate than the “after age 20 variables,” while both sets of variables were included in the computation of the “UVR exposure pattern variables” and “the UVR average intensity variables.” In a sensitivity analysis, we adjusted for sunbathing before age 20, indoor tanning before age 20, and sunburn before age 20 in addition to the abovementioned variables (Tables S2–S4).

We used two-sided tests and a 0.05 level of significance in all analyses. Data analyses were performed using Stata version 16.1 (StataCorp).

### Results

In total, 27,772 participants (25,215 males and 2557 females) were included in the study sample (Figure 1). The mean age at baseline was 43 years for males and 39 years for females (Table 1). The most frequent main occupational activity among males was maintenance/inspection/deck construction (50%), while among females 67% were engaged in catering and health/office/administration. Females generally reported higher UVR exposure than males both before and after age 20 (Table 1).

Table 2 shows tumor characteristics of the 227 melanoma cases and 137 SCC cases. The mean age at diagnosis was 59 and 69 years for melanoma and SCC, respectively. Among the melanoma cases, 76% were in a local stage. Thin tumors (T1) constituted 48% of the melanomas. The most common anatomical sites of melanoma were the trunk for males (60%) and the lower limbs for females (55%), while head and neck were the most common sites of SCC for both sexes (males: 44%, females: 40%) (Table S5).

Results from complete-case and multiple imputation analyses were quite similar for UVR exposure and melanoma (Table 3) and SCC (Table 4), and the results from multiple imputation are reported here (if not stated otherwise). For sunbathing after age 20 and melanoma risk, a significant positive trend was found (\(p_{\text{trend}} = 0.031\)) (Table 3). For patterns of sunburn before and after age 20, we found significantly increased melanoma risk for high-low compared with low-low (HR = 1.46; 95% CI: 1.03, 2.08). We found a nonsignificant positive trend for average intensity of sunbathing (HR = 1.08; 95% CI: 0.99, 1.17) and a significant positive trend for average intensity of sunburn (HR = 1.21; 95% CI: 1.02, 1.44). For the average intensity of
TABLE 2  Characteristics of melanoma and SCC cases in the Norwegian Offshore Petroleum Workers cohort (n = 27,772)

|                  | Melanoma (n = 227) | SCC (n = 137) |
|------------------|---------------------|---------------|
| Sex, n (%)       |                     |               |
| Men              | 198 (87)            | 127 (93)      |
| Women            | 29 (13)             | 10 (7)        |
| Age at diagnosis, mean (range) | 59 (28–86) | 69 (41–87) |
| Anatomical site, n (%)       |                     |               |
| Head and neck    | 19 (8)              | 60 (45)       |
| Trunk            | 126 (56)            | 29 (21)       |
| Upper limbs      | 26 (11)             | 14 (10)       |
| Lower limbs      | 42 (19)             | 6 (4)         |
| Not otherwise specified | 14 (6) | 28 (20) |
| Clinical stage, n (%)        |                     |               |
| Localized        | 171 (76)            | 111 (81)      |
| Regional metastasis | 3 (1)              | 2 (1)         |
| Distant metastasis | 17 (7)             | 0 (0)         |
| Unspecified      | 36 (16)             | 24 (18)       |
| Breslow thickness, median (mm) (25th–75th percentile) | 0.9 (0.5–1.6) | – |
| T category, n (%)      |                     |               |
| T1 (<1.0 mm)     | 109 (48)            | –             |
| T2 (1.0–2.0 mm)  | 39 (17)             | –             |
| T3 (2.0–4.0 mm)  | 23 (10)             | –             |
| T4 (>4.0 mm)     | 12 (5)              | –             |
| Missing          | 44 (20)             | –             |
| Histological subtype, n (%)  |                     |               |
| Superficial spreading melanoma | 134 (59) | – |
| Nodular melanoma  | 31 (14)             | –             |
| Not otherwise specified | 55 (24) | – |
| Other*           | 7 (3)               | –             |

Abbreviations: ICD-O-3, International Classification of Diseases for Oncology, 3rd Edition; SCC, squamous cell carcinoma.
*According to ICD-O-3: 80003, 87233, 87303, 87423, 87443, 87453, 87703, 87723.

indoor tanning, the splined model showed the best fit to the data ($p_{\text{interaction}} = 0.023$, complete-case sample), and melanoma risk seemed to increase exponentially with an increasing number of sessions per year (Figure S1). No association was found in relation to ambient UVR of residence for melanoma. Workers that almost always used sunscreen had a significantly higher risk than those who never/rarely used sunscreen (HR = 2.16; 95% CI: 1.42, 3.27). No interaction was found between the UVR exposure variables (including sunscreen and ambient UVR of residence) and sex for melanoma ($0.179 \leq p_{\text{interaction}} \leq 0.986$). Cross-tabulation of UVR exposure after age 20 and main occupational activity in the last position showed little variation (Table S6). Interaction was only found between sunburns after age 20 and main occupational activity in the last position for melanoma ($p_{\text{interaction}} = 0.025$; Table S7a). Analyses stratified by occupation showed little difference in the sunburn–melanoma association between the main occupational categories (Table S8a).

Risk of SCC increased with increasing indoor tanning after age 20 (HR = 2.72; 95% CI: 1.22, 6.05 for ≥3 times/month vs. never) and with increasing sunburn frequency after age 20 (HR = 2.49; 95% CI: 1.00, 6.24 for ≥4 times/year vs. never) (Table 4). Compared to workers with consistently few sessions of indoor tanning before and after age 20 (low-low), those who had a low-high, high-low, or high-high pattern showed a nearly twofold increased risk of SCC (HR = 1.85; 95% CI: 1.00, 3.43). We observed a significant positive trend for sunburn pattern before and after age 20 ($p_{\text{trend}} < 0.001$). We found a significant positive trend for average intensity of indoor tanning ($p_{\text{trend}} < 0.009$) and sunburns ($p_{\text{trend}} < 0.001$). For the average intensity variables, linear models showed the best fit ($p_{\text{nonlinear}} > 0.05$, complete-case sample). Workers residing in the north-middle counties had significantly lower SCC risk (HR = 0.43; 95% CI: 0.21, 0.89) compared with those in the southwest counties. Workers that used sunscreen almost always had significantly higher risk than never/rarely users (HR = 2.15, 95% CI: 1.42, 3.26). In supplemental analyses (Table S7a), we found interactions between main occupational activity and sunburn after age 20 ($p_{\text{interaction}} = 0.007$), sunbathing average intensity ($p_{\text{interaction}} = 0.027$), and sunscreen use ($p_{\text{interaction}} = 0.041$). Analyses stratified by occupation (Table S8b) yielded statistically significant associations for sunbathing average intensity among drillers (HR = 1.66; 95% CI: 1.15, 2.40; continuous) and sunburn after age 20 among catering workers (HR = 7.24; 95% CI: 2.85, 18; ≥2 times/year vs. never). For SCC, we also found interaction between sunscreen use and ambient UVR of residence ($p_{\text{interaction}} = 0.006$; Table S7b), and the stratified analysis showed an increased risk among workers living in the southeast (HR = 4.67; 95% CI: 2.32, 9.36 for almost always vs. never/rarely; Table S8c). No interaction was found between the UVR exposure variables and sex for SCC ($0.171 \leq p_{\text{interaction}} \leq 0.994$).

Table 5 shows PAFs (95% CIs) of melanoma and SCC associated with dichotomized UVR exposure variables before and after age 20 for the complete-case sample. For melanoma, the estimated PAFs for sunbathing and sunburn were 70% (10%, 90%) and 44% (5%, 67%), respectively. For SCC, the estimated PAF for sunburn was 63% (24%, 82%).

Table 6 shows ORs for being diagnosed with thick versus thin melanoma in relation to UVR exposure. Odds of thick melanoma decreased with increasing sunbathing frequency after age 20 and sunbathing average intensity (ORs [95% CIs], 0.38 [0.16, 0.90] and 0.79 [0.63, 0.97], respectively; $p_{\text{trend}} \leq 0.028$; multiple imputation analysis). We found increased odds of thicker melanoma for those that used sunscreen often or almost always, compared with never/rarely ($p_{\text{trend}} = 0.063$). In a supplemental analysis, we estimated Breslow thickness as a continuous outcome in relation to these UVR exposure variables but did not find any statistically significant associations (Table S1). Additional adjustment for sunbathing before age 20, indoor tanning before age 20, and sunburn before age 20, depending on the UVR exposure in question, did not change the results materially (Tables S2–S4).
### Table 3: Hazard ratios of melanoma according to UVR exposure in the Norwegian Offshore Petroleum Workers cohort

| UVR exposure variable | No. of participants | No. of cases | Complete case (n = 23,982) | Multiple imputation (n = 27,772) |
|-----------------------|---------------------|--------------|----------------------------|----------------------------------|
|                       | HR (95% CI)         | p trend      | HR (95% CI)                | p trend                          |
| Sunbathing after age 20a |                     |              |                            |                                  |
| Never                 | 1746                | 6            | 0.47 (0.20, 1.09)          | 0.55 (0.26, 1.15)                |
| 1 week/year           | 6873                | 47           | 1.00 (reference)           | 1.00 (reference)                 |
| 2-3 weeks/year        | 9790                | 79           | 1.18 (0.82, 1.69)          | 1.13 (0.81, 1.58)                |
| ≥4 weeks/year         | 5573                | 56           | 1.38 (0.93, 2.04)          | 1.24 (0.86, 1.79)                |
| Indoor tanning after age 20a |                   |              |                            |                                  |
| Never                 | 10,653              | 90           | 1.00 (reference)           | 1.00 (reference)                 |
| Rarely                | 10,575              | 85           | 1.27 (0.93, 1.73)          | 1.33 (0.99, 1.78)                |
| 1-2 times/month       | 1825                | 6            | 0.61 (0.26, 1.41)          | 0.84 (0.43, 1.64)                |
| ≥3 times/month        | 929                 | 7            | 1.34 (0.61, 2.97)          | 1.38 (0.69, 2.78)                |
| Sunburn after age 20b |                      |              |                            |                                  |
| Never                 | 5557                | 33           | 0.73 (0.49, 1.07)          | 0.74 (0.52, 1.05)                |
| 1 time/year           | 15,664              | 131          | 1.00 (reference)           | 1.00 (reference)                 |
| 2-3 times/year        | 2471                | 18           | 0.82 (0.50, 1.34)          | 0.84 (0.53, 1.33)                |
| ≥4 times/year         | 290                 | 6            | 2.18 (0.95, 4.99)          | 1.85 (0.81, 4.23)                |
| Sunbathing pattern before and after age 20a |                   |              |                            |                                  |
| Low-low (always <2 weeks/year) | 6203 | 35 | 1.00 (reference) | 1.00 (reference) |
| Low-high (<2 weeks/year to ≥2 weeks/year) | 1921 | 21 | 1.83 (1.06, 3.15) | 1.64 (0.98, 2.76) |
| High-low (≥2 weeks/year to <2 weeks/year) | 2416 | 18 | 1.21 (0.68, 2.14) | 1.21 (0.70, 2.10) |
| High-high (always ≥2 weeks/year) | 13,442 | 114 | 1.45 (0.99, 2.12) | 1.41 (0.98, 2.02) |
| Indoor tanning pattern before and after age 20a |                   |              |                            |                                  |
| Low-low (always <1 time/month) | 20,905 | 173 | 1.00 (reference) | 1.00 (reference) |
| Low-high, high-low, or high-high | 3077 | 15 | 0.80 (0.47, 1.38) | 0.86 (0.52, 1.40) |
| Sunburn pattern before and after age 20a |                   |              |                            |                                  |
| Low-low (always <2 times/year) | 17,910 | 124 | 1.00 (reference) | 1.00 (reference) |
| Low-high (<2 times/year to ≥2 times/year) | 613 | 6 | 1.17 (0.51, 2.67) | 1.05 (0.47, 2.37) |
| High-low (≥2 times/year to <2 times/year) | 3311 | 40 | 1.64 (1.14, 2.36) | 1.46 (1.03, 2.08) |
| High-high (always ≥2 times/year) | 2148 | 18 | 1.17 (0.71, 1.93) | 1.17 (0.74, 1.87) |
| Sunbathing average intensitya | 23,982 | 188 | 1.09 (1.00, 1.19) | 0.048 (0.99, 1.17) |
| Indoor tanning average intensitya | 23,982 | 188 | 1.00 (0.98, 1.03) | 0.079 (0.98, 1.03) |
| Sunburn average intensityd | 23,982 | 188 | 1.24 (1.04, 1.48) | 0.016 (1.02, 1.44) |
| Ambient UVR of residence in 1998e |                   |              |                            |                                  |
| North-Middle           | 2993                | 20           | 0.81 (0.50, 1.32)          | 0.86 (0.56, 1.32)                |
| Southwest              | 13,740              | 100          | 1.00 (reference)           | 1.00 (reference)                 |
| Southeast inland       | 2770                | 27           | 1.17 (0.76, 1.79)          | 1.07 (0.72, 1.60)                |
| Southeast coast        | 4479                | 41           | 1.04 (0.72, 1.51)          | 1.07 (0.77, 1.49)                |

(Continues)
TABLE 3 (Continued)

| UVR exposure variable | No. of participants | No. of cases | Complete case (n = 23,982) HR (95% CI) p trend | Multiple imputation (n = 27,772) HR (95% CI) p trend |
|-----------------------|---------------------|-------------|---------------------------------|---------------------------------|
| Sunscreen use in 1998 |                     |             |                                  |                                  |
| Never/rarely          | 9120                | 69          | 1.00 (reference)                 | 1.00 (reference)                |
| Often                 | 8109                | 60          | 1.05 (0.74, 1.50)                | 1.49 (0.96, 2.31)               |
| Almost always         | 6753                | 59          | 1.21 (0.84, 1.73)                | 2.16 (1.42, 3.27)               |

Abbreviations: CI, confidence interval; HR, hazard ratio; UVR, ultraviolet radiation.

*Adjusted for age, sex, height, ambient UVR of residence, education, and main occupational activity in last position.
*Adjusted for age, sex, height, ambient UVR of residence, education, and sunbathing after age 20.
*Adjusted for age, sex, height, ambient UVR of residence, education, and sunbathing average intensity.
*Adjusted for age.
*Adjusted for age, sex, height, ambient UVR of residence, education, sunbathing after age 20, sunburn after age 20.
*Modeled as a continuous variable to test for linear trend.

4 | DISCUSSION

This prospective analysis found positive associations between the number of sunburns and sunscreen use and risk of melanoma and SCC in a cohort of male and female offshore petroleum workers. Further, melanoma risk increased with increasing sunbathing frequency after age 20, and a positive association was found between indoor tanning after age 20 and SCC. Workers living in the northernmost part of Norway had lower SCC risk, while no significant association was observed between the county of residence and melanoma. Sunbathing seemed to be inversely associated with being diagnosed with thick melanomas.

Our findings suggest that individual UVR exposure may explain much of the previously reported excesses in skin cancer incidence and mortality in petroleum workers from Australia, Canada, Norway, and the United Kingdom, although awareness around sun protection is probably more vigilant in southern latitudes.6–10 Our results were also concordant with the hypothesis that sunbathing vacations and sunburns (an important marker of intermittent exposure) increase melanoma risk.38–42 Indoor tanning is classified as carcinogenic to humans,43 but in contrast to prior studies,30,44,45 we did not find a positive association between indoor tanning and melanoma risk. This was probably due to the low frequency of indoor tanning in our cohort and, hence limited power, as also seen in other cohort studies reporting a nonsignificant increased risk of melanoma among indoor tanners.46,47

For SCC risk, our findings accord with two papers from the Norwegian Women and Cancer (NOWAC) study39,48 for indoor tanning but differ with respect to sunburn, where we found a positive association. One possible explanation can be that the NOWAC studies include women only. However, in Green et al.,41 where both genders were combined, they reported a positive trend between sunburn and SCC risk, in line with our results. Consistent with the literature, we also found that low ambient UVR exposure was associated with low SCC risk,50 but not for melanoma, which differs from previous population-based studies in Norway.51

In a recent meta-analysis, Rueegg et al.52 acknowledged the challenges in assessing the sunscreen–melanoma association. They found a protective effect of sunscreen in a randomized control trial, but cohort studies combined showed a positive association,52 as found in the present analysis. This result may be explained by an “intention-to-tan” or that people at higher risk of skin cancer use more sunscreen more often or regularly. This is consistent with the findings of Ghiasvand et al.,53,54 who reported that female sunscreen users had a higher frequency of sunbathing vacations, indoor tanning, and sunburns, and that sunscreen use was associated with fair skin, skin sensitivity, and the number of nevi.

Compared with the results from a previous follow-up of the NOPW cohort, which only addressed male workers,16 we also found increased melanoma risk in relation to the increasing frequency of sunburns and indoor tanning, but not for sunbathing. This might be due to longer follow-up, which allowed more cases to occur, and the inclusion of female workers in the present analysis. For SCC, the present study confirmed previous findings of increased risk of nonmelanoma skin cancer (mainly SCC) in relation to sunburns and sunscreen use and provided stronger evidence for an association with indoor tanning than we previously reported.16

Our estimated PAFs were largely in accordance with what has been reported previously, although not directly comparable. PAFs of melanoma and SCC have commonly been estimated in relation to different aspects of UVR exposure. Previous studies have reported that 63%–86% of melanomas are attributable to excess ambient UVR exposure.55–57 For SCC, Olsen et al.55 estimated that virtually all keratinocyte cancers could be attributed to high background levels of UVR. On the contrary, an occupational study in Canada reported that 9% of SCC was attributed to occupational sun exposure.58
| UVR exposure variable | No. of participants | No. of cases | Complete case (n = 23,982) HR (95% CI) p trend | Multiple imputation (n = 27,772) HR (95% CI) p trend |
|-----------------------|---------------------|--------------|-----------------------------------------------|--------------------------------------------------|
| **Sunbathing after age 20**<sup>a</sup> |                      |              |                                               |                                                  |
| Never                 | 1746                | 7            | 0.67 (0.30, 1.54) 0.79 (0.38, 1.64)           | 0.362 0.353                                      |
| 1 week/year           | 6873                | 30           | 1.00 (reference) 1.00 (reference)             |                                                  |
| 2–3 weeks/year        | 9790                | 43           | 0.96 (0.60, 1.53) 1.04 (0.67, 1.62)           |                                                  |
| ≥4 weeks/year         | 5573                | 35           | 1.08 (0.66, 1.78) 1.13 (0.71, 1.80)           |                                                  |
| **Indoor tanning after age 20**<sup>a</sup> |                      |              |                                               |                                                  |
| Never                 | 10,653              | 66           | 1.00 (reference) 1.00 (reference)             | 0.007 0.019                                      |
| Rarely                | 10,575              | 38           | 1.33 (0.88, 2.01) 1.41 (0.97, 2.06)           |                                                  |
| 1–2 times/month       | 1825                | 4            | 1.29 (0.46, 3.60) 1.05 (0.38, 2.88)           |                                                  |
| ≥3 times/month        | 929                 | 7            | 3.49 (1.54, 7.87) 2.72 (1.22, 6.05)           |                                                  |
| **Sunburn after age 20**<sup>b</sup> |                      |              |                                               |                                                  |
| Never                 | 5557                | 19           | 0.66 (0.39, 1.11) 0.58 (0.36, 0.96)           | 0.001 <0.001                                     |
| 1 time/year           | 15,664              | 69           | 1.00 (reference) 1.00 (reference)             |                                                  |
| 2–3 times/year        | 2471                | 22           | 1.95 (1.20, 3.18) 1.66 (1.03, 2.69)           |                                                  |
| ≥4 times/year         | 290                 | 5            | 3.03 (1.20, 7.64) 2.49 (1.00, 6.24)           |                                                  |
| **Sunbathing pattern before and after age 20**<sup>a</sup> |                      |              |                                               |                                                  |
| Low-low (always <2 weeks/year) | 6203               | 22           | 1.00 (reference) 1.00 (reference)             | <0.001 <0.001                                   |
| Low-high (<2 weeks/year to ≥2 weeks/year) | 1921               | 15           | 1.99 (1.03, 3.84) 1.80 (0.94, 3.45)           |                                                  |
| High-low (≥2 weeks/year to <2 weeks/year) | 2416               | 15           | 1.61 (0.83, 3.10) 1.52 (0.81, 2.86)           |                                                  |
| High-high (always ≥2 weeks/year) | 13,442             | 63           | 1.21 (0.74, 1.96) 1.21 (0.77, 1.91)           |                                                  |
| **Indoor tanning pattern before and after age 20**<sup>a</sup> |                      |              |                                               |                                                  |
| Low-low (always <1 time/month) | 20,905             | 103          | 1.00 (reference) 1.00 (reference)             | 0.822 0.687                                      |
| Low-high, high-low or high-high | 3077               | 12           | 2.03 (1.09, 3.78) 1.85 (1.00, 3.43)           |                                                  |
| **Sunburn pattern before and after age 20**<sup>c</sup> |                      |              |                                               |                                                  |
| Low-low (always <2 times/year) | 17,910             | 66           | 1.00 (reference) 1.00 (reference)             | <0.001 <0.001                                   |
| Low-high (<2 times/year to ≥2 times/year) | 613                | 7            | 2.22 (1.01, 4.90) 2.12 (0.95, 4.73)           |                                                  |
| High-low (≥2 times/year to <2 times/year) | 3311               | 22           | 1.78 (1.08, 2.91) 1.96 (1.24, 3.11)           |                                                  |
| High-high (always ≥2 times/year) | 2148               | 20           | 2.82 (1.69, 4.69) 2.66 (1.59, 4.46)           |                                                  |
| **Sunbathing average intensity**<sup>a</sup> | 23,982              | 115          | 1.01 (0.91, 1.12) 0.879 (0.92, 1.13) 0.688    |                                                  |
| Indoor tanning average intensity<sup>a</sup> | 23,982              | 115          | 1.04 (1.01, 1.07) 0.005 (1.01, 1.06) 0.009    |                                                  |
| **Sunburn average intensity**<sup>d</sup> | 23,982              | 115          | 1.49 (1.26, 1.76) <0.001 (1.25, 1.73) <0.001  |                                                  |
| Ambient UVR of residence in 1998<sup>e</sup> |                      |              |                                               |                                                  |
| North-Middle          | 2993                | 6            | 0.36 (0.15, 0.82) 0.43 (0.21, 0.89)           | 0.228 0.163                                      |
| Southwest             | 13,740              | 64           | 1.00 (reference) 1.00 (reference)             |                                                  |
| Southeast inland      | 2770                | 14           | 0.82 (0.46, 1.47) 0.94 (0.56, 1.57)           |                                                  |
| Southeast coast       | 4479                | 31           | 0.96 (0.63, 1.48) 1.02 (0.69, 1.51)           |                                                  |

(Continues)
We observed that 15% of the melanoma cases in this occupational cohort were diagnosed in stages T3 and T4, which is substantially lower than the 24% reported from the Janus cohort, a Norwegian population-based study.59 This may be explained by the mandatory frequent health examinations of offshore workers, possibly leading to early melanoma detection,8,60 or by sex and age differences. Also, the NOPW cohort had 20% missing on Breslow thickness versus 14% in the Janus cohort, reducing comparability. Our results suggest that prediagnostic sunbathing is inversely associated with being diagnosed with a thick melanoma, which is consistent with the finding of Gandini et al.26 However, they collected information on UVR exposure at diagnosis, which may have introduced differential misclassification in exposure level.61 Therefore, we cannot rule out that misclassification has biased the effect estimates (both away and toward the null) in our multivariable models.62 Moreover, low case numbers in some exposure categories reduced the statistical power. We also lacked information on host factors (i.e., skin/hair pigmentation, nevi, freckling, and family history) and had no information on work-related UVR exposure and UVR exposure during follow-up. We cannot distinguish work-related UVR exposure from leisure time UVR exposure based on the self-reported questionnaire. However, considering the strict PPE usage, the unique work schedule, and high income among offshore workers, we argue that the UVR exposure data reflects a kind of work-related UVR exposure particular to this occupation. With 67% engaged in catering, health, or administration activities, female workers were over-represented in typical indoor jobs and were likely exposed to UVR mainly during

### TABLE 4 (Continued)

| UVR exposure variable | No. of participants | No. of cases | Complete case (n = 23,982) HR (95% CI) p trend<sup>g</sup> | Multiple imputation (n = 27,772) HR (95% CI) p trend<sup>g</sup> |
|-----------------------|---------------------|--------------|------------------------------------------------|------------------------------------------------|
| Sunscreen use in 1998<sup>i</sup> | | | | |
| Never/rarely | 9120 | 42 | 1.00 (reference) | 1.00 (reference) |
| Often | 8109 | 32 | 1.33 (0.83, 2.13) | 1.51 (0.97, 2.33) |
| Almost always | 6753 | 41 | 2.06 (1.32, 3.21) | 2.15 (1.42, 3.26) |

Abbreviations: CI, confidence interval; HR, hazard ratio; SCC, squamous cell carcinoma; UVR, ultraviolet radiation.

<sup>a</sup>Adjusted for age, sex, ambient UVR of residence, education, and main occupational activity in last position.
<sup>b</sup>Adjusted for age, sex, ambient UVR of residence, education, and sunbathing after age 20.
<sup>c</sup>Adjusted for age, sex, ambient UVR of residence, education, and sunbathing pattern before and after age 20.
<sup>d</sup>Adjusted for age, sex, ambient UVR of residence, education, and sunbathing average intensity.
<sup>e</sup>Adjusted for age.
<sup>f</sup>Adjusted for age, sex, ambient UVR of residence, education, sunbathing after age 20, sunburn after age 20.
<sup>g</sup>Modeled as a continuous variable to test for linear trend.

### TABLE 5 PAFs with 95% CIs of melanoma and SCC associated with UVR exposures (complete-case sample, n = 23,982)

| UVR exposure variable | Melanoma PAF (95% CI) | SCC PAF (95% CI) |
|-----------------------|-----------------------|------------------|
| Sunbathing before and after age 20<sup>a</sup> | 0.70 (0.10, 0.90) | 0.60 (−0.18, 0.86) |
| Indoor tanning before and after age 20<sup>a</sup> | 0.13 (−0.01, 0.25) | 0.12 (−0.01, 0.23) |
| Sunburn before and after age 20<sup>a</sup> | 0.44 (0.05, 0.67) | 0.63 (0.24, 0.82) |

Abbreviations: CI, confidence interval; PAF, population attributable fraction; SCC, squamous cell carcinoma; UVR, ultraviolet radiation.

<sup>a</sup>Adjusted for age, sex, ambient UVR of residence, education, and main occupational activity in last position.
<sup>b</sup>Adjusted for age, sex, ambient UVR of residence, education, and sunbathing before and after age 20.
<sup>c</sup>Additionally adjusted for height.
<sup>d</sup>Dichotomized exposure variables showing PAFs of being never versus ever exposed.
### TABLE 6  Odds ratios of thick (>1 mm) versus thin (≤1 mm) melanoma according to UVR exposure in the Norwegian Offshore Petroleum Workers cohort

| UVR exposure variable | No. of cases | Complete case (n = 23,982) | Multiple imputation (n = 27,772) |
|-----------------------|--------------|-----------------------------|----------------------------------|
|                       | OR (95% CI)  | p trend                      | OR (95% CI)                      | p trend                      |
| Sunbathing after age 20a |              |                             |                                  |                               |
| Never                 | 6            | 0.86 (0.14, 5.33)            | 1.57 (0.30, 8.15)                |                               |
| 1 week/year           | 40           | 1.00 (reference)             | 1.00 (reference)                 |                               |
| 2–3 weeks/year        | 77           | 0.65 (0.28, 1.49)            | 0.72 (0.33, 1.57)                |                               |
| ≥4 weeks/year         | 50           | 0.35 (0.14, 0.87)            | 0.38 (0.16, 0.90)                |                               |
| Indoor tanning after age 20a |        |                             | 0.029                            | 0.014                          |
| Never                 | 80           | 1.00 (reference)             | 1.00 (reference)                 | 1.00 (reference)              |
| Rarely                | 81           | 1.14 (0.58, 2.23)            | 1.33 (0.99, 1.78)                |                               |
| 1–2 times/month       | 6            | 0.49 (0.08, 3.18)            | 0.84 (0.43, 1.64)                |                               |
| ≥3 times/month        | 6            | 1.08 (0.18, 6.40)            | 1.38 (0.69, 2.78)                |                               |
| Sunburn after age 20b |              |                             | 0.941                            | 0.983                          |
| Never                 | 30           | 1.49 (0.63, 3.53)            | 1.35 (0.63, 2.92)                |                               |
| 1 time/year           | 120          | 1.00 (reference)             | 1.00 (reference)                 |                               |
| 2–3 times/year        | 18           | 0.52 (0.17, 1.57)            | 0.71 (0.26, 1.97)                |                               |
| ≥4 times/year         | 5            | 1.12 (0.16, 7.83)            | 1.19 (0.17, 8.24)                |                               |
| Sunbathing pattern before and after age 20a | |                             | 0.195                            | 0.379                          |
| Low-low (always <2 weeks/year) | 31 | 1.00 (reference)          | 1.00 (reference)                |                               |
| Low-high (<2 weeks/year to ≥2 weeks/year) | 20 | 1.34 (0.39, 4.65) | 1.30 (0.40, 4.18) |
| High-low (≥2 weeks/year to <2 weeks/year) | 15 | 6.52 (1.40, 30.43) | 2.72 (0.73, 10) |
| High-high (always ≥2 weeks/year) | 107 | 0.85 (0.36, 2.03) | 0.65 (0.29, 1.49) |
| Indoor tanning pattern before and after age 20a | |                             | 0.457                            | 0.158                          |
| Low-low (always <1 time/month) | 159 | 1.00 (reference) | 1.00 (reference) |
| Low-high, high-low, or high-high | 14 | 0.64 (0.20, 2.08) | 0.95 (0.34, 2.66) |
| Sunburn pattern before and after age 20c | |                             | 0.668                            | 0.794                          |
| Low-low (always <2 times/year) | 113 | 1.00 (reference) | 1.00 (reference) |
| Low-high (<2 times/year to ≥2 times/year) | 6 | 0.17 (0.02, 1.66) | 0.21 (0.02, 2.02) |
| High-low (≥2 times/year to <2 times/year) | 37 | 0.98 (0.45, 2.13) | 1.00 (0.46, 2.18) |
| High-high (always ≥2 times/year) | 17 | 0.77 (0.26, 2.30) | 0.87 (0.31, 2.43) |

(Continues)
off-duty activities. The sex difference observed between anatomical sites of melanoma also suggests sex-specific off-duty sun tanning habits, although no interaction was found between sex and UVR exposure variables.

In conclusion, our findings in this large prospective cohort provide supporting evidence for associations between UVR exposures and risk of melanoma and SCC in male and female offshore petroleum workers. Northern hemisphere offshore petroleum workers may benefit from targeted sun protection advice to reduce skin cancer risk.

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CONFLICTS OF INTEREST
Tom K. Grimsrud and Jo S. Stenehjem note that the Research Council of Norway (governmental agency) awarded an industry-collaborative grant to the CRN (governmental agency) in 2019 to establish a cohort of offshore petroleum workers. A condition pertaining to such industry-collaborative grants is that 20% (US $175,000) of the grant was provided by the petroleum industry and 80% (US $700,000) by the Research Council itself with the intention of joining forces for the common interest of improved occupational health among petroleum workers. The grant-application process was governed by the Research Council without any involvement from the petroleum industry. Tom K. Grimsrud and Jo S. Stenehjem are affiliated and employed by the CRN, but the grant does not cover their salary. The remaining authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD
Leena Nylander-French declares that she has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS
Jo S. Stenehjem and Tom K. Grimsrud conceived the study. Fei-Chih Liu, Tom K. Grimsrud, Marit B. Veierad, Trude E. Robsahm, Reza Ghiassvand, Ronnie Babigumira, Nita K. Shala, and Jo S. Stenehjem contributed to the project design. Fei-Chih Liu performed the data analyses. Fei-Chih Liu, Ronnie Babigumira, and Jo S. Stenehjem

| UVR exposure variable | No. of cases | Complete case (n = 23,982) | Multiple imputation (n = 27,772) |
|-----------------------|-------------|-----------------------------|----------------------------------|
| Sunbathing average intensity | 173         | 0.79 (0.63, 1.00) | 0.046 0.79 (0.63, 0.97) | 0.028 |
| Indoor tanning average intensity | 173         | 0.97 (0.91, 1.03) | 0.333 0.99 (0.93, 1.05) | 0.723 |
| Sunburn average intensity | 173         | 0.78 (0.49, 1.23) | 0.285 0.85 (0.55, 1.33) | 0.478 |
| Ambient UVR of residence in 1998 | | | | |
| North-Middle | 19         | 1.46 (0.53, 3.97) | 1.02 (0.41, 2.49) | 0.934 |
| Southwest | 89         | 1.00 (reference) | 1.00 (reference) | 0.989 |
| Southeast inland | 27         | 1.95 (0.80, 4.75) | 1.84 (0.80, 4.26) | 0.934 |
| Southeast coast | 38         | 0.98 (0.46, 2.11) | 0.87 (0.43, 1.74) | 0.934 |
| Sunscreen use in 1998 | | | | |
| Never/rarely | 63         | 1.00 (reference) | 1.00 (reference) | 0.146 |
| Often | 52         | 1.06 (0.47, 2.40) | 1.39 (0.66, 2.94) | 0.063 |
| Almost always | 58         | 1.86 (0.82, 4.17) | 2.01 (0.96, 4.19) | 0.063 |

Abbreviations: CI, confidence interval; OR, odds ratio; UVR, ultraviolet radiation.

*Adjusted for age, sex, height, ambient UVR of residence, education, and main occupational activity in last position.

*Adjusted for age, sex, height, ambient UVR of residence, education, and sunbathing after age 20.

*Adjusted for age, sex, height, ambient UVR of residence, education, and sunbathing pattern before and after age 20.

*Adjusted for age, sex, height, ambient UVR of residence, education, and sunbathing average intensity.

*Adjusted for age.

*Adjusted for age, sex, height, ambient UVR of residence, education, sunbathing after age 20, sunburn after age 20.

*Modeled as a continuous variable to test for linear trend.
performed data management. Marit B. Veierød, Trude E. Robsahm, and Ronnie Babigumira contributed with their expertise on skin cancer epidemiology. Fei-Chih Liu drafted the manuscript and all authors reviewed and revised it critically for important intellectual content and approved the final version for submission. Fei-Chih Liu and Jo S. Stenehjem are the guarantors.

DATA AVAILABILITY STATEMENT
The data are held by the CRN. Requests for data sharing/case pooling may be directed to principal investigator Dr. Tom K. Grimsrud [tom.k.grimsrud@kreftregisteret.no]. Participation in the NOPW cohort studies is based on informed consent, which must be considered whenever the use of data deviates from the original plans. Moreover, the research file uses data derived from state government registries, which deliver data under license from regional committees for research ethics and data custodians. Thus, any requests to share these data will be subject to formal considerations, and approval must be obtained from each data source. Background information on the study, the scientific team, and study progress is available through the study website https://www.kreftregisteret.no/en/Research/Projects/cancer-among-offshore-workers-in-norway.

ETHICS APPROVAL AND INFORMED CONSENT
This study was performed at the CRN after legal and ethical approvals were obtained from the Norwegian Data Inspectorate, the Regional Committee for Medical Research Ethics (2018/1162), and the Norwegian Directorate of Health.

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