Cancer Causes Control
DOI 10.1007/s10552-010-9562-1

ORIGINAL PAPER

Occupational exposure to the sun and risk of skin and lip cancer among male wage earners in Denmark: a population-based case–control study

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Received: 27 May 2009 / Accepted: 31 March 2010

Abstract
Objective We examined the association between outdoor work and the risks of non-melanoma skin cancer, cutaneous malignant melanoma, and lip cancer in a population-based case–control study.
Methods Among all male wage earners in Denmark, 42,542 cases of non-melanoma skin cancer, 7,690 cases of cutaneous malignant melanoma, and 2,341 cases of lip cancer were identified in the nationwide Danish Cancer Registry. Population controls matched on sex and year of birth were selected at random among wage earners by incidence density sampling. Conditional logistic regression models were used to calculate odds ratios for risks of non-melanoma skin cancer, malignant melanoma, and lip cancer in relation to outdoor work after adjusting for covariates.
Results For outdoor workers employed more than 10 years, the adjusted odds ratios were 0.83 (95% confidence interval (CI) 0.77–0.88) for non-melanoma skin cancer and 1.67 (95% CI 1.38–2.03) for lip cancer. Significantly reduced risk of basal cell cancers on the head, trunk, upper, or lower extremities were observed (range of odds ratios, 0.36 to 0.86).
Conclusions The results support the hypothesis of a decreased risk of non-melanoma skin cancer and an increased risk of lip cancer among outdoor workers in the Northern Hemisphere.

Keywords Sunlight · Occupational exposure · Skin neoplasms · Melanoma · Lip cancer

This study was supported by grants from the Danish Working Environment Authority.

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Introduction

As the incidences of non-melanoma skin cancer and cutaneous malignant melanoma have increased rapidly in Denmark over the past 50 years [1], skin cancer represents an important source of morbidity, cosmetic damage, and health-care expenditure. The commonest type of non-melanoma skin cancer is basal cell cancer, followed by squamous cell cancer; during the period 1977–2003, these two types accounted for approximately 95% of all non-melanoma skin cancers in Denmark [2]. Solar ultraviolet radiation is the most important known risk factor for skin cancer, accounting for an estimated 80–85% of all skin cancers [3]. Solar ultraviolet radiation has also long been considered to be causally associated with lip cancer, although this cancer is classified as a cancer of the oral cavity [4].

In 1992, the International Agency for Research on Cancer concluded that solar ultraviolet radiation causes non-melanoma skin cancer and cutaneous malignant melanoma in humans [5]. Given that outdoor workers receive a high annual dose of ultraviolet radiation, several studies have been conducted of the relation between outdoor work

Published online: 11 April 2010

and skin cancer, exposure to the sun being used as a proxy for ultraviolet radiation. The studies had inconsistent findings, some showing a positive association with non-melanoma skin cancer [6–9] and cutaneous malignant melanoma [8, 10] and others showing a protective effect of occupational exposure to the sun against these cancers [11–16]. The results are difficult to compare, for several reasons, including different measures of exposure, difficulty in differentiating between occupational and recreational exposure, and cultural and social differences in clothing and time spent outside. Furthermore, the studies were conducted at different latitudes and altitudes.

We conducted a nationwide, population-based case–control study with complete follow-up to examine the association between outdoor work and non-melanoma skin cancer, cutaneous malignant melanoma, and lip cancer among outdoor workers in Denmark.

Materials and methods

Study populations

Cases

Male patients in whom non-melanoma skin cancer ($n = 51{,}003$), cutaneous malignant melanoma ($n = 8{,}515$), or lip cancer ($n = 3{,}187$) was diagnosed in the period 1 January 1970–1 June 2003 were ascertained from the Danish Cancer Registry. The Registry contains data on the incidence of cancer throughout Denmark since 1943 and information including the unique 10-digit identification number attributed to all residents of Denmark, date of diagnosis, method of verification, topography, and morphology. Tumors are classified according to a modified Danish version of the *International Classification of Diseases*, version 7 (ICD7) and, since 1978, also according to ICD10. We included cases in men who had been wage earners in Denmark for at least 6 months since 1964, were born after 1 April 1897, were 16–84 years of age at the date of diagnosis, and had no diagnosis of cancer (except for non-melanoma skin cancer for the study of cutaneous malignant melanoma and lip cancer) in the period 1 January 1943–31 December 1969. A total of 42,542 cases of non-melanoma skin cancer, 7,690 of cutaneous malignant melanoma, and 2,341 of lip cancer were included in the study (Table 1). For each case, we retrieved job title, place of birth, and vital status through the 10-digit identification number.

Controls

Population controls matched on sex and year of birth were chosen at random from the files of the Danish Central Person Registry, which was established in 1968. As the Registry is based on the 10-digit identification number, we retrieved information on job title, place of birth, and vital status. The inclusion criteria for controls were the same as those for the cases. Furthermore, controls had to be alive at the date of diagnosis of cancer in their corresponding case. Controls were assigned the same date of diagnosis as their respective cases in order to end exposure simultaneously. One control per case was chosen for the study of non-melanoma skin cancer, two for the study of cutaneous malignant melanoma, and four for the study of lip cancer, yielding a total of 42,542 controls for the study of non-melanoma skin cancer, 15,380 for the study of cutaneous malignant melanoma, and 9,361 for the study of lip cancer (Table 1). One case of lip cancer was matched with only one control.

Occupational history

Past employment was reconstructed from the files of the Supplementary Pension Fund. The scheme has been a compulsory supplement to the State pension since 1964 for wage earners aged 18–66 and since 1978 those aged 16–66. The pension supplement is financed by the wage earners themselves and from their employer. All contributions are paid to the fund, which retains the information on employer, pensioners, and diseased persons. The employer fills out a standard registration form with a description of the most important activities of the company, including type of industry. For each company, an industrial code has been allocated by use of an extended version of the International Standard Industrial Classification of All Economic Activities (1968 version) [17]. We established a full employment history since 1964 for all study subjects with the identity of the industrial codes and date of start and end of employment.

Exposure assessment

To identify industries in which work was mainly outdoors and therefore involving frequent exposure to the sun, we used information from Danish job–exposure matrixes and from a national survey. In the job–exposure matrix for Denmark developed for the Nordic Occupational Cancer Study [18], occupations in which the estimated exposure of workers to solar radiation was at least 150 J/m^2 per day were classified as outdoor industries. The database of the International Information System on Occupational Exposure to Carcinogens (CAREX) of the Finnish Institute of Occupational Health contains estimates of the numbers of workers occupationally exposed to carcinogens by industry in 15 previous countries of the European Union (data for 1990–1993) and in four of the 10 countries that joined the

Table 1 Characteristics of patients with non-melanoma skin cancer, cutaneous malignant melanoma, or lip cancer and population controls

Characteristic	Non-melanoma skin cancer		Cutaneous malignant melanoma		Lip cancer	
	Controls (n = 42,542)	Cases (n = 42,542)	Controls (n = 15,380)	Cases (n = 7,690)	Controls (n = 9,361)	Cases (n = 2,341)
Year of birth (%)						
Mean (SE[a])	1,926.9 (0.0697)	1,926.9 (0.0697)	1,936 (0.1301)	1,936 (0.1840)	1,921.6 (0.1306)	1,921.6 (0.2614)
<1900	373 (0.9)	373 (0.9)	46 (0.3)	23 (0.3)	161 (1.7)	41 (1.7)
1900–1909	3,538 (8.3)	3,538 (8.3)	516 (3.4)	258 (3.4)	1,344 (14.4)	336 (14.4)
1910–1919	9,195 (21.6)	9,195 (21.6)	1,774 (11.5)	887 (11.5)	2,548 (27.2)	637 (27.2)
1920–1929	11,623 (27.3)	11,623 (27.3)	3,032 (19.7)	1,516 (19.7)	2,692 (28.8)	673 (28.8)
1929–1939	9,001 (21.2)	9,001 (21.2)	3,408 (22.2)	1,704 (22.2)	1,744 (18.6)	436 (18.6)
≥1940	8,812 (20.7)	8,812 (20.7)	6,604 (42.9)	3,302 (42.9)	872 (9.3)	218 (9.3)
Age at diagnosis (years) (%)						
Mean (SE)	63.9 (0.0595)	63.9 (0.0595)	54.7 (0.1193)	54.7 (0.1688)	63.2 (0.1178)	63.2 (0.2357)
<50	5,651 (13.3)	5,651 (13.3)	5,616 (36.5)	2,808 (36.5)	1,220 (13.0)	305 (13.0)
50–59	7,671 (18.0)	7,671 (18.0)	3,310 (21.5)	1,655 (21.5)	1,820 (19.4)	455 (19.4)
60–69	12,063 (28.4)	12,063 (28.4)	3,374 (21.9)	1,687 (21.9)	2,928 (31.3)	732 (31.3)
70–79	12,539 (29.5)	12,539 (29.5)	2,412 (15.7)	1,206 (15.7)	2,688 (28.7)	672 (28.7)
≥80	4,618 (10.9)	4,618 (10.9)	668 (4.3)	334 (4.3)	705 (7.5)	177 (7.5)
Social class (%)						
I	5,004 (11.8)	6,219 (14.6)	1,744 (11.3)	1,175 (15.3)	1,072 (11.5)	183 (7.8)
II	2,832 (6.7)	3,877 (9.1)	1,145 (7.4)	822 (10.7)	559 (6.0)	66 (2.8)
III	5,265 (12.4)	6,066 (14.3)	1,957 (12.7)	1,163 (15.1)	1,043 (11.1)	178 (7.6)
IV	11,890 (28.0)	11,753 (27.6)	4,545 (29.6)	2,218 (28.8)	2,433 (26.0)	499 (21.3)
V	11,720 (27.6)	10,319 (24.3)	3,920 (25.5)	1,562 (20.3)	2,675 (28.6)	1,208 (51.6)
Unknown	5,831 (13.7)	4,308 (10.1)	2,069 (13.5)	750 (9.8)	1,579 (16.9)	207 (8.8)
Employed in construction (%)	9,203 (21.6)	7,568 (17.8)	3,592 (23.4)	1,433 (18.6)	1,758 (18.8)	739 (31.6)
Employed in agriculture (%)	3,036 (7.1)	1,918 (4.5)	1,252 (8.1)	444 (5.8)	591 (6.3)	276 (11.8)
Employed in forestry (%)	528 (1.2)	394 (0.7)	179 (1.2)	78 (1.0)	113 (1.2)	66 (2.8)
Employed in gardening (%)	956 (2.2)	704 (1.6)	430 (2.8)	173 (2.2)	184 (2.0)	93 (4.0)
Employed in fishing (%)	476 (1.1)	381 (0.9)	213 (1.4)	71 (0.9)	86 (0.9)	42 (2.2)

SE standard error

Union in 2004 (data from 1997) [19]. For our study, at least 20% of all persons employed in an industry had to be exposed to solar radiation in order for that industry to be included as involving outdoor work. We also used information from the Danish Work Environment Cohort Study carried out by the National Research Centre for the Working Environment, which is part of the monitoring program of the Ministry of Employment of work environments in Denmark, in which a random sample of Danish wage earners and self-employed are asked about their working conditions and health, including outdoor work (Hermann Burr, National Research Centre for the Working Environment, 2008). If at least 40% of the employees in a selected occupation spent the majority of their working time outside, this occupation was classified as an outdoor occupation. We categorized the selected industries into five groups: construction (public construction workers, contractors, paviour masters, bricklayers, joiners and carpenters, glaziers, insulators, roofers, scaffolding, and other construction work), agriculture (farming, horticulture, animal husbandry, machine pools, fur-farming, bee-keeping, and stud farming), forestry, gardening (gardening and orchards, and landscape and gardening), and fishing (deep-sea and inshore fishing, and freshwater and fish farming).

We did not have information on individual sun exposure. Since sun exposure has been considered to be causally associated with lip cancer, we analyzed the risk of lip cancer among outdoor workers to determine whether those in the defined outdoor occupations had higher risks than other wage earners.

We categorized job titles into six social classes: academics (I), high salary (II), low salary (III), skilled worker (IV), unskilled worker (V), and unknown (VI). Place of birth was classified as: Copenhagen, Aarhus and Odense, other large cities, rest of Denmark, or born abroad. Skin color was based on country of birth, and was classified according to light (Nordic countries, Faroe Islands, northern, northwestern or northeastern Europe, North America, Australia, or New Zealand) or dark (southern Europe, Greenland, Turkey, Asia, Middle East, Central or South America, Africa, or other Oceania).

Statistical analysis

Conditional logistic regression was used to compare the occupational histories of cancer patients with those of population controls. We analyzed the five outdoor industries separately and together and classified exposure categories into 1–5, 5–10, and >10 years of employment. All statistical tests of statistical significance were 2-sided and the associations were expressed as odds ratios with 95% confidence intervals. The odds ratios were adjusted for first known year of employment (≤1964, 1965–1969, 1970–1979, >1980), place of birth, skin color, and social class. The referent group consisted of Danish wage earners who had never been employed in one of the five defined outdoor industries or had worked for <1 year in any outdoor industry.

Sub-analyses were made of topography (head, body, upper, and lower extremities) and morphology (basal cell cancer and squamous cell cancer) for non-melanoma skin cancer and of topography for cutaneous malignant melanoma (head, body, upper, and lower extremities) and lip cancer (upper and lower lip). Owing to limited numbers of participants, sub-analyses were performed only for all outdoor occupations combined and for persons with non-melanoma skin cancer born after 1944, in order to study wage earners from the beginning of their working lives. We also conducted an analysis excluding all cases and controls for whom no information was available on social class. We performed all the analyses with a lag time of either 1 or 10 years. As we found no significant difference, only results after 10 years' lag time are presented. All analyses were performed by using Stata version 9.2 [20].

Results

Descriptive results

Tables 1 and 2 show the distribution of selected characteristics of cases and controls. The average age at diagnosis of non-melanoma skin cancer was 63.9 years, for cutaneous malignant melanoma 54.7 years, and for lip cancer 62.2 years. A higher percentage of cases with non-melanoma skin cancer and cutaneous malignant melanoma, compared with controls, belonged to social class I, II, and III whereas almost twice as many cases with lip cancer were in social class V. For cases with non-melanoma skin cancer and cutaneous malignant melanoma, fewer cases than controls had ever had an outdoor work whereas more cases with lip cancer ever worked outdoors. Almost 80% of the non-melanoma skin cancers were basal cell cancer, and 11% were squamous cell cancer; the majority of these cancers were localized on the head. About half of the melanomas were localized on the body. Finally, the overwhelming majority of the lip cancers were on the lower lip.

Table 2 Characteristics of patients with non-melanoma skin cancer, cutaneous malignant melanoma, or lip cancer by morphology and topography[a]

Characteristic	Cases (n = 42,542)
Non-melanoma skin cancer	
Morphology (%)	4,800 (11.3)
Squamous cell cancer	33,838 (79.5)
Basal cell cancer	611 (1.4)
Other non-melanomas	3,293 (7.7)
Diagnosed <1978[b]	
Topography (%)	
Head	22,789 (53.6)
Body	5,752 (13.5)
Upper extremities	1,975 (4.6)
Lower extremities	903 (2.1)
Other sites[c]	11,123 (26.2)
Characteristic	Cases (n = 7,690)
Cutaneous malignant melanoma	
Topography (%)	
Head	1,133 (14.7)
Body	3,993 (51.9)
Upper extremities	864 (11.2)
Lower extremities	1,239 (16.1)
Other sites[c]	461 (6.0)
Characteristic	Cases (n = 2,341)
Lip cancer	
Topography (%)	
Upper lip	83 (3.6)
Lower lip	2,153 (92.0)
Unspecified or commissure of the lips	105 (4.5)

[a] Controls have same morphology and topography as their respective cases

[b] Information on morphology available from 1978

[c] Unspecified, multiple, or anus

Non-melanoma skin cancer

Outdoor work for >10 years was associated with a decreased risk of non-melanoma skin cancer (odds ratio (OR), 0.83, 95% confidence interval (CI), 0.77–0.88) (Table 3). For men employed in agriculture, we observed a negative trend in risk with increasing duration of employment. The odds ratio was 0.64 (95% CI, 0.57–0.72) for 1–5 years employment, 0.61 (95% CI, 0.50–0.74) for 5–10 years employment, and 0.55 (95% CI, 0.45–0.67) for >10 years employment. A significantly decreased risk for non-melanoma skin cancer was also seen for men in construction.

We conducted a stratified analysis of the topography and morphology of basal cell and squamous cell cancers on different body sites (Table 4). In the analysis of the risks of basal cell cancer on the head, body, upper, and lower extremities, decreased risks of 14–64% were found for outdoor workers. The decreased risk of cancer on the head appeared to be due to a decreased risk among men in agriculture with an odds ratio of 0.64 (95% CI, 0.48–0.85) for >10 years employment (data not shown), and the

Table 3 Outdoor work and odds ratios (and 95% confidence intervals) of non-melanoma skin cancer, cutaneous malignant melanoma, or lip cancer

Occupation (years)	Non-melanoma skin cancer			Cutaneous malignant melanoma			Lip cancer		
	$n = 85{,}084$	$OR^{b}_{adjusted}$	95% CI	$n = 23{,}070$	$OR^{c}_{adjusted}$	95% CI	$n = 11{,}702$	$OR^{d}_{adjusted}$	95% CI
Outdoor		$P < 0.001$			$P = 0.014$			$P < 0.001$	
Reference	72,104	1		19,536	1		9,852	1	
1–5	5,501	0.78	0.74, 0.83	1,577	0.81	0.72, 0.91	726	1.63	1.37, 1.95
5–10	3,427	0.85	0.79, 0.91	883	0.88	0.75, 1.02	542	1.30	1.06, 1.60
>10	4,052	0.83	0.77, 0.88	1,074	0.97	0.84, 1.11	582	1.67	1.38, 2.03
Construction		$P < 0.001$			$P = 0.368$			$P < 0.001$	
Reference	75,044	1		20,436	1		10,351	1	
1–5	4,245	0.87	0.82, 0.93	1,146	0.87	0.76, 0.99	558	1.53	1.25, 1.87
5–10	2,606	0.93	0.85, 1.00	659	0.95	0.79, 1.12	394	1.21	0.95, 1.54
>10	3,189	0.88	0.82, 0.95	829	1.06	0.91, 1.23	399	1.68	1.33, 2.13
Agriculture		$P < 0.001$			$P = 0.004$			$P = 0.376$	
Reference	82,945	1		22,392	1		11,329	1	
1–5	1,201	0.64	0.57, 0.72	422	0.84	0.68, 1.05	185	1.08	0.77, 1.52
5–10	468	0.61	0.50, 0.74	124	0.69	0.45, 1.04	81	1.06	0.62, 1.80
>10	470	0.55	0.45, 0.67	132	0.55	0.36, 0.85	107	1.46	0.95, 2.23
Forestry		$P = 0.060$			P 0.391			$P = 0.045$	
Reference	84,706	1		22,980	1		11,638	1	
1–5	209	0.72	0.54, 0.96	55	0.74	0.39, 1.39	29	2.86	1.33, 6.15
5–10	85	0.74	0.47, 1.15	21	1.72	0.70, 4.21	21	0.58	0.17, 2.02
>10	84	1.13	0.73, 1.74	14	1.77	0.61, 5.18	14	1.16	0.34, 3.98
Gardening		$P = 0.031$			$P = 0.459$			$P = 0.071$	
Reference	84,565	1		22,914	1		11,623	1	
1–5	301	0.73	0.58, 0.93	94	0.68	0.42, 1.11	47	1.49	0.77, 2.86
5–10	140	0.78	0.55, 1.10	32	1.12	0.54, 2.34	24	2.80	1.19, 6.59
>10	78	1.02	0.65, 1.60	30	1.34	0.62, 2.89	8	1.81	0.42, 7.80
Fishing		$P = 0.465$			$P = 0.310$		11,630	$P = 0.232$	
Reference	84,670	1		22,953	1			1	
1–5	226	0.82	0.62, 1.07	57	0.64	0.34, 1.22	32	1.51	0.71, 3.19
5–10	100	0.88	0.59, 1.32	28	0.65	0.26, 1.62	26	1.70	0.75, 3.85
>10	88	0.99	0.65, 1.51	32	0.61	0.25, 1.49	14	2.09	0.72, 6.08

[a] Test of same risk in all groups

[b] Adjusted for first registration year in Supplementary Pension Fund, social class, place of birth and skin color

[c] Adjusted for social class, place of birth, and skin color

[d] Adjusted for social class and place of birth

Table 4 Outdoor work and odds ratios (and 95% confidence intervals) of basal cell cancer, squamous cell cancer, and cutaneous malignant melanoma located on the head, body, and upper, and lower extremities

Occupation (years)	Head			Body			Upper extremities			Lower extremities		
	$n = 34{,}276$	$OR^{b}_{adjusted}$	95% CI	$n = 10{,}266$	$OR^{b}_{adjusted}$	95% CI	$n = 2{,}442$	$OR^{b}_{adjusted}$	95% CI	$n = 1{,}254$	$OR^{b}_{adjusted}$	95% CI
Basal cell cancer												
Outdoor		$P < 0.001$			$P < 0.001$			$P = 0.0238$			$P = 0.001$	
Reference	28,517	1		8,669	1		2,052	1		1,076	1	
1–5	2,429	0.83	0.77, 0.90	683	0.60	0.51, 0.71	179	0.65	0.47, 0.91	71	0.68	0.40, 1.15
5–10	1,518	0.84	0.76, 0.93	403	0.63	0.51, 0.78	83	0.70	0.44, 1.11	50	0.36	0.18, 0.71
>10	1,812	0.86	0.78, 0.95	511	0.63	0.52, 0.76	128	0.81	0.56, 1.19	57	0.45	0.25, 0.83
Occupation (years)	Head			Body			Upper extremities			Lower extremities		
	$n = 5{,}826$	$OR^{b}_{adjusted}$	95% CI	$n = 496$	$OR^{b}_{adjusted}$	95% CI	$n = 1{,}182$	$OR^{b}_{adjusted}$	95% CI	$n = 392$	$OR^{b}_{adjusted}$	95% CI
Squamous cell cancer												
Outdoor		$P = 0.3091$			$P = 0.4711$			$P = 0.3641$			$P = 0.2081$	
Reference	4,827	1		404			972			316		
1–5	419	0.92	0.75, 1.12	37	1.22	0.59, 2.49	99	0.78	0.50, 1.23	33	0.51	0.22, 1.17
5–10	291	1.23	0.96, 1.56	16	0.63	0.22, 1.79	60	1.34	0.75, 2.40	16	0.60	0.21, 1.70
>10	289	1.01	0.80, 1.29	39	1.50	0.76, 2.95	51	0.77	0.42, 1.40	27	0.57	0.25, 1.30
Occupation (years)	Head			Body			Upper extremities			Lower extremities		
	$n = 3{,}399$	$OR^{b}_{adjusted}$	95% CI	$n = 11{,}979$	$OR^{b}_{adjusted}$	95% CI	$n = 2{,}592$	$OR^{b}_{adjusted}$	95% CI	$n = 3{,}717$	$OR^{b}_{adjusted}$	95% CI
Cutaneous malignant melanoma												
Outdoor		$P = 0.061$			$P = 0.030$			$P = 0.153$			$P = 0.054$	
Reference	2,888	1		10,107	1		2,216	1		3,177	1	
1–5	230	0.76	0.56, 1.03	843	0.80	0.68, 0.93	158	0.78	0.54, 1.13	245	0.76	0.56, 1.03
5–10	115	0.67	0.43, 1.04	460	0.91	0.74, 1.13	100	0.63	0.39, 1.02	145	1.05	0.73, 1.50
>10	166	1.15	0.83, 1.61	569	0.92	0.77, 1.11	118	1.03	0.69, 1.54	150	0.66	0.45, 0.97

CI confidence interval, *OR* odds ratio

[a] Test of same risk in all groups

[b] Adjusted for first registration year in Supplementary Pension Fund, social class, place of birth, and skin color

[c] Adjusted for social class, place of birth, and skin color

decreased risk of basal cell cancer on the body to a decreased risk among men with >10 years employment in agriculture (OR, 0.46; 95% CI, 0.27–0.78) (data not shown). We found no evidence of an association between outdoor work and squamous cell cancer.

The sub-analysis of non-melanoma skin cancer in which only participants born after 1944 were included substantiated the finding of an overall decreased risk for this cancer among outdoor workers (data not shown). Employment in an outdoor work >10 years was associated with a decrease in the odds ratio of non-melanoma skin cancer (OR, 0.74; 95% CI, 0.63–0.88).

Cutaneous malignant melanoma

Compared with other wage earners, we found a decrease in the odds ratio for cutaneous malignant melanoma among outdoor workers employed 1–5 years (OR, 0.81; 95% CI, 0.72–0.91), 5–10 years (OR, 0.88, 95% CI, 0.75–1.02), and >10 years (OR, 0.97, 95% CI, 0.84–1.11) (Table 3). In the topographical analysis, we found no evidence of an association between outdoor work and localization of cutaneous malignant melanoma (Table 4).

Lip cancer

We observed an increased risk for lip cancer among men employed >10 years in an outdoor industry (OR, 1.67, 95% CI, 1.35–2.03) (Table 3). With regard to individual outdoor industries, we found a tendency for increased risks associated with construction and gardening. In the topographical analysis, men who had work >10 years outdoors had a decrease in the odds ratio of cancer on the lower lip (OR, 2.06, 95% CI, 1.70–2.50) (data not shown).

Discussion

In this population-based case–control study, we found decreased risks of non-melanoma skin cancer and cutaneous malignant melanoma and an increased risk of lip cancer among outdoor workers in Denmark. Among men employed in agriculture and construction, the risk of non-melanoma skin cancer was decreased by up to 45%. We found decreased risks of basal cell cancer on parts of the body that are often covered (body and lower extremities) or uncovered (head and upper extremities); no such tendency was found for squamous cell cancer. An increased risk of cancer on the lower lip was found among outdoor workers.

Previous epidemiological studies in the Nordic countries have also shown decreased risks of non-melanoma skin cancer and cutaneous malignant melanoma and an increased risk of lip cancer among outdoor workers. Two large register-based cohort studies of occupational cancer in Denmark and in the Nordic countries found a tendency to decreased risks of both non-melanoma skin cancer and cutaneous malignant melanoma among people with outdoor occupations [21, 22]. The study populations in these two studies and in our study partly overlap; however, we included several new cases of skin cancer, and we classified exposure so as to examine outdoor occupations. In addition, they did not differentiate between basal cell cancer and squamous cell cancer. Other Nordic studies have also shown decreased risks of non-melanoma skin cancer [12] and cutaneous malignant melanoma [13, 15, 23–25] among people working outdoors. Our finding of an increased risk of lip cancer among outdoor workers is consistent with the results of previous studies [4, 8, 11, 26–29]. The lower lip receives more direct sunlight than the upper lip, in line with our finding of an increased risk of cancer located on the lower lip. Our finding of an excess risk of lip cancer indicates that outdoor workers in Denmark receive a higher annual dose of solar radiation than other wage earners.

High cumulative exposure to the sun has been found previously to increase the risk of squamous cell cancer of the skin [7, 30, 31]. We did not corroborate this finding. There are several reasons why outdoor workers in Denmark have a decreased risk of skin cancer. Outdoor workers tend to have a more uniform exposure to ultraviolet radiation, giving them natural protection due to tanning and thickening of the external skin layers, whereas intermittent exposure does not provide the same protection [8]. Furthermore, Denmark is located between latitudes 55° and 58°, where the doses of ultraviolet radiation are above the erythema threshold only from April to September [32]. Therefore, outdoor workers in Denmark and other Nordic countries might receive smaller doses than those at lower latitudes. However, a common assumption is that individuals with sun sensitive skin types avoid outdoor work. In an Australian study of solar ultraviolet radiation exposure among outdoor workers in building and construction industries, the skin types of the workers was monitored, and the results of the study did not support this assumption [33].

The decreased risk of skin cancer among outdoor workers might also be due to an inhibitory effect of vitamin D. It has been shown that vitamin D metabolites inhibit the growth of melanoma cells in tissue culture [34], and an inhibitory effect of vitamin D on other cancers has been reported [35]. These observations led to the suggestion that melanomas initiated earlier by exposure to the sun will develop into clinical disease in people deprived of continuous sunlight and with low levels of vitamin D, such as indoor workers [36]. A biological hypothesis of protective mechanisms initiated by a positive adaptive effect of

sunlight on critical cells, e.g., lymphocytes, might be indicated. A study of sunlight-induced DNA damage showed that sunlight penetrates the epidermis and damages DNA in lymphocytes circulating in skin vessels; however, these authors also observed increased DNA repair, implying induced ability of the lymphocytes to repair DNA damage [37].

We observed excess risks of both non-melanoma skin cancer and cutaneous malignant melanoma among people in social classes I and II, which comprise mainly indoor workers with intermittent exposure to the sun, consistent with the findings of previous studies [15, 38, 39]. The result did not change when the analysis was conducted with and without men of unknown social class. The lifestyle of higher social classes might involve increased intense, intermittent exposure to the sun during indoor work or leisure, such as traveling to sunny climates [15, 39].

We found that outdoor workers have decreased risks of basal cell cancer and cutaneous malignant melanoma on parts of the body that are often covered, indicating that their recreational exposure to the sun also has a protective effect on their risk of skin cancer. Thus, short, intense exposure to the sun might be less harmful to outdoor workers. The authors of a Dutch case–control study of intermittent exposure to sunlight found that leisure activities such as sunbathing and vacations in sunny countries increased the risk of cutaneous malignant melanoma in indoor workers but not in outdoor workers [40].

People living at different latitudes receive different ambient doses of ultraviolet radiation due to factors such as solar zenith angle, ozone layer, season, and outdoor activity [41]. The measured dose of ambient ultraviolet radiation of the Australian population is up to 15% higher than that of populations living in the Northern Hemisphere [42]. These factors might explain the differences in the results of studies of skin cancer. Furthermore, cancer registries often exclude or have incomplete data on non-melanoma skin cancer, further reducing the comparability of results.

Strengths and limitations

The strengths of our study include identification of cases in a nationwide cancer registry with great accuracy in the registration of cancer diagnoses [43], unbiased selection of controls through linkage to a population registry, and a large number of participants. In addition, we used registers to collect information on both disease and occupation, thus eliminating recall bias.

Ascertainment of information on exposure only from registers can introduce non-differential misclassification, which will tend to dilute any association and lead to an underestimated risk. As we did not have information on individual exposure, outdoor industry was used as a proxy for exposure to the sun, and duration of employment was used as a proxy for length of exposure. Furthermore, occupational information could be dated back only to 1964, so that the vast majority of the occupational history of several participants was unavailable. The eldest of the participants might have worked in an outdoor industry years before we had information in the register. As the decreased risks of non-melanoma skin cancer often seen in occupations of 1–5 years' duration might indicate misclassification, we conducted a sub-analysis of non-melanoma skin cancer including only participants born in 1944 or after. We observed that the largest protective effect of working in an outdoor industry was for outdoor workers with 5–10 and >10 years' employment, indicating little misclassification in the head analysis.

When we adjusted for potential confounders in the analyses, the estimates changed only slightly and did not change direction, indicating a limited degree of confounding in these data. As in many other studies of occupational skin cancer, we did not have any information on concurrent exposure to the sun during leisure pursuits or during childhood, which might have confounded our results. Finally, mass significance might appear in a large register-based study like ours. The highly significant results, the general tendency to decreased risks for non-melanoma skin cancer and cutaneous malignant melanoma, and the excess risk for lip cancer, however, indicate that our findings did not occur by chance.

In conclusion, we observed that male outdoor workers in Denmark have decreased risks for basal cell cancer and cutaneous malignant melanoma and an increased risk for lip cancer. Outdoor workers in the Nordic countries therefore appear to have a pattern of occupational and recreational exposure to the sun that protects them against skin cancer.

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