American Journal of Epidemiology Vol. 135, No.7

The Association of Cutaneous Malignant Melanoma and Fluorescent Light Exposure

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Data are presented from an interview case-control study (583 cases and 608 controls), performed in southern Ontario, Canada, from October 1984 to September 1986, on the association of cutaneous malignant melanoma with exposure to fluorescent light. Males showed a significant trend with cumulative years of occupational exposure and with various indices of exposure to domestic fluorescent light. The risk was more pronounced for lesions on the arms and for superficial spreading melanomas. There was no consistent association in females. These effects were similar when adjusted for other major risk factors for melanoma, including the amount of time spent outdoors occupationally. Comparisons of melanoma cases interviewed before or after diagnosis revealed no evidence of rumination bias. Comparisons of sample data from the same cases and controls by interview and mail questionnaire showed reasonable levels of reliability with no evidence of recall bias. A small sample of subjects was also selected for exposure validation with employers; this revealed very accurate recall of occupational exposure. On the basis of these results, previous epidemiologic studies, and clinical and animal evidence, the authors conclude that fluorescent light exposure remains a potential risk factor for melanoma. *Am J Epidemiol* 1992; 135:749-62.

lighting; melanoma; ultraviolet rays

The incidence of melanoma is increasing rapidly, for reasons that are poorly understood. The association of melanoma with exposure to ultraviolet radiation is generally well accepted. Although solar exposure has been studied most often, ultraviolet exposure can occur from a variety of nonsolar sources, including sunbeds/lamps, certain projection and insecticidal lamps, welding arcs, and fluorescent lights. These sources vary in their relative and absolute concentrations of radiation in the ultraviolet A, B and C ranges (wavelengths 320-400, 280- and less than 280 nm, respectively). There is still uncertainty about the relative importance of the different wavelengths in the etiology of melanoma (1). In the context of concern about depletion of atmospheric ozone, ultraviolet B has been suggested as the exposure with the greatest mutagenic and carcinogenic potential (2). Substantial doses of ultraviolet B (and even ultraviolet C) can be delivered even by so-called ultraviolet A device such as sunbeds. In addition, the nonsolar sources can deliver doses of ultraviolet A

Received for publication November 15, 1990, and in final form August 21, 1991.

Abbreviations: lm, lumen; PCB polychlorinated biphenyl

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Supported by grants from the National Cancer Institute of Canada and from Health and Welfare Canada, by a National Health Scientist award to Dr. Stephen Walter, and by a National Health Scholar award to Dr. Loraine Marrett.

The authors thank Norma Mishkel and Isabel Fan for administrative coordination of the study and Eric Duku for assistance with the statistical analysis.

far in excess of normal solar exposures. Because of the continuing uncertainty about the dose-response relation of melanoma to ultraviolet B, a number of recent epidemiologic studies have considered the nonsolar sources of ultraviolet radiation. There have been several case control studies of sunbeds and sunlamps (3 - and one study of special lamps with ultraviolet emissions (8).

The possibility of an association of melanoma and fluorescent light has been investigated in several previous studies (4, 7-13). It is a difficult association to study epidemiologically. The rarity of melanoma essentially dictates a retrospective design. In addition, exposure to fluorescent light is ubiquitous in many populations. Much exposure occurs in locations such as offices, where the lighting is not under personal control. This accentuates difficulties of recalling past exposure levels.

Possibly because of these methodological difficulties, results *of* previous studies on fluorescent light have been mixed. However, there is a suggestion, discussed later, that the studies with better methodology have been somewhat more likely to show a positive association. A recent National Institutes *of* Health Consensus Conference (1) determined that the long-term effect of exposure to fluorescent bulbs was "an unresolved issue." Elwood concluded that "the potential for health hazards from ultraviolet radiation from fluorescent and from other artificial lighting sources cannot yet be dismissed and requires further work" (14, p. 136). He also noted that study results would be more convincing if "efforts could be made to take and verify histories of exposure to fluorescent light sources" (14, p. 135), such as by using more than one method of obtaining information and visiting places of employment.

The plausibility for fluorescent light as a risk factor for melanoma depends on the distribution of its ultraviolet emissions and its relation to solar emissions, and on the available clinical and animal evidence.

Fluorescent light devices generate light by a process in which electrical current is passed through a mixture of mercury and a rare gas (to assist ignition). The mercury atoms become electronically excited, leading to electro- typical incandescent value of 75 ,uW/lm and a sunlight value of 400 ,uW/lm. Other tests (17) magnetic radiation at specific wavelengths, mostly in the invisible ultraviolet domain. The dominant emission is at 254 nm, with lesser peaks at 185, 297, 313, 334, and 365 nm and other higher wavelengths (15, 16). Visible light is produced by fluorescent activation when the 254nm radiation strikes phosphor on the interior lining of the tube. The glass material of the tube absorbs almost all of the ultraviolet radiation below about 290 nm, but higher wavelength energy, particularly that at 297 nm, is transmitted.

The earth's atmosphere absorbs much of the short wavelength ultraviolet radiation in the solar spectrum, below about 290 nm. The ambient level of ultraviolet B at the earth's surface is highly variable, depending on factors such as solar altitude, season, thickness of the ozone layer, temperature, wind, humidity, cloud cover, and pollutant levels. Solar flare cycles can increase ozone production, leading to as much as 400 percent variation in 300 nm exposure levels. Human exposure is also modified by the nature of nearby ground cover (snow, vegetation, water, etc.) and terrestrial altitude (1). Overall, the ratio *of* solar ultraviolet A to ultraviolet B exposure is approximately 10 to 100.

Only one report has systematically quantified the relative flux from solar and fluorescent light sources at various wavelengths (15). The comparison was between unshaded, continuous daily sunrise-sunset exposure over the year at the latitude of Sydney, Australia (34*S), with daily fluorescent light exposure for 40 hours per week, 50 weeks per year. It was found that at wavelengths near 295 nm, most fluorescent light devices give an irradiance comparable with the sun. At shorter wavelengths, fluorescent lights delivered flux an order of magnitude larger than the sun; for instance, at 290 nm, fluorescent tubes emitted 10-30 times the solar emission, and at still shorter wavelengths the solar energy was negligible, while weaker fluorescent emissions persisted.

Related evidence comes from government testing of commercial fluorescent and incandescent devices (16). Performance is expressed in terms of the relative ultraviolet emission per unit of visible light. Various fluorescent devices gave ultraviolet emissions of 33-644,uW/lumen (lm) compared with the

have shown that the energy levels in ultraviolet

A and ultraviolet B from fluorescent light emissions are approximately equal.

In total, these data suggest that human exposure to fluorescent lights may result in ultraviolet B doses much greater than that from the sun. Ultraviolet B and shorter wavelength exposure can also be increased by other artificial devices such as sunbeds, welding arcs, and special lamps for projection, insecticidal, germicidal, and horticultural uses. In contrast, human ultraviolet A exposure is typically far less from fluorescent lights than from & sun (15, 18). although it too can be modified by artificial exposures such as sunlamps, which may deliver up to five times the solar dose per unit time (1). To further complicate matters, many so-called ultraviolet A devices can also include ultraviolet B and shorter wavelength energy in their emission spectra; the National Institutes of Health Consensus Conference stated that "even I % ultraviolet-B emission from a ultraviolet-A source can cause a significant increase in the potential for skin cancer" (1, p. 7).

Several other types of data enhance the plausibility of ultraviolet B involvement in the etiology of melanoma. Animal experiments have shown similar dose-response mutagenic effects of fluorescent light and ultraviolet exposures in mouse embryo cell cultures (19). Case reports have documented skin sensitivity of patients to fluorescent light, some of which were specific to energy in the ultraviolet B domain, with no reaction to ultraviolet A exposures (20, 21). In general populations, ultraviolet B is perhaps 1,000 times more effective in producing erythema than ultraviolet A, leading to ultraviolet B sometimes being referred to as the "sunburn" energy range (1, 21). There are also animal and human data indicating that nonmelanoma skin cancer is more clearly related to ultraviolet B exposure than to ultraviolet A (1, 22).

At the molecular level, it has been argued that the wavelength of the energy may be more important than its intensity in its potential to damage DNA. In analogy with the photoelectric effect, there may be a ultraviolet wavelength threshold, above which no damage will occur (15). Furthermore, while experimental evidence indicates that DNA damage occurs with ultraviolet B exposure, some repair may take place with exposure to ultraviolet A and visible light (22). Thus, both the amount and the ratio of ultraviolet A and B exposure may be involved in determining the risk of malignancy. It may be noted that persons with xeroderma pigmentosum, who are unable to repair DNA damage resulting from ultraviolet B exposure, are at very high risk of melanoma (2).

In summary, if fluorescent light exposure plays a role in the etiology of melanoma, it is most likely because of its high ultraviolet B energy dose relative to other sources, including the sun. Such positive findings as may emerge from epidemiologic studies of fluorescent light and melanoma will add to the plausibility of ultraviolet B as a risk factor.

MATERIALS AND METHODS

We report here on data concerning fluorescent light exposure from a large population-based case-control study, in which exposure to ultraviolet radiation (particularly from nonsolar sources) was the main concern. Complete details of our case and control sampling are given elsewhere (3), so we review only the main points here. All histologically confirmed cases of cutaneous malignant melanoma (including diagnoses of Hutchison's melanotic freckle, lentigo maligna, and melanoma in situ) aged 20-69 years at diagnosis during the period October 1984 to September 1986, who were resident in a six-county area of southern Ontario were included. A standardized pathology review was performed. Recurrent cases were excluded.

Ascertainment of cases was usually through notification by a pathology laboratory. However, a group of patients being investigated at the Bayview Pigmented Lesion Clinic for suspected melanoma was ascertained and interviewed before the diagnosis was established. This group constitutes a "blinded" set of cases that can be compared with subjects ascertained after diagnosis, to evaluate questions of recall bias. The prediagnostic data from patients who were subsequently found to have diagnoses other than melanoma are not reported here.

Community controls were selected randomly from the property tax assessment rolls within each of the 39 municipalities of the study area and were approximately matched to the cases on age, sex, and
municipality. In addition to property tax collection, the rolls are used to generate electoral lists and for school planning. They are updated at intervals up to 3 years, depending on the type of dwelling.

A special study of completeness as part of another cancer study revealed that 86 per cent of cases were found on the rolls, after searching one of the 32 provincial regions, using name and address as linkage variables (L. D. Marrett. unpublished data). This completeness rate is an underestimate, be cause many of the remaining 14 percent of the cases may have moved to another region of the province; the precise number of such cases cannot be determined because of the difficulty of searching the rolls of all the other regions with name as the only avail l able linkage variable of the remaining 14 percent of the cases may have moved to another region of the province; the precise number of such cases cannot be determined because of the difficulty of searching the rolls of all the other regions with name as the only available linkage variable.

Data collection

With the exception of the Bayview cases, subjects were approached by letter and telephone to request participation in the study. Attending physician consent was also obtained in advance for cases. Bayview cases were interviewed directly at the clinic, with the consent of the clinic physicians. All other participants were interviewed at a time and place convenient to them, usually at home. The interview, which took about 30 minutes on average, emphasized various exposures to solar and nonsolar ultraviolet emissions domestically, at work, and during leisure time. It included a complete residential history. For dwellings used for at least 6 months, subjects were asked if fluorescent light was present in the kitchen, bathroom, and another room named by the respondent, where he or she spent the most time. There was also a complete occupational history which included the major light source in each job. For indoor jobs, the placement of lights (ceiling vs. desk lamps), the typical frequency of their use, and whether they were covered or bare were asked. The average number of-daylight hours per week spent outdoors on each job was also determined.

From this large amount of]Information, summary indices of exposure were calculated, such as the presence or absence of fluorescent lights in the home I year before the interview. The estimated cumulative years of occupational exposure to fluorescent light was computed, with the objective of assessing the dose -response relation. Use of sunbeds and sunlamps was also determined; results for these factors have been reported previously (3). Data were also gathered on occupational and domestic exposures to a variety of other light sources with known ultraviolet emissions.

Finally, there were questions dealing with other potential risk factors for melanoma that might act as confounders. These included skin color, assessed by matching to a prosthetic skin sample (23); nevus density, on the arm as physically assessed by the interviewer, and on the whole body assessed by self-report using diagrams (3); tendency of skin to tan and/or bum on solar exposure; previous severe sunburn; natural hair color; ethnicity; eye color; and socioeconomic status.

Reliability and validity work

The questionnaire included a few "distractor" items dealing with use of microwave ovens, personal computers, and video games. These exposures are not plausibly related to melanoma risk, but might be perceived to be so by some persons. These questions were thus intended to assist in the evaluation of recall bias, through comparisons of the Bayview cases with non-Bayview cases. The latter cases were interviewed several weeks or months after diagnosis, and so had greater potential for rumination and/or recall bias (24) compared with the Bayview cases interviewed before diagnosis.

Further information on reliability and rumination was provided by a mail survey of the cases and controls ascertained during I month of the study. Certain key exposures were reassessed in the mail survey, using the same questions as in the interview. Comparisons of

interview and mail responses thus permit us to assess the possibility of relative over - or underreporting at the time of interview for both cases and controls.

Finally, a sample of jobs given by cases and controls was selected for validation of reported fluorescent light exposure. Jobs were selected to encompass a range of job types and to be with larger employers so that the identity of the study participants could not be inferred, thereby maintaining our assurances of confidentiality. One job per subject was investigated. The companies for which the subjects worked were contacted, and the personnel with knowledge of historical lighting conditions were identified. They were visited or contacted by telephone and told the reported occupations on the questionnaires; from these, they determined what type of lighting had been in use. This procedure was conducted without knowledge of the respondent's case or control status.

Analysis

The main comparisons were between the entire sets of cases and controls, with emphasis on the fluorescent light exposure history at work
and in the home. Analyses were carried out separately for males and females. Adjustment for age and other confounders was through use of the Mantel-Haenszel method (25). Significance was assessed at the 5 percent level, and 95 percent confidence intervals were obtained for the adjusted odds ratios. Cochran's test (25) for trends in proportions was used to assess dose-response relations. Subgroup analyses were conducted according to body site and histologic type of melanoma. The same statistical methods were used in the comparison of the Bayview cases with other cases to investigate the likelihood of recall bias.

For the subset of cases and controls who responded to the mail questionnaire, comparisons with their previous interview responses were made using a paired analysis. Agreement of the two responses was characterized using the crude agreement and the K indices (26). McNemar's test was also used to test for differences in reporting between the two methods. Similar methods were used to compare the subject and employer reports of occupational fluorescent light exposure.

RESULTS

There were 583 cases (277 males and 306 females) and 608 controls (283 males and 325 females) who completed the study interview. These represent response rates of 89 and 91 percent in male and female cases, and 79 and 82 percent in male and female controls, respectively. Further details of reasons for nonresponse have been given elsewhere (3). The main results reported here are age adjusted, although, because of the similarity of the case and control age distributions, the adjustment did not materially affect the results.

Table I gives the numbers and proportions of cases and controls who indicated that their main light source at work was fluorescent light, at I year and 10 years before the interview. Also shown is a dose response relation, based on the estimated cumulative years of exposure. In the results for particular' exposure times, there was an odds ratio of 1.5 in the males for fluorescent light exposure 10 years earlier, but the other effects were small. However, when cumulative exposure was considered, odds ratios near 2 were found in males for cumulative exposures of more than 20 years. The odds ratios increased progressively with cumulative exposure in males, and the dose response relation was significant.

Occupational fluorescent lighting, when present, was almost always in the ceiling and was usually reported to be on all the time. Respondents often had difficulty in recalling whether the lights were covered or bare. It was felt, therefore, that the variation and/or quality in these variables was insufficient to be useful analytically, and they were not pursued further.

Table 2 shows domestic exposures, considering the presence of fluorescent light in the kitchen, bathroom, and "other room" chosen by the respondent. There were significant odds ratios of

approximately 1.7 in the male cases for fluorescent light exposures I and 10 years before in both kitchen and bathroom. Exposure in the "other" room was less common, but the males did still show an elevated point estimate of the odds ratio. In females, there were only small risk elevations associated with kitchen fluorescent light exposure for both time points. Very similar results were obtained when the exposures currently and 5 years before were assessed.