

Trends in the incidence of malignant melanoma in Denmark 1978-2007

Incidence on the island of Bornholm compared with the whole country incidence in Denmark

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ABSTRACT

INTRODUCTION: In Denmark, malignant melanoma is among the most rapidly increasing cancer types. Malignant melanoma accounts for the majority of skin cancer-related deaths. Sunshine is the main cause of the increase seen in melanoma incidence. Within Denmark, Bornholm is the area that receives most sunshine. It is therefore relevant to compare incidence data between Denmark and Bornholm.

MATERIAL AND METHODS: Incidence data from the period 1978-2007 were extracted from The National Cancer Database. Incidence rates were analysed to determine any difference between *Bornholm and Denmark* in total. A prognosis was made based on extrapolation of incidence data from 1978-2007.

RESULTS: Incidence rates increased exponentially in Denmark as well as on Bornholm. A significant annual increase in incidence rates over the 1978-2007 period was found. The difference in incidence was estimated to be 3.4%. The annual increase was significantly higher on Bornholm than in the rest of Denmark, a 20% increase was assessed.

The increase in incidence rates in malignant melanoma is supported by the literature. The difference between Bornholm and Denmark is possibly due to differences in behaviour that translate into differences in UV exposure.

CONCLUSION: If the current development continues, the incidence rate will increase more than 100% from 2007 to 2030. The effect of campaigns addressing behavioural sun exposure has yet to be recorded. UV exposure is expected to comprise the main reason for the difference in incidence rate between Bornholm and Denmark in total. More evidence is needed on the relation between malignant melanoma and UV radiation and socio-demographic conditions.

The incidence of cutaneous malignant melanoma (CMM) in Denmark has risen more than 17% during the 1988-1997 period [1]. CMM is responsible for approximately 90% of all skin cancer-related deaths. On a global scale, CMM is one of the most rapidly growing cancer types [2]. In order to reduce the incidence rate and to improve the survival rate, it is necessary to understand in depth the aetiology of melanoma.

At the Department of Plastic Surgery, Breast Surgery and Burns Treatment at the Copenhagen

University Hospital (Rigshospitalet), we have observed a pronounced increase in the number of patients referred with CMM from the island of Bornholm over recent years. The number of referred patients has been markedly higher than expected taking into account the island's population.

Bornholm is an island in the Baltic Sea, situated to the South East of Denmark. It consists of bedrock and enjoys climatic conditions slightly different from those of the rest of Denmark. Its population is comparable to that of the rest of the country, but probably more prone to outdoor activities and exposure to ultraviolet (UV) light. Differences in melanoma incidence within the Danish population could help us understand the contribution of UV exposure to the documented increase in incidence.

The aim of this study was to quantify and to analyse the difference in melanoma incidence between Bornholm and the rest of Denmark.

MATERIAL AND METHOD

Data were extracted from the Danish National Cancer Registry [3] which is managed by the Danish Board of Health (DBH). Data were available for the 1978-2007 period and were validated by the DBH.

Age and sex-adjusted incidence data for "Bornholm's municipality" and for "Denmark in total" were extracted (**Figure 1**). Data concerning the population size was extracted from the Danish National Survey Institute [4]. All statistical analyses were performed in the SAS 9.1 software.

ANALYSES

Incidence rates, per 100,000 per year, show a parabolic shape with an accelerating annual increase (**Figure 1**). Incidence data from both Bornholm and "Denmark in total" show an exponential development. The data fulfil the criteria of the Poisson distribution and a statistical test for trends and differences was made.

RESULTS

During the 1978-2007 period, an annual increase in incidence rates was documented for "Denmark in total"

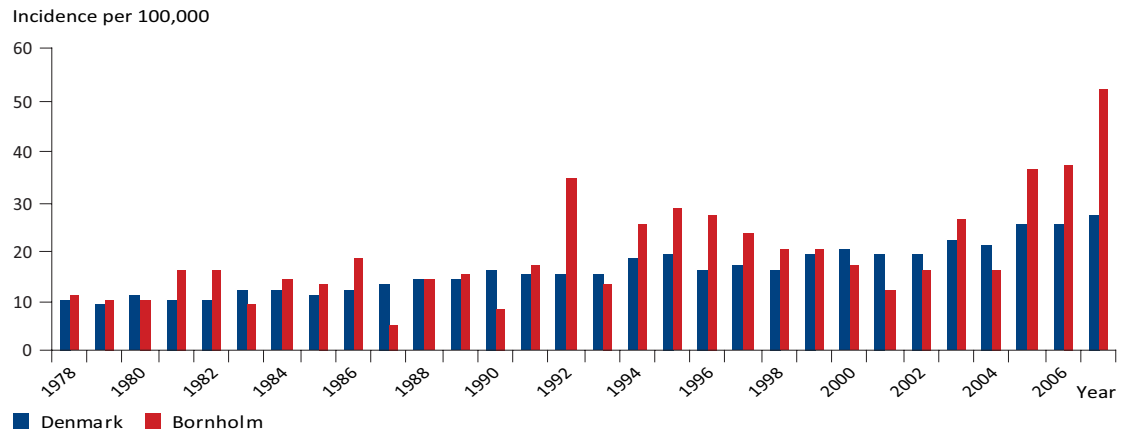
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FIGURE 1

Incidence rate of malignant melanoma. Data from "Denmark in total" and Bornholm, adjusted for age and sex.



(Table 1). For "Denmark in total", we calculated an annual increase of 3.4% and for Bornholm the annual increase was 4%. Both estimates are significant, $p < 0.001$.

By comparing incidence rates on the basis of the Poisson distribution parameters, we found that melanoma incidence rates on Bornholm are significantly higher than the corresponding Danish rates. The difference was estimated to constitute 20.5% (Table 1).

Based on the trend in melanoma incidence in "Denmark in total" from 1978 to 2007, an extrapolation for the coming years was made (Figure 2). Given a steady increase in incidence rate of 3.4% per year, the expected incidence rate will be more than twice as high (114% increase) in 2030 as in 2007 (Table 2).

DISCUSSION

Data from the Danish National Cancer Database was only available in an age- and sex-standardized form if extracted as incidence rates. The incidence rates were transformed into incidences by multiplying the incidence rate by the annual population of Bornholm and Denmark, respectively. The data are therefore encumbered with more unreliability than estimates based on raw data. On the other hand, estimates are more reliable when adjusted for the influence of age and sex. Both age and sex range among the strongest risk factors for melanoma [5].

A corresponding increase in incidence rate was found in a large-scale register study performed on a US population (290 mill. person years, 70,596 cases). In the US study, the annual increase was estimated to 3.1%.

The Bornholm incidence data are included in the incidence data for "Denmark in total". This will cause any difference between the two groups to be underestimated. In the 1978-2007 period, the population of Bornholm on average represented 0.9% of the entire Danish population [4].

The extrapolation into the coming years is based on incidence rates for "Denmark in total". The trend remained constant during the 1978-2007 period, and there was limited variation in the annual incidence rates, which improves the reliability of the extrapolation. The extrapolation should, however, be interpreted with some caution because it was not possible to account for all conditions. The extrapolation becomes less reliable the further into the future it predicts. Nevertheless, the data may serve as the basis for estimation of the effect of future campaigns and other prophylactic initiatives.

Various conditions might be involved in the overall incidence pattern for Bornholm and "Denmark in total". Three main factors contribute to melanoma aetiology:

TABLE 1

Statistical test to confirm the Poisson distribution.

	Annual increase in incidence rate of malignant melanoma		
	incidence	95% CI	p
Denmark	1.034	(1.0322-1.0353)	< 0.001
Bornholm	1.0403	(1.0254-1.0553)	< 0.001
Difference	1.2045	(1.0667-1.03601)	0.027

CI = confidence interval.

TABLE 2

Prognosis of incidence rates of malignant melanoma in Denmark based on the incidence rates from 1978-2007. Calculations are based on the Poisson distribution.

	Prognosis of the future incidence rate			
	2007	2010	2020	2030
Incidence rate	24.8	27.4	38.1	53
Increase, %	Ref.	10	54	114

sun-related behaviour, constitutional factors and environmental conditions.

Behavioural risk factors include pattern and amount of sun exposure, artificial sunlight and sunburns. Both exposure to artificial sunlight [6] from sunbeds and sunburns [7-9] are categorized as peak intermittent sun exposure. Intermittent sun exposure is believed to be associated with an increased risk of malignant melanoma compared with more regular sun exposure [7, 8, 10].

Differences in behaviour result in different sun exposure patterns and amounts. A person with sun-seeking behaviour can increase the exposure many folds compared with a person with sun-avoiding behaviour. Intermittent sun exposure patterns are typical for indoor workers. Danish studies have documented that indoor workers experience more sunburns and more intermittent exposure than outdoor workers [11, 12]. No data exist on behavioural differences between regions of Denmark, and it is not possible to compare behavioural differences between the population of Bornholm and "Denmark in total" based on data provided by the Danish National Survey Institute. It is expected that the population of Bornholm is more prone to outdoor activities than people in other parts of Denmark. Whether this results in regular or intermittent sun exposure patterns remains unknown.

Constitutional factors [9, 13, 14] associated with melanoma are widely known (light phenotype, e.g. red or blond hair, fair skin and freckle and nevus density). A family history of melanoma is strongly associated with melanoma. No indications support that the population of Bornholm should differ from the population of "Denmark in total". During the observed period of time, the population of Bornholm has declined from approximately 47,000 in 1978 to 43,000 in 2006. Because of the introduction of a new municipality structure in 2003, it is not possible to achieve a complete overview of local migration [15]. The period 2003 to 2005 saw an annual net emigration of 140 persons (a little over 1,000 immigrants and nearly 1,200 emigrants) [15]. Compared with Denmark, Bornholm receives less immigrants per capita per year which is not consistent with a hypothesis that the melanoma cases may be imported from other countries. Higher immigration rates in "Denmark in total" compared with Bornholm could lead to an increasing share of people with darker skin and thereby a lower risk of melanoma in "Denmark in total" relative to Bornholm. The national distribution of ethnicity and phenotype characteristics is unknown. However, continuing emigration from Bornholm to other regions of Denmark will tend to equalize the differences in melanoma incidence between Bornholm and Denmark.

The environmental conditions of relevance include climatic differences and geological differences.

Denmark has a limited geographical extension and the ultraviolet index (UVI), sun ray angle and thickness of the ozone layer are therefore assumed to be the identical across the country. Moreover, both UVI and ozone layer thickness have been assessed too briefly to document any constant change with ensuing biological effects.

"Hours of sunshine" is the one climatic factor where there are local differences within Denmark as it depends on cloud cover and aerosols. For Denmark there has been a 6.3% increase in sunshine hours from 1968 to 2007 [16]. The average difference in sunshine hours between Bornholm and Denmark was 5.4% in the 1961-1990 period [17].

Bornholm consists of bedrock which contains radium. With radium decay, radon is formed. Radon gas up-concentrates in basements and buildings without sufficient protection [18]. Radon is the primary contributor to the mean radiation doses received by the Danish population, radiotherapy excluded. Ionizing radiation is to some extent associated with the development of melanoma, but the association is neither strong nor well-documented [19, 20].

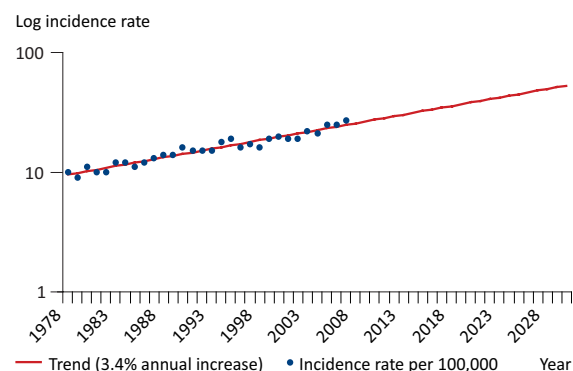
CONCLUSION

Annual incidence rates for both Bornholm (4.0%) and "Denmark in total" (3.4%) have risen significantly from 1978 to 2007. The Bornholm incidence rate is 20% higher than the incidence in "Denmark in total". This difference is significant. A similar annual increase in melanoma incidence was found in a recent American study.

The cause of the difference in melanoma incidence rates between Bornholm and "Denmark in total" is probably associated with differences in sun exposure. In

 FIGURE 2

Incidence rates from "Denmark in total" for the 1978-2007 period displayed in a single logarithmic system of coordinates. The tendency line was calculated from the Poisson distribution.



Referred patient suspected of malignant melanoma.



in this context, the personal sun exposure pattern is essential, as it may dramatically affect UV exposure. Climatic and geological conditions may also play a role. The inter-regional differences and the changes over time in sunshine hours are too small to explain the continuing increase in melanoma incidences. More evidence is needed on the relation between melanoma and UV radiation and socio-demographic patterns within Denmark.

It is estimated that the melanoma incidence rate in Denmark will rise by more than 50% by 2020 and by more than 100% by 2030 compared with 2007. In order to reduce the increase in melanoma incidence rate, further prevention campaigns are needed. Campaigns should primarily focus on high-risk individuals according to phenotypic characteristics and on groups displaying risk behaviour.

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CONFLICTS OF INTEREST: None

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