Trends in mortality rates from malignant melanoma in Sweden 1953–1987 and forecasts up to 2007

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Summary To monitor mortality rates from malignant melanoma we analysed all patients in Sweden (6,324) who died of malignant melanoma in 1953 through 1987. Age-standardised rates per 105 increased from 1.1 to 4.0 in men and from 1.0 to 2.6 in women. The average annual increase levelled off in men from 4.6% during 1953–1967 to 2.0% in 1978–1987; and in women from 3.7% to 0%. Multivariate analyses showed that the change in rates for men was mainly due to a birth-cohort effect, whereas in women the rates changed similarly in all age-groups in accordance with a time-period effect. The risk of dying of malignant melanoma increased in men for birth cohorts up to 1932, whereas in women the rise continued for cohorts born as late as 1947. The best-fitted multivariate models were extrapolated to the year 2007, among men a slight increase in mortality rates seemed likely, whereas among women the rates will probably remain unchanged.

Statistical methods

Age-standardised mortality rates were calculated for men and women annually. The direct method of standardisation (Fleiss, 1981) was used with the Swedish population of 1970 as reference. A log-linear regression model, which implies a constant annual percentage change, was used to estimate the temporal trends of the rates. Age-specific mortality rates were estimated as the average rate per year during each 5-year time period, starting with 1953–1957 and ending with 1983–1987, using the age-groups <30, 30–39, 40–49, 50–59, 60–69 and ≥70 years of age.

In the multivariate analysis the number of deaths was assumed to be Poisson-distributed, with a mean μ which depends on multiplication of the explanatory variables of age, period and cohort. The full model may be formulated as

\[ \mu_{ijk} = N_{ijk} \exp(\alpha \beta \gamma), \]

where \( N \) is person-years and \( \alpha, \beta \) and \( \gamma \) are the effects of age, period and cohort. The model was estimated by the maximum likelihood method, using the GLIM software package (Baker & Nelder, 1978). Submodels, such as a combination of age and period and a combination of age and cohort, were fitted in addition to the full model. The special case when the effects of period or cohort on the logarithmic rates in age-period and age-cohort models was assumed to be linear was also considered. In that case, it was impossible to separate the period effects from the cohort effects, and the combined linear effect is denoted 'drift' (Clayton & Schifflers, 1987). The model fit was evaluated in terms of the deviance, which has an asymptotic chi-square distribution. By determining the difference in deviance, various models can be compared. When the deviance is close to the degrees of freedom of the model, the fit may be considered adequate.
Table I Number of deaths and age-standardised mortality rates in patients with malignant melanoma in Sweden, 1953–1987, by sex and year of death

| Year   | Number of deaths | Age-standardised ratea |
|--------|------------------|------------------------|
|        | Men | Women | Men | Women |
| 1953–1957 | 213 | 167 | 1.31 | 1.00 |
| 1958–1962 | 327 | 242 | 1.90 | 1.31 |
| 1963–1967 | 373 | 299 | 2.05 | 1.52 |
| 1968–1972 | 536 | 397 | 2.82 | 1.89 |
| 1973–1977 | 615 | 435 | 3.13 | 1.92 |
| 1978–1982 | 713 | 573 | 3.54 | 2.41 |
| 1983–1987 | 843 | 591 | 4.07 | 2.39 |
| Total   | 3620 | 2704 |

*aAverage rate per year.

Results

Age-standardised rates

The age-standardised mortality rates increased from 1.1 per 100,000 in 1953 to 4.0 in 1987 in men and from 1.0 to 2.6, respectively, in women. The average annual percentage change during the entire study period was 3.7% (95% confidence interval (CI) = 3.2–4.2%) in men and 2.8% (95% CI = 2.4–3.2%) in women. When the trends were estimated for the 15-year period 1953–1967, the corresponding annual increase in men was 4.7% (95% CI = 2.5–6.8%) and in women 3.7% (95% CI = 2.3–5.1%). However, during the following 10-year period, 1968–1977, the annual change decreased in men to 2.4% (95% CI = 1.5–3.4%) and in women to 0.2% (95% CI = 0.1–1.8%). Similarly, during the last 10-year period, 1978–1987, the annual changes in rates were in men 2.0% (95% CI = 0–4.2%) and in women 0% (95% CI = −1.9–1.8%). Thus, in men the rate of increase levelled off during later years and in women the mortality rates stabilised. However, the rates in women stabilised at a higher level during 1978–1987 than 1968–1977 (Figure 1).

Age-specific rates

In men younger than 50 years of age, there was no increase in the mortality rates after 1968. In contrast, men aged 50 years or more showed increasing rates during the entire study period (Figure 2).

In women aged 30 to 50 years, the rates increased slightly, except during the last five-year time period, 1983–1987. Women older than 50 years had steadily increasing mortality rates, except those older than 70 years who had decreasing rates during the last 5-year time period (Figure 3).

Multivariate analysis

In both sexes, 'drift'-models (which includes linear effects of period and cohort) were significantly superior to simple age models in explaining the mortality rates. Further, in men, an age-cohort model – which in contrast to the age-drift model allows the cohort effects to be non-linear – was a significant improvement ($P<0.01$) on the age-drift model. An age-period model was also an improvement on the age-drift model ($P<0.05$). The full model (age + period + cohort) further lowered the deviance, however, the change was not significant ($P = 0.07$) compared to the age-cohort model. In women, the use of an age-cohort model did not significantly improve the age-drift model. An age-period model, however, was a significant improvement ($P<0.01$) on the age-drift model. The full model was not an improvement on the age-period model ($P = 0.29$) (Table II).

In the age-cohort model in men, the relative risk of dying of malignant melanoma increased continuously by birth cohort up to a seven-fold higher relative risk in those born...
around 1932, compared to men born in 1878–1887; in later-born cohorts the risk decreased gradually and markedly to a relative risk below four in the youngest cohort (Figure 4). In women, however, the relative risk by cohort increased almost sevenfold up to the birth cohort 1943–1952 before declining (Figure 4). The age-effects in the age-cohort model had a nearly constant slope for both men and women.

The relative risk by period increased continuously throughout the study period for men up to 3.0 compared to the earliest time period 1953–1957. In women the risk increased stepwise up to 2.6 and did not change during the time period 1973–1977 as compared to 1968–1972 and during 1983–1987 as compared to 1978–1982 (Figure 5).

**Extrapolations of future mortality rates**

In men, the age-period model generated considerably higher estimates than the age-cohort model. In both models the predictions were rather insensitive to using two or five recent period values or cohort values as the basis for the extrapolation (Table III). Since the mortality trends in men have mostly followed a cohort pattern hitherto, this model was considered more reliable even for future predictions. Thus, an about 35% increase in age-standardised mortality rates was estimated for the 20-year period following 1987. However, the rate of increase will probably decline gradually from about 14% between the first two 5-year periods to less than 5% between the last two periods.

In women, predictions from the cohort model were identical when two and five recent cohort values were included. In contrast, the extrapolation of period effects which, according to the multivariate analysis may be more relevant in women, was very sensitive to the number of period values included. Estimates based on two period values (10 years of the observation) suggest that the maximum was reached in 1978 through 1987 and that future age-standardised rates will stabilise at annual rates close to 3 per 10^5. Predictions that proceed from five recent period values, on the other hand, are strongly influenced by the apparent stepwise increase in mortality rate from 1973–1977 to 1978–1982 (Figure 5). Consequently, this model predicts a continuing 80% increase from 1987 through the year 2007 (Table III).

**Discussion**

Our analysis of mortality rates from malignant melanoma in Sweden 1953–1987 showed increasing rates in men and stabilising rates in women. The change in rates was best explained by cohort effects in men and by period effects in women. The relative risk of dying of malignant melanoma increased in men by birth cohort continuously up to men born around 1932, whereas in women the rise continued for cohorts born as late as 1947. In future, the increase in mortality rates will probably slow down for men, whereas in women predictions are more uncertain due to a stepwise increase in the late 1970s. Thus, mortality rates in women may stabilise around 3 per 10^5 or increase up to 5.7 per 10^5 during the next 20 years.

Mortality rates from malignant melanoma are affected by both the causative factors determining the incident number of cases and by factors related to the prognosis of the disease. One possible source of error affecting trends in mortality is the varying accuracy of the certified underlying cause of death. In Sweden, a comparison between diagnoses of skin cancer and malignant melanoma in the Stockholm Cancer
Register and the certified underlying cause of death in the Cause of Death Register, during 1978, showed concordant diagnoses in 88% of the cases (Mattsson et al., 1984). To our knowledge, no such investigation has been performed for the years after 1978 or specifically for malignant melanoma. However, the reporting practices have probably improved and we consider it unlikely that the results of our study are seriously biased because of changes in reporting practices.

Mortality rates from malignant melanoma in Sweden, adjusted to the European standard population for comparison (IARC, 1976), were lower than rates in Australia and New Zealand; they were similar to those in the United States and higher than the rates recorded in England, Ireland and Wales (Lee et al., 1979; Venzon & Moolgavkar, 1984). In men, the mean annual percentage increases in mortality rates, from the 1950s to the 1970s, were almost identical in Sweden, Australia and New Zealand, whereas they were lower among men in England and Wales, Canada and the white population of the United States. Among women the increases in mortality rates were similar in Sweden, New Zealand, Australia, Canada, England and Wales but lower among white women in the United States.

Age-period-cohort models are superior to simple descriptive methods. It is possible to test whether a significant improvement is obtained when further factors are included in the model. It can be stated whether the full model is an improvement on an age-period or an age-cohort model. However, the individual parameters of the full model cannot be identified, this fact makes the interpretation of the results rather difficult and limits the use of the method. In our analysis, two-factor models (age-cohort or age-period) were found to be adequate and it was not necessary to identify the full model.

In contrast to earlier studies, in which it was mainly cohort effects that explained the changes in mortality rates in both sexes (Lee et al., 1979; Holman et al., 1980; Venzon & Moolgavkar, 1984), we found that period effects were more important in women. Similar results were obtained in a multivariate analysis of incidence rates of malignant melanoma in Sweden (Thörn et al., 1990). Thus the temporal changes in exposure to causative factors – as revealed by trends in incidence – are fairly well reflected also by the mortality rates. However, the increasing incidence trend has been more pronounced than the mortality trend particularly in women. This discrepancy can be explained by the large temporal improvement in relative survival from malignant melanoma documented earlier (Thörn et al., 1989).

In the forecasts, the number of values chosen as the basis for the extrapolations is crucial for the results predicted with the age-period model. The age-cohort model is less sensitive to the number of values included because the mortality is small in the youngest age-groups which are influenced by the extrapolated cohort-values. Consequently, the two alternative extrapolations in our study gave largely similar mortality rates in the cohort model, whereas in the period model the results were different, especially for women (Table III).

The overall achievements in control of malignant melanoma are best evaluated by studying the changes in the mortality rates. The planning of interventional strategies – e.g., educational programs to reduce sun exposure and screening programs for earlier diagnosis – should be guided by estimates of the mortality rates in the future. Malignant melanoma currently accounts for about 1.5% of all cancer related deaths in Sweden (Statistics Sweden, 1990). Our study suggests that the mortality from malignant melanoma is likely to increase only slightly during the next 20 years. Under such circumstances, malignant melanoma will retain a limited quantitative role in the overall burden of death from cancer.

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Table III  Age-standardised mortality rates from malignant melanoma in patients between 20–84 years of age during 5-year periods, in Sweden, 1953–1987, and extrapolations of future mortality rates. The extrapolated rates are based on the two most recent period- or cohort-values and on five values, respectively

| Period       | Observed age-standardised rates | Extrapolated age-standardised rates |
|--------------|---------------------------------|-----------------------------------|
|              | Men                             | Women                            |
|              | age-period model | age-cohort model | age-period model | age-cohort model | age-period model | age-cohort model |
| 1953–1957    | 1.77                            | 1.20                             | 6.26              | 6.46              | 6.26              | 6.26              |
| 1958–1962    | 2.50                            | 1.78                             | 3.12              | 3.85              | 3.12              | 3.85              |
| 1963–1967    | 2.76                            | 2.01                             | 3.09              | 4.40              | 3.09              | 4.40              |
| 1968–1972    | 3.78                            | 2.52                             | 3.06              | 5.01              | 3.06              | 5.01              |
| 1973–1977    | 4.16                            | 3.18                             | 3.04              | 5.72              | 3.04              | 5.72              |
| 1978–1982    | 4.71                            | 3.17                             | 4.57              | 4.99              | 4.57              | 4.99              |
| 1983–1987    | 5.47                            | 3.17                             | 4.57              | 4.99              | 4.57              | 4.99              |

*Average rate per 10^5 per year.
