Age-period-cohort effects on ischaemic heart disease mortality in Sweden from 1969 to 1993, and forecasts up to 2003

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Aims Mortality from ischaemic heart disease has been decreasing in most industrialized countries since the 1960s. The aim of this study was to analyse ischaemic heart disease mortality during 1969–1993 in Sweden, and to predict mortality trends until 2003.

Methods and results Age-period-cohort models were used to analyse ischaemic heart disease mortality in Sweden between 1969 and 1993, and to predict age-specific death rates and total number of deaths for the periods 1994–1998 and 1999–2003. Mortality rates in the age group 25–89 years decreased from 719 to 487 per 100 000 for men, and from 402 to 215 per 100 000 for women over the study period (average annual decrease of 1.5% for men and 2.2% for women). The decline started earlier for women than for men. The ratio of age-adjusted mortality between men and women increased steadily over the study period. Predictions based on the full age-period-cohort model for the period 1999–2003 gave mortality rates of 346 and 155 per 100 000 for men and women, respectively. Despite the ageing of the population, the total numbers of ischaemic heart disease deaths in Sweden are predicted to decline by approximately 25% in both men and women from 1989–93 to 1999–2003.

Conclusion A major decline in ischaemic heart disease mortality has been observed in the last 15 years in Sweden. Both factors, cohort and calendar period, contain information which helps explain the decline in ischaemic heart disease mortality trends in Sweden. Predictions indicate that the decline of both age-specific and total mortality is to continue.

Key Words: Age-period-cohort models, ischaemic heart disease; ischaemic heart disease mortality, Sweden, time trends

Introduction
Mortality from ischaemic heart disease increased in most industrialized countries until the 1960s, when a peak was reached, and mortality has decreased since then[1]. In Eastern Europe the mortality due to ischaemic heart disease has not been declining as in Western Europe[2]. In Sweden the trend has been similar to other industrialized countries for women, but for men the decline in mortality did not start until the early 1980s[3-5].

The age-period-cohort model[6-8] has been used to describe variations in mortality and incidence trends. The effect of birth cohort includes risk factors and environmental exposures which are present in early life or which are typical for a given generation[7]. Period effects contain factors that act around the time of death; these include advent of medical care procedures or modifications in certification practices[7]. The aim of this study was to analyse variations in mortality rates for ischaemic heart disease in Sweden over the period 1969–1993. Specifically, it was of interest to identify and measure effects of the three interrelated factors age, calendar period of death and birth cohort, on mortality from ischaemic heart disease. In addition, the estimated models for mortality rates were used to make projections of future mortality rates and total number of deaths from ischaemic heart disease.

Materials and methods

Mortality and population data
Data on number of deaths, grouped by sex and 5-year age groups (25 to 89 years) from 1969 to 1993 were obtained from the Central Bureau of Statistics, Sweden. Ischaemic heart disease was defined as codes 410–414 in the 8th and 9th version of The International Statistical Classification of Diseases (ICD). Data on mid-year changes in population by 5-year age groups were obtained from the Central Bureau of Statistics, Sweden.

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population estimates and forecasts for population statistics for periods 1994–2003 were obtained from publications of the Central Bureau of Statistics.

**Statistical methods**

Annual mortality rates for men and women were age-adjusted with the Swedish population in 1981 as a standard population and are presented by calendar period and sex. Age-specific mortality rates are presented by sex and birth cohort in 5-year age groups. Furthermore, the time trends were analysed with an age-period-cohort model. It was assumed that the number of cases follow Poisson distribution, and that the effects of age, period and cohort are multiplicative. Parameters of the model were estimated with the method of maximum likelihood using the Gauss statistics package (program software). In addition to the full model with all three factors age, period and cohort, various submodels were estimated in order to evaluate which factors were important. Goodness-of-fit of the models were evaluated by the deviance measure. Pearson’s residuals were calculated and analysed to assess the assumptions of the models. For women, different models were compared using difference in deviance. For men, due to overdispersion, the maximum likelihood method and tests were modified as described by Breslow, and are presented as F-tests.

The final model was used to forecast the mortality rates for ischaemic heart disease for the next two 5-year periods (1994–1998 and 1999–2003). The unknown values for period and cohort effects were estimated by linear regression using arbitrarily chosen numbers of the most recent period and cohort values. We report results from calculations based on the three most recent period values and the five most recent cohort values, as the regression models used provided the best fit with these numbers. The estimated mortality rates were applied to predictions of population estimates in order to predict total number of ischaemic heart disease deaths during the next two periods. The linear dependency between factors age, period and cohort implies that estimates of the parameters in the model are not unique. However, estimating future mortality rates with an age-period-cohort model is not affected by the problem of non-identifiability.

**Results**

**Description of trends**

During the study period 1969–1993, a total of 735,326 deaths from ischaemic heart disease were listed in the routine mortality register in Sweden. Figure 1 shows age-adjusted mortality rates for ischaemic heart disease in men and women, aged 25–89 years, for the study period. Mortality rates for ischaemic heart disease decreased from 402 to 215 per 100,000 for women (average annual decrease of 2.2%). For men the mortality rates showed no clear trend over a ten-year period starting 1970, followed by a rapid decline after the early 1980s. Mortality rates in men declined from 719 to 487 per 100,000 over the whole study period (average annual decrease of 1.5%). The decline between 1981 and 1993 was 3.6% on average per year. The relative risk of mortality between men and women increased over the study period, from 1.78 in 1969 to 2.27 in 1993.

Figure 2 shows the age-specific ischaemic heart disease mortality rates by sex and birth cohort. For age...
IHD mortality in Sweden  1309

Figure 2  Mortality rates per 100 000 for ischaemic heart disease in Sweden during 1969–1993 by birth cohorts and age groups. Men and women, age 25–89 years.

For ischaemic heart disease mortality, the age–period–cohort model provided a better fit than the age–cohort or the age–period models in both sexes (men: test of period effect, \( F\)-test = 119.5, \( P<0.0001 \) with 6 and 33 degrees of freedom, df; test of cohort effect \( F\)-test = 3.03, \( P=0.004 \) with 15 and 33 df, women: test of period effect, difference in deviance \( \Delta D = 642.2, P<0.0001 \) with \( df=15 \).

In addition, the age–period and age–cohort models provided a significantly better fit than a model with factors age and linear effect of calendar period.

**Age, period and cohort effects**

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In addition, the age–period and age–cohort models provided a significantly better fit than a model with factors age and linear effect of calendar period.

**Predictions of future mortality rates**

Predictions of future mortality rates for ischaemic heart disease were based on the full age–period–cohort model.
The predicted numbers of deaths for 1999-2003 were, despite an increasing and ageing population. The total numbers of deaths in Sweden were found to have steadily declined in women during the 1969—1993 period. In men, the mortality rate was constant over a ten year period in the beginning of the study period. The decline in mortality started in 1982, and together with stroke they account for approximately 37% of all deaths[12]. A declining trend of age-adjusted ischaemic heart disease mortality has been observed in most industrialized countries after reaching a peak in the 1960s and 1970s. In this study, mortality rates from ischaemic heart disease in Sweden were found to have steadily declined in women during the 1969—1993 period. In men, the mortality rate was constant over a ten year period in the beginning of the study period. The decline in mortality started in 1982, considered later than in other comparable countries, and as it could explain variations in rates significantly better than age-cohort and age-period models. In Table 1, the age-specific and age-adjusted observed and predicted mortality rates from ischaemic heart disease for men and women are shown. Age-standardized mortality from ischaemic heart disease was predicted to decrease from 777 to 346 per 100 000 for men, and from 427 to 155 per 100 000 for women between 1969—1973 and 1997—2003. For both men and women the decline was present in the older age groups, but for the youngest age groups of women mortality rates were predicted to increase. Prediction of number of total deaths is made by applying the predicted age-specific mortality rates to the projected population figures. The observed and predicted total numbers of deaths from ischaemic heart disease in the age group 25—89 years are shown in Fig. 3. As seen from the figure, total number of deaths is going to decrease, despite an increasing and ageing population. The total numbers of deaths were 67 900 and 45 000 for men and women, respectively, in the 5-year period 1989—1993. The predicted numbers of deaths for 1999—2003 were 50 700 and 33 200 for men and women, respectively. In order to evaluate how accurate predictions from the models would be, we used only a subset of the data, periods 1969—1973, 1974—1978, 1979—1983 and 1984—1988, to estimate a full age-period-cohort model, and used it to predict mortality rates for the period 1989—1993. Generally, the predicted mortality rates were higher than those actually observed, which reflects the accelerated decline in mortality that has occurred in the later part of the study period.

### Discussion

Ischaemic heart disorders account for approximately 27% of all deaths in Sweden in the age group 25—89 years, and together with stroke they account for approximately 37% of all deaths[12]. A declining trend of age-adjusted ischaemic heart disease mortality has been observed in most industrialized countries after reaching a peak in the 1960s and 1970s. In this study, mortality rates from ischaemic heart disease in Sweden were found to have steadily declined in women during the 1969—1993 period. In men, the mortality rate was constant over a ten year period in the beginning of the study period. The decline in mortality started in 1982, considered later than in other comparable countries, and

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**Table 1** Observed (1969—1993) and predicted (1994—2003) mortality rates per 100 000 for ischaemic heart disease, Sweden, men and women

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Age adjusted = period 1979—1983, men and women, age 25—89 years, as standard population.

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has since then been more marked than the decline in women during the same period in absolute terms. Over the whole study period, the decline in the mortality rates has been somewhat more marked for women resulting in increased relative risk of death due ischaemic heart disease for men vs women.

Disease incidence and case-fatality rate are the two components which affect mortality. Incidence, in turn, is affected by changes in population levels of major cardiovascular risk-factors. Variations in case-fatality rate can partly be explained by changes in medical care. In addition, changes in risk-factor levels could also affect case fatality indirectly by changing the severity of the disease. Data from the WHO MONICA study show that the age-specific incidence of ischaemic heart disease in Northern Sweden has declined markedly over the period 1985–1993 in men but not in women. Reports from southern Sweden show that mortality following hospital discharge has decreased during the period 1968–1985 and the levels of cardiovascular risk factors have declined. A decline in incidence has also been reported for Finland, U.S.A., Australia and New Zealand. In Finland, a country with one of the highest ischaemic heart disease mortality rates in the world, a rapid decline in mortality started in the 1970s.

In this study, the age–period–cohort model was used to describe variations in mortality rates over the years. Variations in mortality trends for ischaemic heart disease were best described by the full age–period–cohort model for both men and women. This means that when explaining variations in rates over the years, cohort factors are relevant even if one adjusts for period effects, and the period factor contains information even after adjusting for cohort effects. Projected future mortality rates based on the age–period–cohort models indicate that the observed declining trend for age-adjusted ischaemic heart disease mortality is to continue. This decline is attributable to declining mortality rates in the older age groups. However, for the youngest age groups mortality rates are projected to increase in women, which may reflect the increase in smoking in these groups. A major decline in mortality rates for ischaemic heart disease has also been predicted by the end of century in Britain, but unlike our predictions, the decline is projected to be most marked among the middle-aged.

By combining predicted mortality rates with predicted population statistics the total future number of deaths can be estimated. Our analysis showed that if the rate of decline in ischaemic heart disease mortality follows the pattern it has up until now, it will overcome the increase in numbers due to the ageing and the increasing size of the population. The net result is that the total number of deaths is going to decrease. Similar results have been observed for mortality from stroke in Sweden.

The use of age–period–cohort models for predictions of future mortality rates is based upon the assumption that the experienced progress in cohort and period effects is to continue. Therefore, it is not possible to take into account such factors as new medical treatments or changes in risk factor profiles in the community which do not agree with the observed trends. In addition, the predictions are sensitive to the number of values chosen to predict period effects, a choice which is arbitrary. It should also be noted that predictions of total numbers of deaths include an extra source of uncertainty, namely predictions of population growth. The validation of the prognostic ability of the present models using only a subset of the data showed that, for both men and
women, the observed values declined more than what was predicted. This is partly due to the introduction of new preventive and therapeutic methods in the 1980s (e.g. thrombolysis) on case-fatality, which the model was not able to take into account. If this applies to periods predicted with the full set of data, the decline in mortality rates and total numbers of deaths due to ischaemic heart disease will be even greater than reported here.

Changes in coding practices of diseases could affect mortality statistics. In Sweden, the ICD coding practice was changed once under the study period, from the 8th to the 9th revision in 1986. There are some minor changes in coding between the two revisions of ICD codes regarding ischaemic heart disease. However, the changes in coding should be of no practical importance, as the broad definition of ischaemic heart disease used in the study, including ICD codes 410–414, improves the validity of comparing data from the two different time periods.

In our study, mortality rates during the period 1969–1985 with the 8th revision of the ICD and the period 1986–93 with the 9th revision showed similar trends for women. For men the decline in mortality started prior to the change in ICD coding, so the observed decline cannot only be due to changes in coding. In addition, when compared with two Swedish subpopulations in the WHOs MONICA study in which independent assessment of all ischaemic heart disease deaths was used, the routine mortality register (based on death certificate rates) showed similar mortality rates.

The decline in ischaemic heart disease mortality in Sweden is following a pattern similar to the trend in stroke mortality. However, unlike the trend in stroke mortality, the decline in ischaemic heart disease mortality appears to reflect changes in disease incidence, which is also declining. During the study period total mortality had declined in the age groups studied. The effect of this has been an increase in life expectancy from 71.7 to 75.5 years for men and from 76.1 to 80.8 years for women from 1969 through 1993. As trends in mortality from other major disease groups, e.g. cancer, have been stable during the period studied, it is concluded that improvements in cardiovascular disease mortality have had a major impact on the increased life expectancy in Sweden.

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