Coronary Heart Disease Mortality in Czech Men, 1980-2004

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Background: The Czech Republic belongs to countries with high coronary heart disease (CHD) mortality. The aim was to analyze age, period and cohort specific CHD mortality in men from the Czech Republic.

Design and Methods: National data on mortality of men (30-74 yrs.) in the Czech Republic in 1980-2004 were explored. The Poisson regression model was applied to evaluate age, period and cohort effects on mortality.

Results: An adequate fit of CHD men's mortality provided the age-period-cohort model (p=0.121). The ratio of mortality of the age group 45-49 to 40-44 was by 17 % lower than that of the age group 40-44 to 35-39. The ratio of the relative risk of period 1995-1999 to 1990-1994 was by 19 % lower than that of the period 1990-1994 to 1985-1989. The ratios of the relative risks between adjoining birth cohort-groups were close to 1.

Conclusions: The fatal CHD risk in Czech men was significantly depended on age (the risk increasing with age), calendar period (the risk reduced in the recent years), and birth cohort (the risk decreasing with birth cohort). The crucial positive change in the CHD mortality trend was observed after the collapse of communism in 1989, and in men past age 40 years.

Keywords: coronary heart disease, cardiovascular, mortality, risk function

Figure 1. European age-standardized coronary heart disease mortality in some European countries, by sex, 0-64 yrs., 1980[1], 2004.
[1]In Azerbaijan, Belarus, Kazakstan, Kyrgyzstan, Lithuania and Ukraine mortality in 1981 is presented. Source [1].

Introduction

At the turn of the 21st century in the European Union countries cardiovascular diseases (CVD) cause between 26 % of deaths (France) and 62 % (Bulgaria) in men and between 31 % of deaths (France) and 71 % (Bulgaria) in women [1]. CVD remain the main cause of death in men and in women in all European countries, except men in France, the Netherlands, and Spain. Over a third of deaths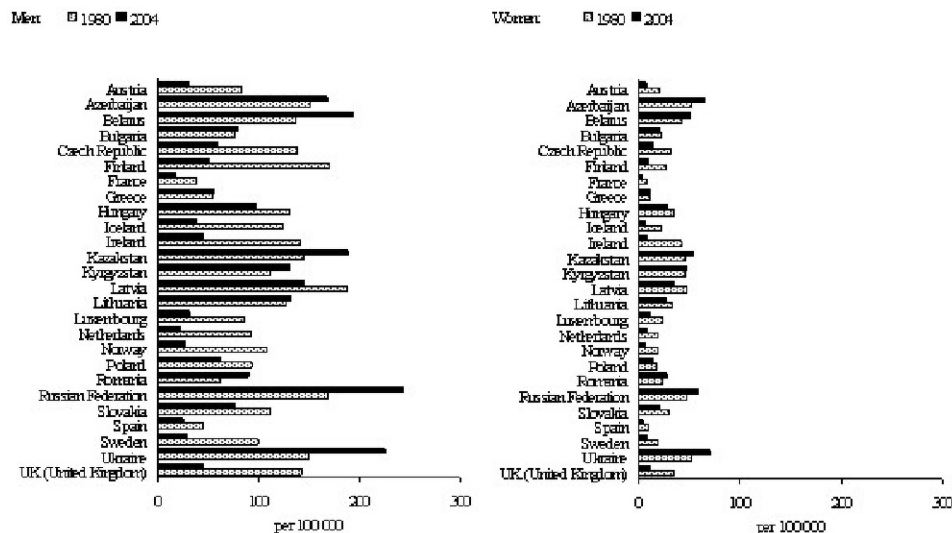 from CVD are from coronary heart disease (CHD), which by itself is the most common cause of death in Europe. Figure 1 shows age-standardized mortality from CHD in some European countries.

In 1970-2000 mortality from CVD declined almost linearly in western European countries [2]. In eastern European countries, CVD mortality reached a maximum in 1990-1994, followed by a decline in Poland, in Hungary, and in the Baltic states (Estonia, Latvia, Lithuania). An appreciable reversal of the trend was also observed in the Czech Republic (CR) [3]. A main role in the decline in CVD mortality in CR plays most likely a decreasing trend in the occurence of most major CVD risk factors observed in the 1985-2000/01 period [4].

Nevertheless, in 2006 diseases of the circulatory system were the most frequent cause of death in CR (the 2nd most frequent cause of death were malignant neoplasms, the 3rd injuries) [5]. They were responsible for 50.3 % of all deaths. The leading cause of death from the cardiovascular diseases was CHD. It caused 47.1 % of all death from CVD in men, and 40.8 % in women. The aim of this article is to analyze mortality from CHD in Czech men in 1980-2004.

Material and Methods
Source data
The numbers of CHD (codes D410-D414 in the 8th Revision of International Classification of Diseases (ICD-8), codes 410-414 in ICD-9, codes I20-I25 in ICD-10) and mid-year population by the 5-year age groups (0-4, 5-9,...80-84, 85+) in 1980-2004 are from the publications "Population changes in the Czech Republic" yearly issued by the Czech statistical office. Mortality from CHD was directly age-standardized to the European population [6].

Statistical methods
An age-period-cohort (APC) modelling was applied to analyse mortality from CHD in men aged 30-74 years from CR in 1980-2004 (note: mortality in the younger age group was low and the reliability of death cause in the elderly can be arguable, these age groups were excluded from the

analysis). The number of CHD deaths was modelled by a log-linear Poisson regression as a function of the age at death, period of death, and birth cohort. The APC modelling was done hierarchically as summarized by Arbyn et al. [7], and finally presented in Table 1 in Results. A goodness-of-fit of a given model was measured by the residual deviance with a chi-square test. The contribution of an additional term to the model was evaluated by comparing the difference in the deviances between the given model and the model without the term against chi-square distribution with the degree of freedom (*df*) equalled to the difference in *df* between these two models. The adequacy of the model was further verified by the Akaike's information criterion (AIC) for the fit, and an examination of the Pearson residuals. To test for extra-Poisson variation, the Cameron-Trivedi (C-T) test was applied.

It is well known that a linear dependency exists among the variables of age (a_i, i=1,...,I), period (p_j, j=1,...,J) and cohort (c_k, k=1,...,K): $k=I-i+j$. In the model involving the variables of age, period and cohort simultaneously, the linear dependency results in non-unique estimations of these parameters (note: the multiple estimations, however, yield the same fitted number of deaths). To obtain unique estimations, a constraint on the estimated parameters is required. However, the different constraint leads to estimations of age, period and cohort trends. In our case, the constraints of fixing two period parameters (1985-1989, 1990-1994), and one cohort parameter (1935-1944) to zero and the constraints so-called second differences by Clayton and Schifflers [8] were also used to estimate the parameters of the age, period and cohort. Other differences are the contrasts expressed as the ratio (difference on a logarithmic scale) of two adjacent relative values (more in Results). The statistical analysis was performed using the R software version 2.3.1.

Results

Figure 2 shows the development of age-standardized CHD mortality in men from CR in 1980-2004, in all age groups together, in the age group of 0-64 years, and in the age group of 30-74 years. For the ability of comparison with mortality in other European countries (Figure 1), this mortality was adjusted (recalculated) on the age-structure of the European standard population.

Figure 3 shows the age, period, and birth cohort specific (yearly) mortality in the age group of 30-74 years. Mortality is plotted on a logarithmic scale. Mortality was increasing with age (Figure 3a), decreasing in the recent years (Figure 3b), and decreasing with birth cohort (Figure 3c). In other words, Figure 3 depicts mortality data subsequently stratified by age, period and birth cohort, which we have at our disposal for the statistical analysis testing simultaneously to what extent age, period, and birth cohort influence mortality.
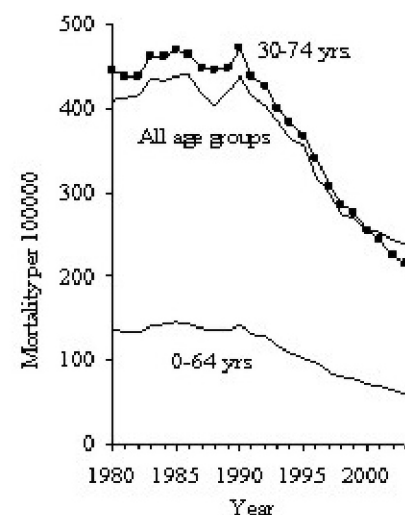

Figure 2. European age-standardized coronary heart mortality in the Czech Republic, men, in all and specific age groups, 1980-2004.
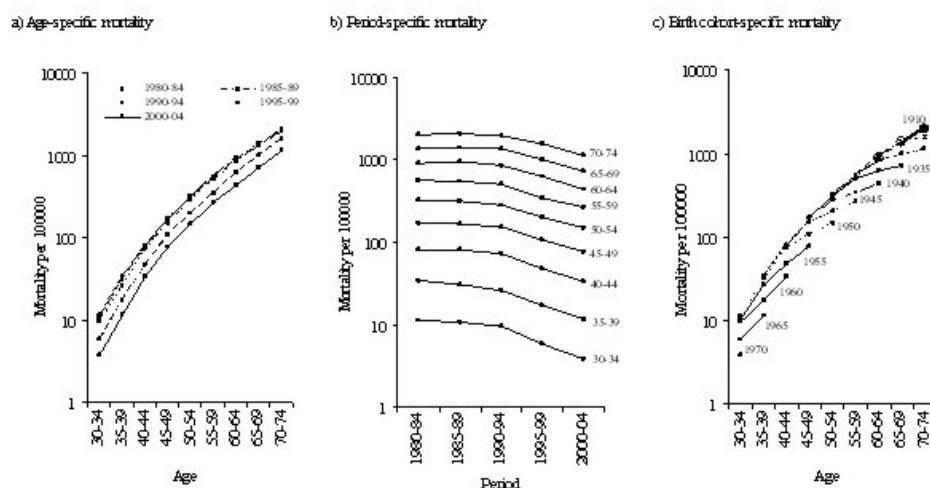

Figure 3. Age, period, birth cohort-specific coronary heart mortality in the Czech Republic, men, 30-74 yrs., 1980-2004[1].
[1]In c), birth cohort notation represents the centre of the 10-year interval, e.g. birth cohort of 1940 represents the cohort of men born from 01/01/1935 to 31/12/1944.

The statistical analysis is presented in Table 1, which summaries the results of APC modelling. The effect of age was significant on mortality (the model 1). The fits of the models 2 and 3a-3c were significantly better compared with the model 1, however, still not sufficient. A more adequate fit provided the APC model (the model 4). It means that the risk of death was significantly depended on all three effects: age, calendar period, and birth cohort. In the APC model, no extra-Poisson variation (in other words, no significance difference between mean and variance) was detected (*p*=0.500), and the

Pearson residuals ranged from -1.864 to 1.784.

The self effects of age, period, and cohort on mortality are demonstrated in Figure 4. The age effect was expressed as age-specific mortality per 100 000, the period and cohort effects as relative risk of death from CHD. Increasing age was elevating CHD mortality (Figure 4a). The risk of death from CHD was reducing in the most recent periods (Figure 4b, compared with 1985-1995, i.e. the reference period), and with birth cohort (Figure 4c).

The cohort risks were related to the risk of the cohort 1940 (the reference cohort). The cohort 1940 included men born around (1935-1944) the beginning of the Second World War in 1939. In fact, it was a central cohort and compared with this cohort, the younger and older cohorts are based on fewer data, Figure 3c (it resulted in the varying width of confidence intervals, Figure 4c).

The numbers in brackets in Figure 4 indicate the ratio of two adjacent values. Remind that these ratios are the same for various age, period and cohort parameter estimates, and thus they solve the non-identifiability problem in the APC model as mentioned in Material and Methods. It is important to emphasize that the ratios indicate neither increasing nor decreasing trend. In fact, the values under 1 indicate "deceleration" of the trend, and the values above 1 indicate "acceleration" of the trend. Let's describe the most essential sudden changes in the trends:

• Following Figure 4a): The ratio of mortality of the age group 45-49 to the age group 40-44 was lower by 17 % than that of the age group 40-44 to the age group 35-39, because the mentioned mortality rate was $\left(\frac{165.2}{87.7}\right)\bigg/\left(\frac{87.7}{38.6}\right) = 83\%$.

The sequent mortality rates were 89 % for the age group of 45-49 years, and 93 %-99 % for the age group of 50 years and over. In summary, the largest deceleration of the mortality trend was observed in men in the age group 40-49 years.

• Following Figure 4b): The ratio of the relative death risk of the period 1995-1999 to the period 1990-1994 was lower by 19 % than that of the period 1990-1994 to the period 1985-1989, because the mentioned risk ratio is $\left(\frac{0.81}{1.0}\right)\bigg/\left(\frac{1.0}{1.0}\right) = 81\%$.

Other more than 10% changes in the trend were not observed. So that, the largest decrease in the mortality trend was achieved in 1995-1999 compared to the previous development of the trend.

• Following Figure 4c): No larger sudden changes in the relative death risk were observed by birth cohorts; the ratio of the relative risks between adjoining cohort-groups ranged from 0.92 to 1.06.

Table 1. Age, period, cohort modelling of coronary heart mortality, men, 30-74 yrs., Czech Republic, 1980-2004.

No.[1]	Model	Residual deviance (D)	Degree of freedom (df)	p-value	Compared with model	Δ(D)[2]	Δ(df)[3]	p-value	AIC[4]
0	Interception	355388.0	44	<0.001					
1	Age	15148.0	36	<0.001	0	340240.0	8	<0.001	15600.6
2	Age-Drift	3255.5	35	<0.001	1	11892.5	1	<0.001	3710.1
3a	Age-Age*Drift	2922.5	27	<0.001	2	333.0	8	<0.001	3393.1
3b	Age-Period	388.2	32	<0.001	2	2867.3	3	<0.001	848.8
3c	Age-Cohort	1872.6	24	<0.001	2	1382.9	11	<0.001	2349.2
4	Age-Period-Cohort	28.7	21	0.121	3b	359.5	11	<0.001	511.3

[1]Follow Figure 2. If the model 1 holds, the age-specific mortality curves by the periods are identical. If the model 2 applies, the age-specific mortality curves are parallel at constant distances (so-called drift). In the case of model 3a, the age-specific mortality curves are not parallel; the age-specific mortality in successive periods differ by the constant specific for each age group. In the case of the model 3b, the age-specific (or equivalently period-specific) mortality curves, are parallel, but at different distances. If the model 3c holds, the birth cohort-specific mortality curves are parallel at different distances. The model 4 allows for the non-parallel age-specific mortality curves as a function of the period and cohort variables.
[2]Difference in residual deviances.
[3]Difference in degree of freedoms.
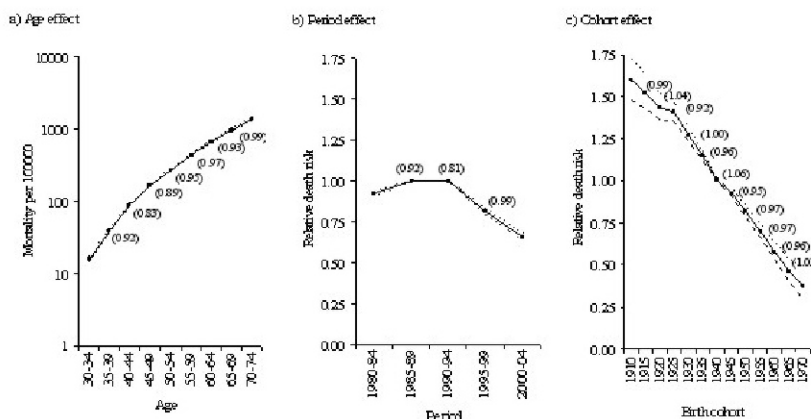[4]Akaike's information criterion.

Figure 4. Estimated effects of age, period1 and birth cohort[2] (with 95% CI) on coronary heart mortality in the Czech Republic, men, 30-74 yrs., 1980-2004 (the numbers in brackets indicate the ratio of two adjacent relative risks[3]).
[1]Periods of 1985-1989 and 1990-1994 was chosen as reference.
[2]Birth cohort of 1940 was chosen as reference; birth cohort notation represents the centre of the 10-year interval, e.g. birth cohort of 1940 represents the cohort of men born from 01/01/1935 to 31/12/1944.
[3]For instance, the ratio of mortality of age group 40-44 (87.7) versus age group 35-39 (38.6) to mortality of age group 35-39 (38.6) versus age group 30-34 (15.6) is (87.7/38.6)/(38.6/15.6)=0.92.

Discussion

APC modelling is used as the method to analyse incidence and mortality from various causes ranged from cancer to cardiovascular diseases. It is a descriptive tool, mainly used for nationally registered data. It helps not only to model but also to predict occurrence of diseases. In this paper, we used APC modelling to explore mortality from CHD in men from CR.

CVD causes nearly half of all death in Europe (48 %), and CHD by itself is the single most common cause of death in Europe [1]. Primary prevention pro-grammes in many countries attempt to reduce occurrence of CHD through risk factor modification. However, in studies so far conducted, such interventions have limited the effect on mortality, as summarized in the literature [9,10]. On the other hand, as stated there, a small but potentially important benefit (about a 10% reduction in CHD mortality) may have been missed in those studies.

Major cardiovascular risk factors are smoking, elevated blood pressure, elevated cholesterol level, and diabetes mellitus. CR belongs to the European countries with high CHD mortality even if mortality from CHD has been decreasing in CR from the beginning of 1990s (Figure 1). In this study, using APC modelling, we found out that mortality in Czech men was significantly dependent on the age of death, calendar period of death and birth cohort.

Mortality from CHD was increasing with age (Figure 4a). The effect of age on mortality was likely to reflect the dependency of mortality on atherosclerosis ("hardening of blood vessels" – the main underlying cause of CVD), which as has been known may begin in childhood, and getting worse as a person gets older. Likely that decisive age for men is the age around 40/50 years, when the largest deceleration of increasing mortality was observed (the mortality ratio of the age group 45-49 to 40-44 was by 17 % lower than that of the age group 40-44 to 35-39; the mortality ratio of the age group 50-54 to 45-49 was by 11 % lower than that of the age group 45-49 to 40-44).

The risk of death from CHD was reduced in the recent period (Figure 4b). The period effect on mortality reflects the risk factors and the level of health care that act in the period of death. The period risks of 1985-1989, 1990-1994 were fixed to 1 (the reference periods) due to been assumed that the risks were approximately same in these years around the collapse of communism in 1989. Decrease of the risk from fatal CHD in the recent periods (compared to 1985-1994) is explained by the collapse of communism, followed by lifestyle changes and modern treatment. The ratio of the relative death risks of the period 1995-1999 to the period 1990-1994 was by 19 % lower than that of period 1990-1994 to period 1985-1989.

The relative risk of dying from CHD was linearly decreasing with birth cohort, and ranged from 0.38 to 1.60 (Figure 4c). No sudden larger trend fluctuations were observed; the ratios of the relative risks between adjoining cohort-groups were close to 1.0. The effect of birth cohort on mortality can be viewed as risk factors and environmental exposures typical for a given generation. Etiology is often related to birth cohort.

One limitation of our APC model is that we did not have data on background characteristics of individuals. Therefore we could not relate the age, period, and cohort trends to trends in cardiovascular risk factors (smoking, blood pressure etc.) and precisely to investigate time from risk factor modification to decline in mortality. Our study is not the analytical study, but the descriptive study, which could help medicine workers understand and speculate about the development of mortality from CHD in CR. For instance, our data suggests that a sharper decline in mortality was demonstrated in 5-10 years (1995-1999) after the risk factor modification, which is supposed to start around 1990. Furher, even if the aim of our study was not to predict the future CHD mortality trend, mortality among men in CR can be expected to decrease, assuming the trend in the risk factors remain unaltered. The decline is mainly expected due to the fact that the risk of CHD death is decreasing with the year of birth, and in the recent periods. APC modelling of CHD was recently also applied in Finland [11] and Japan [12], in which decline in future CHD mortality is also expected. The results of both studies emphasize the significance of maintaining the recent decline of CHD mortality among middle-aged adults. Few studies on APC mortality were found that were conducted in the past century and predicted development mortality from the past to the beginning of the 21st century. For instance, age-period-cohort effects on CHD mortality in Sweden from 1969 to 1993 were analysed, with forecasts up to 2003 [13]. It would be worth to compare predicted and observed mortality in these studies.

In conclusion, the risk of CHD death in Czech men was significantly dependent on the age of death, calendar period, and birth cohort. The crucial positive change in the mortality trend was observed after the collapse of communism in 1989, and in men at the age of 40-49 years. Assuming age, period and cohort trends remain unchanged, the further decrease in mortality from CHD can be expected in Czech men.

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