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ORIGINAL ARTICLE

Causes of death behind low life expectancy of Danish women

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Abstract
Aims: The authors examined causes of death contributing to the relatively high mortality of Danish women born 1915–45, and evaluated the impact of smoking related causes of death. *Methods:* Age–period–cohort analysis of mortality of Danish women aged 40–89 in 1960–98. Estimate of the negative curvature in parabola patterns for 50 causes of death. *Results:* A total of 34 causes of death contributed to the relatively high mortality for women born 1915–45. The main contribution came from smoking-related causes of death. *Conclusion:* The results indicate a high smoking prevalence to be the main explanation behind the relatively low life expectancy of Danish women born 1915–45.

Key Words: *Causes of death, cohort effects, mortality, Denmark*

Background

The life expectancy of Danish women ranks at 32nd in the world, and is low compared with that of other Scandinavian women [1]. Swedish women rank 9th, and Norwegian 14th, Icelandic 15th, and Finnish 17th [1]. The relative stagnation in life expectancy of Danish women started in the 1970s, and led to intensive research for possible causes [2,3]. The main conclusion was that smoking by Danish women explained the stagnation, a conclusion based on the fact that the lung cancer mortality of Danish women had increased steadily over time [4]. Common to these exploratory analyses was their focus on the traditional calendar period perspective. However, as stated by Holford in 1983, trends in the age, period, and cohort may offer aetiological clues, and sometimes one of the three factors can provide a particularly clear summary of the observed data [5]. We found recently that birth cohort was more important than calendar period in explaining the mortality pattern of Danish women [6], as generations born between the two world wars had a particularly high mortality. This finding suggests that the search for causal factors behind the relative stagnation in life expectancy of Danish women should focus on the generations born in the period 1915–45, rather than the women living in the period 1970–2003.

Aims

In the present study we examined 50 causes of death in Danish women born 1915–45 with the aim of identifying causes contributing to the birth cohort effect in total mortality.

Material and methods

The number of deaths by cause and the mid-year population stratified by five-year age groups for Danish women aged 40–89 in the period 1960–98 and born 1915–45 were obtained from the Cause of Death Register of the National Institute of Public Health [7], and the publications of Statistics Denmark [8]. Causes of death were available as four-digit codes following the international classifica-

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tion of diseases (ICD). The revision of the ICD was changed through time as follows: ICD 7 (1960–68), ICD 8 (1969–93), and ICD 10 (1994–98). The three classifications were translated into 50 causes of death using two conversion tables [9,10]. For each of the 50 causes of death, data were organized in a two-way table with rows as five-year age groups, and columns as five-year periods and synthetic birth cohorts represented by the diagonals of the table. Within 5-year age and period groups, the women contributing to such a cohort are born within a 10-year period, the same women contributing to two adjacent synthetic birth cohorts.

In our previous study (6) we fitted age–period–cohort models:

$$\log(rate_{ij}) = \mu + \alpha_i + \beta_j + \varepsilon_c$$

where μ is an intercept, α_i the effect of age group i, β_j the effect of the jth period, and ε_c the effect of the cth cohort, where it is well known that only one linear component in (β_j, ε_c) is identifiable. This identifiable problem exists because of the perfect correlation between any two of the components: age, period, and cohort. The non-linear part of the cohort effect ε_c is uniquely identifiable, and for the cohorts 1915–19 to 1945–49 was approximated by a parabola with negative curvature $\gamma < 0$:

$$\varepsilon_c = \gamma(c - 1930)^2 - 225\gamma$$

We see that γ expresses the strength of the non-linear cohort effect (Figure 1).

The strategy now is to assume that the non-linear effects may be described as parabolas:

$$\varepsilon_c^i = \gamma^i(c - 1930)^2 - 225\gamma^i$$

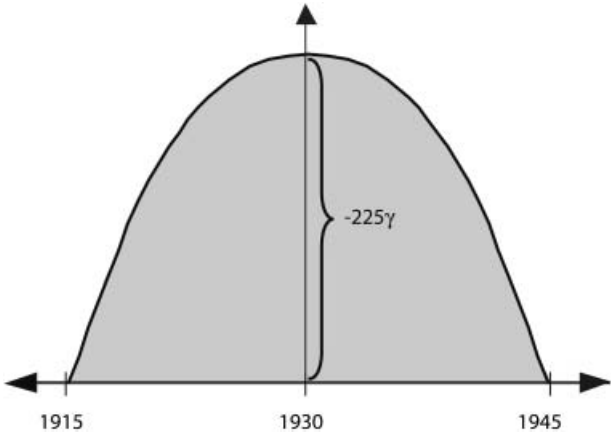

Figure 1. Illustration of the negative parabola fitted to the cohort component in the mortality for Danish women born 1915–45 in the model.

The above development shows that the curvature γ^i corresponding to cause of death i measures the strength of the non-linear variation over 1915–45 of the mortality from this specific cause of death. This provides an individual "aetiological" perspective, but does not account for how common a cause i is. Thus, a negative estimate would contribute to the negative parabola shape for all causes of death, whereas positive estimates would not.

To evaluate the influence of smoking on the cohort effect, causes of deaths were divided into causes related to smoking in two large studies [11–14]. Separate age–period–cohort analyses using equation 1 were performed for smoking-related and non-smoking-related causes of death.

The parameters of the models were estimated using multiplicative Poisson regression models [15] and all statistical analyses were done using the SAS 8.2 package.

Results

For all causes of death combined the curvature estimate was −0.05 (Table I). In total, 34 causes of death could be described with negative parabolas, and for 23 of these the estimated curvature $\hat{\gamma}^i$ was statistically significantly negative (Table I). Among the larger cause of death groups, "Cerebrovascular disease" had the same curvature estimate as the total mortality, −0.05, while "Ischaemic heart disease" had an estimate just below, −0.04, and "Malignant neoplasm of breast" was further down the list, −0.03. The two large groups "Malignant neoplasm of larynx, trachea, bronchus, and lung" and "Bronchitis, emphysema, and asthma", however, had estimates of −0.14 and −0.27, respectively, clearly indicating their major importance for the curvature pattern in the total mortality. In fact, among the 10 causes of death with the strongest cohort effect, 4 were related to the respiratory system ("Tuberculosis", "Bronchitis, emphysema and asthma", "Other diseases of respiratory system", and "Malignant neoplasm of larynx, trachea, bronchus, and lung"), while 3 were related to the urogenital system ("Infections of kidney and calculus of urinary system", "Malignant neoplasm of cervix uteri", and "Other malignant neoplasm of uterus").

The non-linearity in the mortality pattern by birth cohort was found for both smoking-related causes of death and non-smoking related causes of death; the cohort effect was, however, clearly more marked for the smoking-related causes of death than for the other group (Figure 2).

Table I. Influence of specific causes of death on the cohort effect in mortality of Danish women.

Cause of death	Number of deaths	χ^2 (p-value))	Estimate
Tuberculosis	403	19.5 (<0.01)	−0.47
Bronchitis, emphysema, and asthma[a]	14364	314.9 (<0.01)	−0.27
Infections of kidney and calculus of urinary system	1820	13.5 (<0.01)	−0.17
Other diseases of respiratory system	1124	10.4 (<.01)	−0.17
Meningitis	269	3.4 (0.06)	−0.17
Diseases of arteries, arterioles, and capillaries[a]	4770	29.0 (<.01)	−0.16
Active rheum., fever and chronic rheum., heart disease[a]	1609	10.4 (<.01)	−0.15
Malignant neoplasm of larynx, trachea, bronchus, and lung[a]	17867	159.0 (<.01)	−0.14
Malignant neoplasm of cervix uteri[a]	5485	49.4 (<.01)	−0.14
Other malignant neoplasm of uterus	2995	15.4 (<.01)	−0.12
Benign neoplasms and neoplasms of unspecified nature	1994	10.8 (<.01)	−0.12
Acute respiratory infections[a]	426	1.6 (0.21)	−0.12
Congenital anomalies of circulatory system	250	1.9 (0.17)	−0.12
Other diseases of genito-urinary system and diseases of breast	1433	6.6 (0.01)	−0.11
Nephritis and nephrosis	685	3.6 (0.06)	−0.11
Other diseases of the nervous system and sense organs	4021	19.3 (<.01)	−0.1
Diseases of oral cavity, oesophagus, and stomach[b]	2206	5.8 (0.02)	−0.09
Infective and parasitic diseases (except tuberculosis)	1124	3.4 (0.07)	−0.09
Symptoms and other ill-defined conditions	12200	26.7 (<.01)	−0.08
Other forms of heart disease[a]	8813	12.3 (<.01)	−0.08
Malignant neoplasm of stomach[c]	2971	7.3 (<.01)	−0.08
Diseases of skin and musculoskeletal system	1753	4.9 (0.03)	−0.08
Malignant neoplasm of other and unspecified sites	31521	64.3 (<.01)	−0.07
Other congenital anomalies	353	1.1 (0.29)	−0.07
Cerebrovascular disease[a]	19397	14.9 (<.01)	−0.05
Malignant neoplasm of bone and skin	1856	2.2 (0.14)	−0.05
All causes	268014	320.8 (<.01)	−0.05
Ischaemic heart disease[a]	42220	20.9 (<.01)	−0.04
Malignant neoplasm of intestine, except rectum	8852	6.3 (0.01)	−0.04
Other diseases of digestive system	3737	2.2 (0.14)	−0.04
Hypertensive disease[a]	1866	1.4 (0.24)	−0.04
Malignant neoplasm of breast	21366	12.7 (<.01)	−0.03
Suicide and self-inflicted injury	8293	1.3 (0.25)	−0.02
Diabetes mellitus	4409	0.8 (0.36)	−0.02
Anaemias and other diseases of blood and blood-forming organs	416	0.0 (0.99)	0
Malignant neoplasm of rectum and rectosigmoid junction	3865	0.0 (0.99)	0
Malignant neoplasm of buccal cavity and pharynx[a]	2002	0.2 (0.68)	0.01
Mental disorders	2218	0.1 (0.73)	0.01
Leukaemia and other neoplasm. of lymph. and haemato. tissue	6471	0.1 (0.70)	0.01
Endocrine and metabolic diseases, except diabetes mellitus	1369	0.4 (0.52)	0.02
All other accidents	4616	0.6 (0.44)	0.02
All other effects of external causes	1310	0.8 (0.38)	0.03
Motor vehicle accidents	2288	1.1 (0.29)	0.03
Cirrhosis of liver, cholelithiasis, and cholecystitis[2]	4544	7.0 (<.01)	0.05
Pneumonia[a]	3586	3.8 (0.05)	0.06
Other diseases of circulatory system	2302	5.0 (0.03)	0.07
Senility without mention of psychosis	495	0.2 (0.69)	0.19
Complications of pregnancy, childbirth, and the puerperium	21	–	–
Certain causes of perinatal mortality	1	–	–
Cause of death unknown	58	–	–

[a,b,c]Risk associated with smoking according to the CPSII study [11,14], Doll 1998 [13], and Doll et al 1994 [12] respectively.

Discussion

Lung cancer and bronchitis contributed significantly to the non-linear birth cohort effect in the mortality of Danish women born between the two world wars. Both causes of death are known to be strongly associated with cigarette smoking [11–14]. Cardiovascular diseases also contributed to the non-linear birth cohort effect but less so than lung cancer and bronchitis. This is in line with the fact that cardiovascular diseases are positively associated with cigarette smoking but not as strongly as lung cancer and bronchitis [11–14]. Breast cancer, a disease not associated with cigarette smoking [11–14], contributed only weakly to the non-linear pattern. The pattern seen for the individual causes of death was strongly supported by the outcome of the analysis

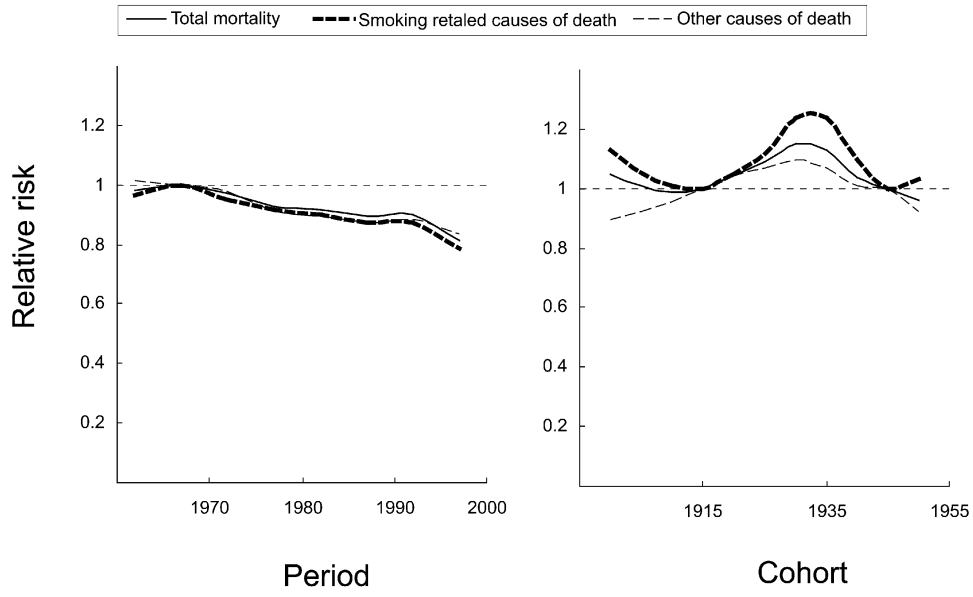

Figure 2. Age-adjusted relative risk of death by smoking-related causes of death, other causes of death, and total mortality of Danish women by period and cohort. Baseline (RR=1) is defined as women aged 50–54 in 1965–69 and born in 1915–19.

dividing the causes of death into smoking- and non-smoking-related diseases where the non-linearity was seen in particular for the first group. Given that the main contribution to the relative high mortality of the interwar generations of Danish women came from smoking-related causes of death, we would expect these women to have smoked more than the older and younger generations. Historical data on smoking prevalence in Denmark are sporadic, but estimates based on population surveys [16] indicate that the generations of women born 1915–45 indeed had a higher smoking prevalence than the other generations (Figure 3).

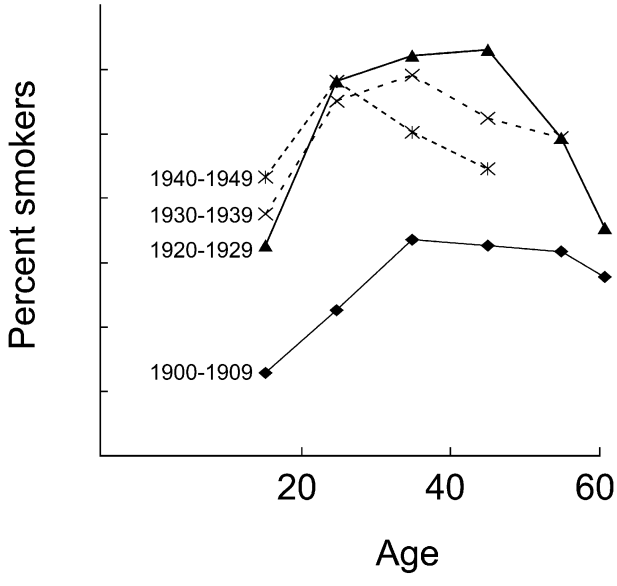

Figure 3. Percentage of smokers for different birth cohorts of Danish women.

The identification in the present study of smoking as the main explanation for the low life expectancy of Danish women is in agreement with results from previous time period analysis [4]. However, there is a major difference in the interpretation of the findings. In the present study we found that the relatively low life expectancy of Danish women was explained by the smoking habits of women born between the two world wars. The period-oriented analysis suggested that the smoking habits of women living during the period 1970 to 2000 caused the relatively low life expectancy. The two types of analysis led to different interpretations. First, the cohort perspective tells us that an anti-smoking campaign among younger generations of Danish women is not the way to overcome the relatively low life expectancy. Second, the cohort perspective also tells us that the relatively low life expectancy of Danish women is a temporal phenomenon expected to disappear with the dying out of the high-risk generations.

In respect of validation of the method used, the large curvature estimate for ''Malignant neoplasm of cervix uteri'' is in accordance with previous findings [17], where this pattern was found to be associated with the sexual habits of these generations.

The basic methodological difficulty with age–period–cohort modelling is the non-identifiability of a linear effect as either a period or a cohort effect,

but the analysis of the mortality of Danish women has clearly shown the strength of these models when a cohort-connected, non-linear effect is found. The parabola analysis was an effective means of decomposition of this non-linear effect into causes of death. The study indicated that the relatively low life expectancy of Danish women at the end of the twentieth century was explained by a high prevalence of cigarette smoking among Danish women born between the two world wars.

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