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Pace of change in coronary heart disease mortality in Finland, Ireland and the United Kingdom from 1985 to 2006

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Background: Finland, Ireland and the United Kingdom have the highest rates of coronary heart disease (CHD) mortality among EU-15 countries. This study examines the pace of change in CHD mortality in these countries from 1985–2006. **Methods:** The percentage change in 5-year average all age, under 65 and 65 years and over age standardized mortality rates from 1985–89 to 2002–06 was calculated for each country. Joinpoint regression analysis was used to analyse age standardized mortality rates to identify points (years) where the slope of the linear trend changed significantly. The pace of change in the CHD mortality rate was measured using annual percentage change (APC). **Results:** The percentage change in 5-year age standardized (under 65) CHD mortality rates was similar in Finland and the UK for both genders whereas in Ireland the rate of change was greater, especially for females. The percentage change in ≥65 year and all age rates was between 8.2% and 12.4% lower for Finnish males, and between 11.6% and 13% lower for Finnish females compared to their Irish and UK counterparts. There were different turning points in the downward trend in CHD mortality across the three countries varying from 1991–2003. The APC in CHD mortality after the turning point was greatest for Irish males (all age = −7.3%, under 65 = −8.2% and 65 and over = −7.1%), and Irish females (under 65 = −7.2%). **Conclusion:** We have identified differing pace of decline in three countries with similar burden of disease and successful national strategies to control CHD.

Keywords: coronary heart disease mortality, Finland, Ireland, pace of change, United Kingdom.

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Introduction

The downward trend in coronary heart disease (CHD) mortality over the last three decades has been observed in most developed countries.[1,2] For the past 20 years, Finland, Ireland and the UK have been in the top three positions for male and female age standardized (all ages) CHD mortality among all EU-15 countries.

The decline in CHD mortality over recent years reflects the effect of risk factor reductions and increases in medical and surgical interventions which have been reported as the primary factors responsible for the decline.[3,4] However, results from the MONICA study suggest that changes in the classic risk factors only partly explain the variation in population trends in CHD, with 15% in women and 40% in men.[5] The EUROASPIRE I and II surveys did suggest some improvements in uptake of secondary preventative therapies in those with established CHD between 1995/1996 and 1999/2000, but concluded that the adverse lifestyle trends among European CHD patients remained a cause for concern, and that blood pressure and cholesterol targets were still not being achieved.[6]

Although much has been published on trends in CHD mortality for different countries, pace of change in CHD mortality, and comparison between countries has not previously been studied with the exception of a study of old-age mortality trends in seven European countries between 1950

and 1999.[7] Study of the pace of change in CHD mortality provides another approach to analysis of the rate of the downward trend in CHD mortality.

This study examines CHD mortality in Finland, Ireland and the UK from 1985 to 2006 to determine if the pace of change in CHD mortality in the three countries has altered over the 22-year period.

Methods

Direct age standardized (all age, under 65 years and 65 year and over) CHD mortality data (ICD-9 410-414; ICD-10 I20-I25) for Finland, Ireland and the UK were obtained from the WHO-HFA database for each year of the 22-year period from 1985 to 2006.[8]

Five year average age adjusted (all age, under 65 years and 65 year and over) CHD mortality rates for 1985–89 and 2002–06 and percentage change in 5 year average age standardized mortality rates from 1985–89 to 2002–06 were calculated for each country. The 5-year period 1985–89 was chosen as the baseline for calculating the percentage change in CHD mortality between 1985–89 and 2002–06.

All age, under 65 years and 65 years and over age standardized CHD mortality rates from 1985 to 2006 for each country were analysed using joinpoint regression analysis to identify points (years) where the slope of the linear trend changed significantly.[9] The joinpoints (also referred to as turning points) are the calendar years at which the rate of change in CHD mortality changed significantly. Each joinpoint subdivides the time trend into distinct time periods, e.g. if there is one joinpoint, there are two distinct time periods. The analysis begins with the assumption that there are no joinpoints, i.e. the slope of the regression line fitted to the age standardized mortality rates does not change over the time period. It tests for at least one statistically significant joinpoint in the model. The model with the optimum number of joinpoints is selected by iteratively fitting models with no

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Table 1 Five year average all age, under 65 years and 65 years and over CHD mortality rates for 1985–89, 2002–06 and percentage decrease from 1985–89 to 2002–06 for males and females in Finland, Ireland and the UK

Country	5 year average age standardized CHD mortality rates—Male			5 year average age standardized CHD mortality rates—Female		
	1985–89	2002–06	Percentage change 1985–89 to 2002–06	1985–89	2002–06	Percentage change 1985–89 to 2002–06
All ages						
Finland	388.2	214.2	−44.8	167.2	101.6	−39.2
Ireland	374.8	171.5	−54.2	175.1	84.9	−51.5
UK	342.8	161.1	−53.0	157.7	76.5	−51.5
Under 65 years						
Finland	131.3	50.2	−61.8	22.4	8.0	−64.2
Ireland	121.8	42.8	−64.9	32.6	9.1	−71.9
UK	115.4	44.1	−61.8	30.8	11.0	−64.1
65 years and over						
Finland	2466.5	1540.8	−37.5	1339.0	858.8	−35.9
Ireland	2421.6	1213.6	−49.9	1327.7	697.6	−47.5
UK	2182.7	1107.9	−49.2	1184.6	606.0	−48.8

joinpoint up to a maximum of three joinpoints. The objective is to choose the model with the smallest number of joinpoints such that if an extra joinpoint is added the resulting improvement in the fit of the model is not statistically significant. Permutation tests and Bayesian Information Criterion (BIC) methods are used to identify the optimum number of joinpoints in the model. For the permutation tests method, the significance level for each iteration used to determine the optimum number of joinpoints in the model is Bonferroni adjusted in order to maintain an overall type 1 error level of 5%.

The pace of change in the CHD mortality rate was measured using annual percentage change (APC). The APC was computed for each distinct time period by fitting a regression line to the natural log of the age standardized mortality rates (response variable, y) and year (predictor variable, x) for each time period, i.e. $y = mx + c$, where m is the slope, and c is the intercept of the regression line. The APC was then estimated using $100 \times (e^m - 1)$ where e is the inverse of the natural log function. A 95% CI for the APC is also computed. If the 95% CI contains 0, this means that the APC is not significantly different from 0.

Separate joinpoint analyses were performed on all ages, under 65 years and 65 years and over age standardized male and female CHD mortality data for each country. The analysis was performed using software developed by the Surveillance Research Programme of the US National Cancer Institute.[10] Where the joinpoint regression model had more than one joinpoint, a model constrained to have no more than one joinpoint was also fitted to facilitate simpler comparison of APC figures between the three countries. The results based on the BIC method were the same as those based on the permutation tests method with just one exception. Results based on the permutation test method were reported because this method is recommended by the US National Cancer Institute.[10]

Results

The percentage change in age standardized CHD mortality (all age and 65 years and over) from 1985–89 to 2002–06 for males and females was lower in Finland compared to Ireland and the UK, both of which had similar percentage changes. However, the magnitude of the percentage change was greater in all age compared to 65 years and over age standardized mortality

rates across all three countries (3.8–7.3% greater for males and 3.7–4.1% greater for females). The percentage change in under 65 years CHD mortality was ∼3% greater for males and ∼8% greater for females in Ireland compared to Finland and the UK, both of which had similar percentage changes (table 1).

The turning points in male (all ages) CHD mortality occurred in 1993 and 2003 for the UK and in 1998 for Ireland with an increase in pace of change after the turning points whereas there was no turning point in the downward trend in Finland. In females (all ages) the turning points also occurred in 1993 and 2003 for the UK and 1998 for Ireland accompanied by an accelerated pace of change in mortality. In Finland, there were turning points in 1993, 1997 and 2002 for female CHD mortality (figure 1). The turning point was 2002 when the joinpoint regression model was constrained to have a single turning point.

The APC after the turning point in Ireland was between 2.5–2.7 times greater than before for both male and female age standardized (all ages) CHD mortality. In the UK the APC after the first turning point was 1.6 (males) and 2.1 (females) times greater than prior to it and 1.5 times greater after the second turning point than prior to it for both males and females. However, the APC remained the same throughout the 22-year period for males in Finland but for females it was 2.2 times greater after the 2002 turning point compared to the average APC from 1985 to 2002.

The trend in male and female age 65 years and over CHD mortality was very similar to the all age pattern except for males in Finland where there was a turning point in the downward trend in 1993. The magnitude of the change in APC after the turning point was greater for age 65 years and over compared to all age CHD mortality across the three countries for both males and females (table 2, Supplementary figure).

However, the trend in the under 65 years age standardized CHD mortality decline was found to be different for both males and females. Whilst the turning point in Ireland for males under 65 also occurred in 1998, the increase in pace of change afterwards (1.7 times greater than before the turning point) was not as great as that observed for all ages. In the UK no turning point occurred for males and so no change in pace during the period 1985–2006 whereas in Finland there was a turning point in 1997 followed by a slowing in the pace of change afterwards. The pattern for female under 65 years age standardized CHD mortality also differed from that of the all age group. There was a single turning point in the UK (1991)
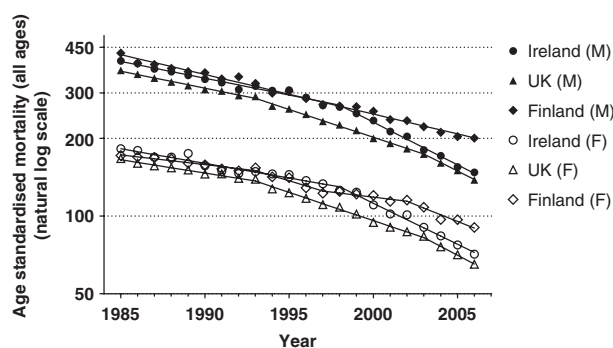
Figure 1 Age standardized (all ages) CHD male (M) and female (F) mortality per 100 000 for Ireland, UK and Finland (1985–2006) with joinpoint regression line overlaid
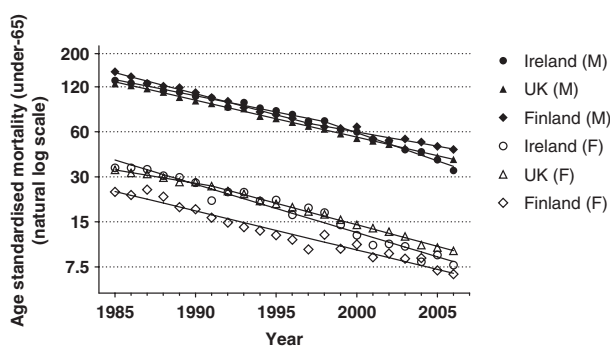

Figure 2 Age standardized (under 65 years) CHD male (M) and female (F) mortality per 100 000 for Ireland, UK and Finland (1985–2006) with joinpoint regression line overlaid

Table 2 APC results from joinpoint regression analysis of all age, under 65 years and 65 years and over age standardized mortality rate data for Finland, Ireland and the UK

Age standardized group	Gender	Country	Time period	APC (95% CI)
All ages	Male	Finland	1985–2006	−3.47 (−3.63 to −3.31)
		Ireland	1985–98	−2.95 (−3.26 to −2.64)
		Ireland	1998–2006	−7.33 (−7.94 to −6.70)
		UK	1985–93	−2.99 (−3.29 to −2.68)
			1993–2003	−4.84 (−5.08 to −4.59)
			2003–06	−7.29 (−8.61 to −5.96)
	Female	Finland	1985–93	−1.74 (−2.39 to −1.08)
			1993–97	−4.47 (−7.34 to −1.51)
			1997–2002	−1.79 (−3.67 to 0.12)[a]
			2002–06	−5.83 (−7.63 to −4.00)
		Ireland	1985–98	−2.58 (−2.99 to −2.16)
			1998–2006	−7.06 (−7.87 to −6.23)
		UK	1985–93	−2.35 (−2.71 to −1.99)
			1993–2003	−4.91 (−5.21 to −4.62)
			2003–06	−7.58 (−9.13 to −6.01)
Under 65 years	Male	Finland	1985–97	−6.28 (−6.79 to −5.77)
			1997–2006	−4.33 (−5.14 to −3.52)
		Ireland	1985–98	−4.85 (−5.41 to −4.29)
			1998–2006	−8.24 (−9.35 to −7.11)
		UK	1985–2006	−5.53 (−5.63 to −5.43)
	Female	Finland	1985–2006	−5.83 (−6.37 to −5.29)
		Ireland	1985–2006	−7.18 (−7.78 to −6.57)
		UK	1985–91	−4.06 (−5.04 to −3.06)
			1991–2006	−6.43 (−6.67 to −6.19)
65 years and over	Male	Finland	1985–93	−1.66 (−2.55 to −0.76)
			1993–2006	−3.32 (−3.74 to −2.9)
		Ireland	1985–98	−2.26 (−2.61 to −1.9)
			1998–2006	−7.10 (−7.80 to −6.39)
		UK	1985–93	−2.08 (−2.46 to −1.69)
			1993–2003	−4.57 (−4.88 to −4.25)
			2003–06	−7.84 (−9.49 to −6.16)
	Female	Finland	1985–93	−1.08 (−1.78 to −0.38)
			1993–97	−4.33 (−7.38 to −1.17)
			1997–2002	−1.70 (−3.70 to 0.34)[a]
			2002–06	−5.69 (−7.61 to −3.73)
		Ireland	1985–99	−2.19 (−2.60 to −1.79)
			1999–2006	−7.42 (−8.51 to −6.32)
		UK	1985–93	−1.88 (−2.29 to −1.46)
			1993–2003	−4.67 (−5.01 to −4.33)
			2003–06	−7.62 (−9.39 to −5.82)

a: APC is not significantly different from 0.

with an acceleration in pace of change after the turn. However, in Ireland and Finland there were no turning point, i.e. no change in pace between 1985 and 2006 (figure 2).

The APC for under 65 years age standardised CHD mortality was 1.7 times greater in Ireland after the turning point for males but there was no significant change in APC for females throughout the 1985–2006 period. There was no alteration in the pace of change for under 65 years age males in the UK whereas the APC for females after the turning point was nearly 1.6 times greater. The APC in Finland after the turning point was 0.7 of that before the turning point for males and the female APC rate remained unchanged throughout the 1985–2006 period.

The APC in the all ages, under 65 years and 65 years and over age standardized CHD mortality rates in Finland, Ireland and the UK were statistically significant for all time periods for males and females except for all ages and 65 years and over female CHD mortality rates in Finland between 1997 and 2002 (table 2).

Discussion

In line with international trends, there have been substantial decreases in CHD mortality in Finland, Ireland and the UK during the period 1985–2006 and while ranking has changed all three still remain in the top three positions among EU-15 countries. The magnitude of improvement in those aged under 65 years and in both genders during this period is similar in Finland and the UK, whereas in Ireland the mortality decline is greater. Within the 65 years and over and all age categories the magnitude of improvement is lower than those aged under 65 years, and noticeably lower for Finnish males and females. Different turning points in the pace of change were seen across all countries but the turning points were the same for males and females (all ages) in Ireland and the UK. Although Finland has a longer history of change from the 1970s, the pace of change has either remained constant or slowed down in Finland with the exception of males and females age 65 years and over and females (all ages).

Why should countries with a similar burden of disease have differing pace of decline in CHD mortality in the latter part of the 1990s? All three countries have targeted the reduction of mortality from heart disease through national strategies. Risk factor reduction as well as improvements in pre-hospital, hospital and primary care[11–14] were the focus of the strategies in Ireland from 1999[15] and in the UK in 1993 and 2000.[16,17] In Finland, the national policy concentrated on risk factor modification in the early 1970s and more recently in 1998.[18,19] Currently their action plan for the years 2005–11 embraces improvements in risk factors and treatments.[11] This difference in the approach in Finland may contribute to the differing pace of decline observed in the late 1990s. Ireland's strategy was launched later than the turning point observed in this work.

Modelling studies to explain the decline in CHD mortality in these countries, have shown that changes in risk factors accounted for a significant proportion of the decline in CHD

mortality in Finland, Ireland, England & Wales and Scotland at 53%, 48%, 58% and 51%, respectively.[20–23] In Finland this was principally due to reductions in mean population cholesterol, accounting for 37% of the decline, which although similar in Ireland (30.2%) was lower in England & Wales (9.5%) and Scotland (6%). The percentage decline due to reduction in smoking prevalence was 8.8% in Finland, 25.6% in Ireland, 48.1% in England & Wales and 36% in Scotland. The contribution of reductions in mean population blood pressure to CHD mortality decline was similar. Improvements in uptake of treatments accounted for 23%, 44%, 42% and 41% of the decline in Finland, Ireland, England & Wales and Scotland, the majority due to increased uptake of secondary preventive therapies accounting for 8.0%, 18%, 11.2% and 8%, respectively. Increased uptake of treatments for heart failure contributed to 1.9%, 9.1%, 12.6% and 8% of the mortality decline in Finland, Ireland, England & Wales and Scotland, respectively, while increased CABG and PTCA procedures accounted for between 4 and 8% of the decline. Although the models were over differing time frames (Finland 1982–97; Ireland 1985–2000; England & Wales 1981–2000; Scotland 1975–94), the results are broadly similar. These studies help to explain the reasons for the decline in mortality in these countries, but not the pace of decline, which would require detailed information on trends decline in the risk factors and in trends of uptake of interventions. While data such as WHO-HFA sources are available comparison in time between risk factor prevalence and treatment across countries is fraught with difficulty due to definitions used, populations studied, as well as quality and completeness of data.

The contribution of economic developments to trends in mortality is not yet unravelled with decline in mortality documented in times of major economic recession as well as growth.[24–29] It is notable, however, that Finland experienced recession in the early 1990s while Ireland underwent a major boom for most of that decade with the UK reporting steady growth throughout.[30,31]

This work addresses time trends over a 20-year period though notably Finland has a longer history of targeting CHD since the early 1970s. Another explanation could be a regression to the mean phenomenon, which may help to explain Ireland's fast pace of change. However, it does not account for the slower pace of change in Finland. Another shortcoming is the small numbers of deaths in females aged under 65 years in Ireland and Finland due to their relatively small populations compared to that of the UK. The impact of several other potential factors is difficult to quantify. These include:(i) effect of deterioration in risk factors such as obesity, diabetes and physical activity; (ii) cohort effects; (iii) time lag between change in prevention and treatment modalities in a population and long-term outcomes, such as mortality; and (iv) the possible role of demographic and migratory shifts in the latter part of the 20th century.

While previous studies have charted the decline and reasons for this decline in CHD mortality in many countries in the latter part of the 20th century, pace of change in decline in CHD mortality has not received the same attention. We used joinpoint regression analysis which has been routinely used to study changes in cancer mortality trends but has only recently been adopted as a technique to study changes in CHD mortality rates.[1,32,33] The advantage of this methodology is that it can model changes in mortality trends over time and identify time-points, i.e. the joinpoints at which such changes occur. This is of benefit at this time with concern that a reversal in the pattern of CHD mortality may happen in the next decade or two. Indeed, this has already been flagged in the UK where the rate of decline in CHD mortality among the 35–44 year age-band in UK has begun to level off and in US where

post-mortem data in 35–54 year olds indicates an increase in atherosclerosis.[33,34]

In conclusion, we have identified differing pace of decline in three countries with similar burden of disease and successful national strategies to control coronary heart disease. There were different turning points in the pace of change in CHD mortality among the three countries ranging from 1991 to 2003. Ireland had the fastest and Finland the slowest pace of change in CHD mortality decline in recent years. We cannot fully explain the differing pattern observed and advocate that further epidemiological research is needed on pace of change at a time of altering risk factor prevalence and increasing pharmacological and interventional treatments yet increasing concern about possible deteriorating CHD mortality.

Supplementary Data

Supplementary data are available at *EURPUB* online.

Conflicts of interest: None declared.

Key points

- The decline in CHD mortality has previously been explained by changes in risk factors and uptake of treatments. Changes in risk factors account for 48–58% of the decrease and increases in uptake of treatments accounts for between 23% and 44% of the reduction in CHD mortality in Finland, Ireland and the UK.
- There were different turning points in the pace of change in CHD mortality in Finland, Ireland and the UK ranging from 1991 to 2003.
- The pace of change in CHD mortality is different in three countries with similar burden of disease and successful national strategies to control CHD.
- The differences in pace of change of CHD mortality have implications for the burden of disease in each country. Although all ages CHD mortality rates in Ireland were similar to those of Finland up to the mid 1990s, they are now lower than in Finland.

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