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Masoud Amiri and Fanny Janssen

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The Decline in Stroke Mortality

Exploration of Future Trends in 7 Western European Countries

Anton E. Kunst, PhD; Masoud Amiri, PhD; Fanny Janssen, PhD

Background and Purpose—This article aims to make projections of future trends in stroke mortality in the Year 2030 based on recent trends in stroke mortality in 7 Western European countries.

Methods—Mortality data were obtained from national cause of death registries. Annual rates of decline in stroke mortality of 1980 to 2005 were determined for men and women in the United Kingdom, France, the Netherlands, and 4 Nordic countries on the basis of regression analysis. Estimated rates of decline were extrapolated until 2030. Cause-elimination life tables were used to determine the effect of stroke in 2030 in terms of potential gain in life expectancy. The absolute numbers of stroke deaths in 2030 were estimated using national population projections of Eurostat.

Results—In all countries, stroke mortality rates declined incessantly until 2005 among both men and women. If these trends were to continue, age-adjusted mortality rates would decline by approximately half between 2005 and 2030 with larger declines in France (approximately two thirds) and smaller declines in the Netherlands, Denmark, and Sweden (approximately one fourth). Similar rates of decline would be observed in terms of potential gain in life expectancy. Because of population aging, the absolute number of stroke deaths would decline slowly in the United Kingdom and France and stabilize or even increase in other countries.

Conclusions—In the near future, stroke may lose much of its effects on life expectancy but remain a frequent cause of death among elderly populations. The prevention of stroke-related disability instead of mortality may become increasingly more important. (*Stroke*. 2011;42:2126-2130.)

Key Words: future ■ mortality ■ projections ■ secular trends ■ stroke

Stroke mortality has strongly declined during the 20th century. Studies from Western Europe^{1,2} and Northern America³ consistently showed that mortality from stroke declined until the most recent years of observation. International reviews showed that this mortality decline is paralleled by declines in both incidence and case-fatality rates.⁴ Whereas declining incidence rates are likely to reflect improvements in lifestyles and environmental exposures in different phases of life, declining case-fatality rates also reflect ongoing progress in secondary prevention and treatment of stroke.

The strong declines in the past raise important questions about the future of stroke mortality. A possible continuation of these declines may or may not imply that the effect of stroke on life expectancy would become marginal. Furthermore, the rapid aging of European populations in the next decades may or may not compensate for this mortality decline. If it were, the absolute number of elderly people dying from stroke would increase rather than decrease in the next decades.

To our knowledge, only a few international studies have presented projections of future trends in stroke mortality.⁵ In

addition, some of these projections were based on stroke mortality trends in the 1980s or early 1990s.⁶ Taking into account more recent trends can, however, change future perspectives. Moreover, to create a stable empirical basis for projections of future trends, it is important to consider stroke mortality trends over a long span of years.⁷ Similarly, the empirical basis for future projections could be expanded by also considering trends in countries with similar levels of socioeconomic development.

The aim of this article is to present projections of future trends in stroke mortality in 7 western European countries until 2030 on the basis of a careful assessment of past trends in these countries.

Materials and Methods

We obtained data for Denmark, Finland, mainland France, the Netherlands, Norway, Sweden, and England and Wales. We selected these countries because they are heterogeneous enough yet have a comparable level of wealth and socioeconomic structure, and their long-term mortality and population data come from data sources that are known to be of good quality.^{8,9}

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From the Department of Public Health (A.E.K.), Academic Medical Centre, University of Amsterdam, Amsterdam, the Netherlands; the Department of Public Health (M.A.), Erasmus Medical Center, Rotterdam, the Netherlands; the Department of Epidemiology and Biostatistics (M.A.), School of Health, Shahrekord University of Medical Sciences, Shahrekord, Iran; and the Population Research Centre (F.J.), Faculty of Spatial Sciences, University of Groningen, Groningen, the Netherlands.

Correspondence to Masoud Amiri, PhD, Department of Public Health, Erasmus Medical Center, Rotterdam, the Netherlands, and the Department of Epidemiology and Biostatistics, School of Health, Shahrekord University of Medical Sciences, Shahrekord, Iran. E-mail masoud.amiri@yahoo.com; or m.amiri@skums.ac.ir

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For each country, we obtained data on the number of deaths from stroke (International Classification of Diseases [ICD] codes 430 to 434 and 436 to 438 for ICD, 8th Revision and ICD, 9th Revision, and I60 to I69 for ICD, 10th Revision) by sex and 5-year age groups for the years 1980 to 2005. In a previous study, national contact persons extracted detailed mortality data files with prespecified formats from national cause of death registries.¹⁰ In more recent analyses, additional data for years after 2000 were obtained from Eurostat (<http://epp.eurostat.ec.europa.eu>) or national sources.¹¹ Corresponding numbers of population at risk were supplied by national contact persons, or derived from Eurostat, on the basis of data from population censuses or population registers. Because the study period included different revisions of the World Health Organization ICD, we adjusted for effects of coding changes using a regression-based method that is reported elsewhere.¹²

To describe trends in stroke mortality between 1980 and 2005, sex-specific age-standardized mortality rates were calculated using direct standardization. As the standard population, we took the total EU25 (the European Union comprising 25 member states) population by 5-year age groups in 2005 as the standard population (<http://epp.eurostat.ec.europa.eu>). In addition, we estimated sex- and country-specific annual mortality changes (percent) over the period 1980 to 2005 by means of log-linear regression analysis. The dependent variable was the number of deaths with the midyear population numbers as the offset variable. The regression model included 5-year age groups (from 0 to 80+ years) as a categorical variable and single calendar year as a continuous variable. Annual mortality changes (percent) were calculated as:

$$100*(exp[b]-1),$$

in which b is the regression coefficient to the calendar year variable.

To project age-specific mortality rates until 2030, we assumed that the mortality trends from 1980 to 2005 would continue for the next 25 years. We therefore applied the estimates of the annual rate of change in mortality in the period 1980 to 2005 to the national age-specific mortality rates in 2005. This projection was made for each sex and county separately. The projection formula was:

$${}_nM_x^{t_0+t} = {}_nM_x^{t_0} \cdot ({}_nc_x^* + 1)^t,$$

where ${}_nM_x$ is mortality rate in the age interval x , $x+n$; t_0 is the baseline year 2005; t is the length of the projection period, with 2006=1 and 2030=25 years; and c^* is the annual rate of mortality change observed over the period 1980 to 2005.

In general, past mortality declines were larger in younger age groups. To take this age effect into account, the factor c^* was estimated for the age groups 40 to 59, 60 to 79, and 80+ years separately.

The absolute number of stroke deaths was projected by applying the projected age-specific mortality rates to the projected age-specific numbers of men and women residing in the different countries up to 2030. The latter numbers were obtained from Eurostat taking the baseline population projection. For Norway, data were obtained from Statistics Norway, taking the medium national growth variant (<http://statbank.ssb.no/statistikbanken>).

We expressed the impact of stroke mortality on life expectancy in 2005 and 2030 by means of the potential gain in life expectancy measure. This measure measures the extent to which life expectancy were to increase in case of the hypothetical elimination of stroke. For 2005, we prepared cause-elimination life tables using all-cause mortality rates and stroke mortality rates observed for 2005. For 2030, we used our own projections of stroke mortality, whereas we also projected all-cause mortality rates for 2030 using the same methodology as used for stroke mortality.

For Denmark, stroke mortality data were available until 2001 instead of 2005. Therefore, Year 2001 was used as the end year for the analysis of past trends in stroke mortality and the baseline year for future projections of stroke mortality. All-cause mortality rates for Denmark for 2002 to 2005 were, however, available from the Human Mortality Database (www.mortality.org).

Results

Figure 1 shows changes in stroke mortality rates in 7 western European countries according to year of death from 1980 to

2005. In all 7 European countries, stroke mortality rates declined among both men and women. In the United Kingdom, Norway, and Finland, stroke mortality rates declined by almost 3% per year. Stronger declines were observed in France (>4% per year). Declines were smallest in Denmark and Sweden (approximately 1% to 1.5% per year) and the Netherlands (approximately 2%). The declines persisted until 2005. Although each country shows irregularities in the pace of decline, there is no consistent evidence for a deceleration of the mortality decline in recent years.

The Table presents the projected age-standardized mortality rates for men and women in the 7 countries in 2030. In all countries, age-adjusted mortality rates would have substantially declined in 2030 compared with 2005 if past trends were to continue. Age-adjusted mortality rates would decline by approximately half between 2005 and 2030. Larger declines would occur in France with the rate ratio of 0.33 for men indicating a two thirds decline. Smaller declines, of approximately one fourth, would occur in the Netherlands, Denmark, and Sweden. In each country, mortality declines are projected to larger among men than among women.

In terms of potential gain in life expectancy, the importance of stroke mortality would also decline to an important extent. When averaged across all countries, the potential gain in life expectancy for men declines from 0.87 years in 2005 to 0.48 years in 2030. For women, the potential gain in life expectancy declines from 1.35 to 0.81 years. Thus, in 2030, the hypothetical elimination of stroke mortality would increase life expectancy at birth by approximately 0.5 years for men and 0.8 years for women. This effect is about equally large in most countries in 2030. The potential gain in life expectancy approaches 1 year only for Swedish and Danish women. Estimates less than 0.50 years are projected for France.

Figure 2 shows the projected absolute number of stroke deaths from 2005 until 2030. This number is projected to decline in the United Kingdom and in France in the first 15 or 20 years. In both countries, this decline would, however, stagnate and even reverse after 2020, when the postwar baby boom cohort will enter old age (≥ 70 years). In the Netherlands, Sweden, and Denmark, increases in the absolute number of stroke deaths are projected to occur over the entire period, but especially after 2020. Relative stable numbers of deaths are projected for Norway and Finland.

Discussion

We observed a strong decline in stroke mortality in the past decades, both among men and women, in each of the 7 countries studied. If these trends were to continue in the future, stroke mortality rates in 2030 would be substantially lower than they were in 2005. Similarly, strong declines would be observed in the effect of stroke on life expectancy. In 2030, this effect would be less than 1 year in nearly all female populations and approximately 0.5 year in most male populations.

Despite this decline in stroke mortality risk, the absolute number of deaths from stroke will not substantially decline and even increase at the shorter and longer term. This increase is due to the aging of the national populations, especially after Year 2020, when the baby boom generations will reach old age. However, although its effect on life

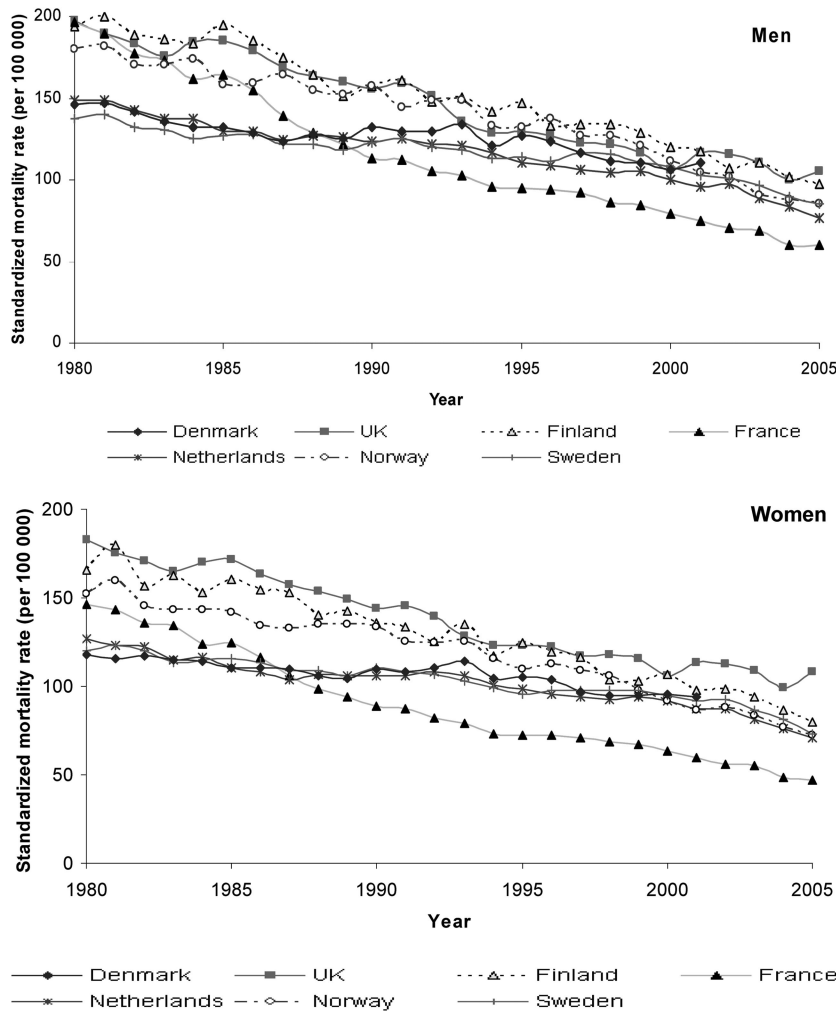


Figure 1. Trend between 1980 and 2005 stroke mortality rates (rates per 100,000 person-years, standardized using the European Union comprising 25 member states [EU25] population by 5 years as the standard population). Men and women in 7 European countries.

expectancy would decline, stroke would remain a common cause of death in western Europe's aging populations.

A potential data problem relates to the coding of underlying causes of death in national published statistics. Problems related to changes in subsequent revisions of the ICD have been evaluated by our team and taken into account where necessary.^{10,12} Changes over time in certification practices by physicians are another area of concern, although they are unlikely to explain the observed decline in stroke mortality.¹³ Moreover, similar rates of mortality decline have been observed in epidemiological studies with standardized ascertainment of stroke cases within registration areas.¹⁴

Our results for 7 western European countries cannot be generalized to other regions of the world. Recent trends in stroke mortality in eastern European countries strongly differed from those in the West,¹⁵ implying that the East might differ also with regard to future trends in stroke mortality. Similarly, trends in stroke incidence and case-fatality in low-income countries were found to notably differ from the trends in high-income countries.⁴ On the other hand, in the United States, stroke mortality has declined over recent decades with approximately 0.3% to 2.9% per year,¹⁶ suggesting similar rates of decline as in western Europe.¹¹⁻¹³

Acknowledged demographers, Wilmoth⁷ and Oepen and Vaupel,¹⁷ argue that future trends in mortality can best depart

from extrapolations of past trends in mortality as observed over a longer period. We therefore based our projections on the declines in stroke mortality as observed in the 7 European countries over a 25-year period. The precise rate of mortality decline varied between countries as it did between subsequent decades. This variability warns us that it is difficult to accurately predict future mortality trends for specific countries during specific decades. We therefore concentrated on longer-term projections and similarities in these projections across the 7 countries, which essentially reflect the substantial and persistent decline in stroke mortality found in all countries in the past 25 years.

The strong decline in stroke mortality in past decades is likely to be attributable to declines in both case-fatality rates and in incidence rates. There is consistent evidence from a large number of epidemiological studies for a steady improvement in survival rates of patients with stroke. For example, an analysis of the complete data of the Monitoring Trends and Determinants in Cardiovascular Disease (MONICA) study concluded that the stroke mortality decline was attributable for approximately two thirds to declining case-fatality rates.¹⁸ However, because this study was limited to individuals 35 to 64 years of age, it is uncertain whether this high estimate is representative for the older ages in which most stroke deaths occur.

Table. Age-Standardized Stroke Mortality Rates and Potential Gain in Life Expectancy (PGL E) Observed in 2005 and Projected for 2030: Men and Women in 7 European Countries

Sex Index	Year*	Country						
		Denmark	United Kingdom	Finland	France	Netherlands	Norway	Sweden
Men								
Mortality rate†	2005	102.76	105.12	97.54	59.59	76.16	85.05	85.38
Per 100 000	2030	76.00	51.42	50.51	20.35	50.10	47.47	65.16
	2030/2005	0.74	0.49	0.52	0.34	0.66	0.56	0.76
PGL E, y	2005	0.87	1.10	0.98	0.70	0.69	0.84	0.88
	2030	0.63	0.51	0.48	0.23	0.43	0.45	0.65
	2030/2005	0.72	0.46	0.49	0.32	0.63	0.53	0.74
Women								
Mortality rate†	2005	90.21	107.97	79.84	47.30	70.69	72.26	72.85
Per 100 000	2030	70.12	57.71	44.12	17.74	51.03	41.14	58.94
	2030/2005	0.78	0.53	0.55	0.37	0.72	0.57	0.81
PGL E, y	2005	1.27	1.69	1.56	1.10	1.16	1.35	1.30
	2030	0.97	0.85	0.83	0.41	0.82	0.74	1.04
	2030/2005	0.76	0.50	0.53	0.37	0.71	0.55	0.80

PGL E indicates potential gain in life expectancy; EU25, the European Union comprising 25 member states.

*2030/2005=value for 2030 as ratio to value for 2005.

†Rates per 100 000 person-years standardized using the EU25 population by 5 y as standard population.

With regard to stroke incidence, the evidence is less consistent, because several studies reported no decrease,¹⁹ whereas others did report a decline in incidence rates.²⁰ However, a systematic review of all available evidence concluded that stroke incidence substantially declined between the 1970s and the 2000s in high-income countries.²¹ Moreover, variations in stroke mortality trends between high-income and low-income countries, and between eastern

and western Europe, are paralleled by similar variations in trends in the incidence of stroke.⁴ Further support comes from the finding that key risk factors for stroke incidence (eg, smoking, hypertension, and raised serum cholesterol) could explain at least half of the secular decline in stroke mortality in some countries.^{22,23}

Future reductions in stroke mortality are likely to be contingent on declines in both incidence rates. Further de-

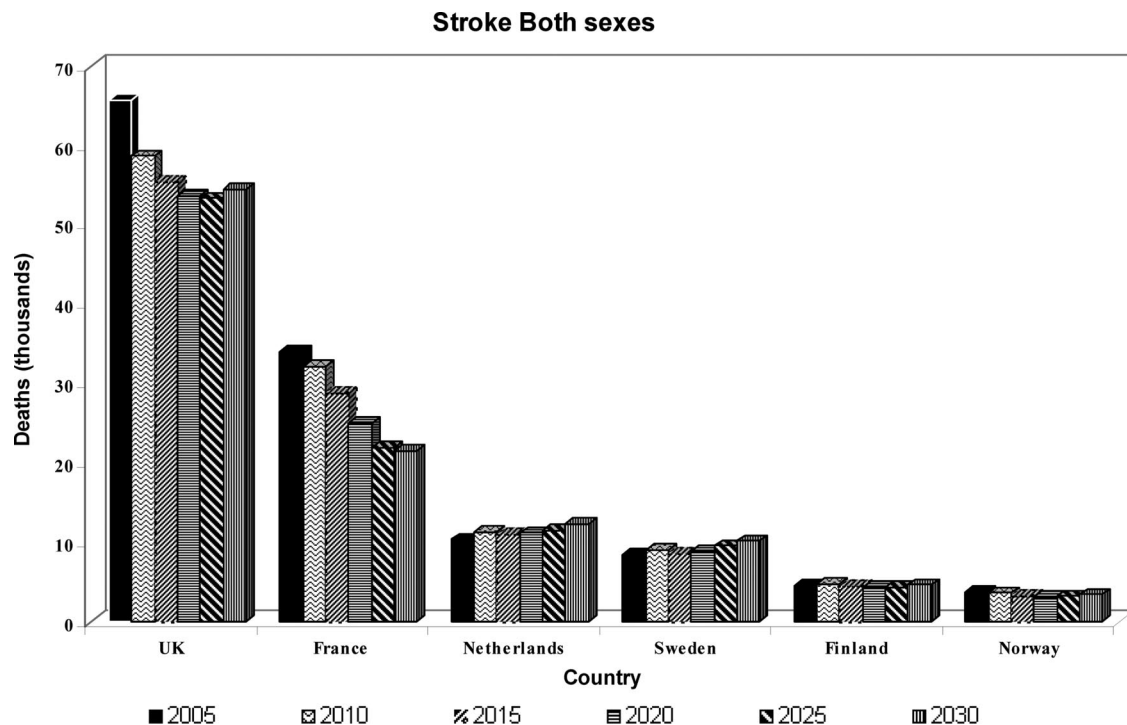


Figure 2. Projected trends between 2005 and 2030 in the absolute number of stroke deaths (men and women combined) in 7 European countries.

clines may follow reductions in the prevalence of risk factors such as smoking, hypertension, and cholesterol. New vigorous tobacco control policies in western Europe since the 1990s are likely to decrease tobacco exposure rates of generations that will reach old age in the mid-21st century.²⁴ Moreover, improvement in environmental and socioeconomic determinants such as the rising educational levels of generations born in the 20th century may contribute to continued declines in stroke incidence in the 21st century.²⁵ Further evidence to expect such a continued decline comes from a cohort analysis that we performed of the same mortality data and from which we concluded that the mortality declines persisted until the youngest generations, possibly due to improved environmental conditions in early life.¹¹

Conclusions

If the rate of decline in stroke mortality in the past 25 years were to continue for the next 25 years, stroke would lose much of its effects on life expectancy, because it would only modestly affect the life expectancy of men and women in western Europe in 2030. A continued decline in stroke mortality rates would, however, not be paralleled by a similar decline in the number of people dying from stroke. Due to aging of the population, the absolute number of stroke deaths would remain at approximately the same level. Moreover, the average age of death of patients with stroke will unavoidably increase. Thus, the absolute number of elderly patients in need of intensive or terminal treatment is unlikely to diminish in the next decades.

To the extent that declines in mortality are achieved by improved survival, instead of decreased incidence, the future number of patients with stroke would increase at a larger rate than the number of stroke deaths.¹⁸ This would imply that the future burden of stroke will gradually shift from a (more or less constant) mortality burden toward a (rising) morbidity burden. To respond to this shift, more emphasis must be given not only to enhance preventive strategies, especially for the elderly people. In addition, improved rehabilitation methods are needed to reduce disability and comorbidity among elderly patients with stroke.

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Disclosures

None.

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