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Briefing 53

Causes of Death: A Study of a Century of Change in England and Wales

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CONTENTS

Summary

Life expectancy has increased over the last century in all high-income countries, including England and Wales. Partly as a consequence of that, the age structure of the population of these countries has changed. A greater proportion of the population was elderly in 2007 than in 1971 and in 1971 than in 1901. Thomas McKeown famously analysed the decline in mortality rates in England and Wales from the mid-19th century to 1971, and put the major part of it down to a reduction in infectious diseases (McKeown, 1979). The decline in infections was largely the result, he suggested, of improvements in nutrition, improvements in the safety of water and better sanitation, as well as changes in personal behaviour.

We have extended McKeown's analysis up to 2007 and have found that the story looks very different for the period 1971-2007. In the last four decades, approximately one fifth of the fall in age-standardised mortality rates in England and Wales is attributable to reductions in infectious diseases, and four fifths to non-infectious diseases. With regard to the individual disease groups, almost half of the fall in mortality rates between 1971 and 2007 was due to a fall in age-standardised mortality rates from cardiovascular disease.

We also present evidence to suggest that a different picture may be observed when examining the extent of illness in the population, not just death rates. For example, although mortality rates from cardiovascular disease have declined in recent years, incidence rates have increased.

Introduction

Compared with a hundred years ago, the population of the UK, as in all other high-income countries, can look forward to enjoying much longer lives. Not only are we living longer, the causes of our eventual deaths have changed. Infectious diseases are no longer rampant, but cardiovascular disease and cancers are far more commonly the cause of death.

Health care is one of the factors that influences the health of a population over the long term. Other developments, principally improved hygiene and general standards of living, have had a large impact in the past. The purpose of this *Briefing* is to extend the time frame explored in the work of McKeown (1976 and 1979) and to update that of Sussex and Yuen (2000), who looked at the reductions in mortality rates in England and Wales between 1901 and 1971 and from 1971 to 1997, respectively. This *Briefing* adds another decade and explores whether long term changes in the causes of death remain apparent in certain disease groups. The methods used here are the same as those used by McKeown and by Sussex and Yuen to allow for comparisons with those earlier findings.

McKeown considered changes in mortality rates over long time periods in England and Wales for different major diseases and used this as a basis for identifying underlying factors that had contributed to reduced rates of mortality. We appreciate that there are issues

with McKeown's approach and, consequently, ours. Ours is not an in-depth econometric analysis of statistical relationships between measures of mortality rates and possible explanatory factors. It is instead a more epidemiological and historical approach, looking at patterns in long term changes in the causes of mortality. Additional analysis looking for specific evidence of the magnitude of the impact of particular individual interventions, such as the introduction of antibiotics, is beyond the scope of this *Briefing*.

Thomas McKeown (1912-1988) was an eminent social physician, medical historian and epidemiologist. His work included two highly cited books: *The Modern Rise of Population* (McKeown, 1976) and *The Role of Medicine* (McKeown, 1979). It is in these publications that his arguments regarding the causes of long term population health improvements are summarised.

Focusing on death rates in England and Wales, McKeown attributed the majority of the decline in mortality rates from the mid-19th century to 1971 to a reduction in infectious diseases (McKeown, 1979). This decline in infections was largely the result, he suggested, of improvements in nutrition, improvements in the safety of water and better sanitation, as well as changes in personal behaviour. He believed that the contribution of personal medical measures over the same time period was relatively minor.

By adding the information that has become available since the early 1970s to McKeown's data, we are able to look at the extent to which changes in different disease groups have affected overall mortality rates since 1971 and to compare the changes in the causes of mortality over the last century to those at the start of this century.

Methods and Data Used

In order to produce data that extend the work undertaken by McKeown in the 1970s and allow for comparison, we used the data found in McKeown's 1979 *The Role of Medicine*. Figures relating to 1838 and 1901 are taken directly from this publication. The calculations by Sussex and Yuen (2000) also have been taken into account. It is important to note that amendments to the 2001 Census by the UK Office for National Statistics (ONS) have necessitated some re-estimation of earlier population data. As a result, some of the calculations for 1997 by Sussex and Yuen (2000) have been revised. This has resulted in slight differences from some of the Sussex and Yuen figures, but not enough to have any significant effect on their findings.

In order to extend the life expectancy calculations up to 2007 (the latest complete data available), as shown in Figure 2, data from the United Nations' *World Population Prospects* (UN, 2009) were utilised.

We age-standardised the mortality figures to the 1901 population structure, for males and females combined, by applying the ONS population data for 2007 for population estimates and projections and population data for 1901 using the method of direct standardisation (ONS, 2011). Age standardisation allows for changes in mortality rates to be explored after adjusting for changes that have occurred in population age structure over the years considered in this *Briefing*. It also allows for comparison with McKeown's work and the subsequent updates by Sussex and Yuen. Trends in age-standardised mortality rates for males and females in England and Wales, shown in Figure 3, were extended to 2007 using ONS data for deaths by age group (ONS, 2008a).

In 1901 the population of England and Wales contained a much higher proportion of children and a much lower proportion of people aged over 65 than it did in 1971 and today. Thus, standardisation is needed for a comparison with McKeown's work. In the present context, there are three ways to perform such standardisation. One is to standardise mortality rates to the 1901 population structure. This gives prominence to factors affecting mortality among children, and less weight to factors affecting mortality among people aged 65 and over. The second alternative is to use the 1971 population age structure to be compatible with Sussex and Yuen (2000). This would change the weighting of influencing factors in favour of those that contributed to the recent decline of mortality in higher age groups. Finally, one could standardise according to the current population, shifting the weights even more towards the most recent innovations (Ahmad, 2001). This third alternative will not be pursued since the emphasis of this *Briefing* is on the comparison with Sussex and Yuen (2000). Still, it is worth checking whether the choice of standardisation affects the conclusions. The age-standardised mortality rates in the main text are based on the 1901 population structure of England and Wales; the 1971-based results are presented in Appendix C. A comparison of the two population structures is provided in Figure 1, below. The change in the age structure of the population of England and Wales can be related, in turn, to declining mortality rates; indeed deaths now are concentrated among the oldest age group (see Figure 4).

Our calculations of deaths by age group per 1,000 conceptions for 1997 and 2007 are based on data from the Office for National Statistics (ONS, 2009; ONS, 2007b; ONS, 1997 and ONS, 2008a). Within McKeown's work, the "prenatal" deaths for 1901 were reported to relate to estimates of miscarriages plus terminations of pregnancy, both legal and illegal. But for 2007 it was not possible to locate estimates of numbers of illegal abortions. We have assumed for the purposes of our calculations underlying Figure 4 that no illegal abortions were performed for women in England and Wales in 2007. As the numbers of illegal abortions may be expected to be low (given the availability of legal terminations), compared to

mortality within both the prenatal group and other age groups, the lack of information on illegal abortions should have negligible impact on the figures for 2007.

The rate of deaths per 1,000 conceptions presented within Figure 4 is the result of births and deaths not just in the study year but over a period of time. The denominator, the number of conceptions, depends on the number of women of childbearing age in the population (among other factors) and the numerator, for example, the number of deaths at age 65 and over, is dependent on the number who have survived to at least age 65.

To calculate the age-standardised deaths by disease category, we obtained the number of deaths within specific disease groups. The 2007 data were taken from the ONS (2008) and the disease groups were matched as closely as possible to the coding of diseases found in Sussex and Yuen. The resulting 2007 figures for death rates by disease group per 1,000 population were then standardised to the 1901 population structure of England and Wales as used in the Sussex and Yuen (2000) calculations. In Appendix C, we present death rates by disease group per 1,000 population when standardised to the 1971 population structure of England and Wales.

The contribution to the fall in mortality rates was then calculated by considering changes in the age-standardised rate of mortality (ASR) between, for example, 1971 and 1997, relative to the overall fall in ASR between the two time points. This mimics the methods used by McKeown and by Sussex and Yuen. Table A1 in Appendix A reports the key figures underlying our calculations.

A number of practical difficulties arise when comparing mortality data over a long period of time, including changes in coding and definitions as well as recognition of new diseases. Between 1997 and 2007, the International Classification of Diseases (ICD) has been revised, which has resulted in complexities in matching codes between ICD-9 and ICD-10 classifications (Janssen, 2004). Every effort has been taken to match as closely as possible disease groups from ICD-9 with those in ICD-10. It is unlikely that any coding changes would affect the overall picture of broad groups (e.g. "external causes", "cancer"). This is because new codings typically occur *within* a broad disease category and our analysis is at the broad category level.

However, statistics for some specific sub-categories of causes of death should be interpreted with caution, most notably "violence". Comparable figures for deaths from violence across time have been difficult to calculate. In addition, the figures for 2007 relate to external causes that include violence as well as other causes, e.g. falls and accidents. Consequently, these figures may not be comparable across time.

Known issues also exist for the coding of pneumonia (Anderson et al., 2001). In ICD-10, the wording of the rules for identifying which cause should take precedence as the underlying cause of death (UCD) is similar to ICD-9, but there are more explanatory notes for ICD-10 that served to widen its scope, particularly for pneumonia and bronchopneumonia (Lung and Asthma Information Agency, 2008; CeLSIUS, 2012). Pneumonia increasingly is considered to be a consequence of a much wider range of conditions. As a result, pneumonia is much less likely to be selected as the underlying cause of death in ICD-10 than in ICD-9 (Brock et al., 2006). Consequently, if a decrease in deaths due to pneumonia – or, more broadly, respiratory diseases – is observed between 1997 and 2007, then it may be an artefact of changes in coding rather than a real change in mortality rates by condition.

We therefore performed further calculations to assess the impact of the choice of standard population on the results. We present the results of using the 1971 age structure in Appendix C in order to answer the question, "Does using the 1971 population structure as a base for 1997 and 2007 calculations lead us to different conclusions from using the 1901 population structure?" The difference in population age structure in England and Wales between 1901 and 1971 is shown in Figure 1. In 1971, the proportion of the population in age groups 45-54 and 55-64 is markedly higher than observed in 1901; the age group 65 and over is a substantially higher proportion. For example in 1901, 3% of the population was aged 65-74, compared to 9% in 1971.

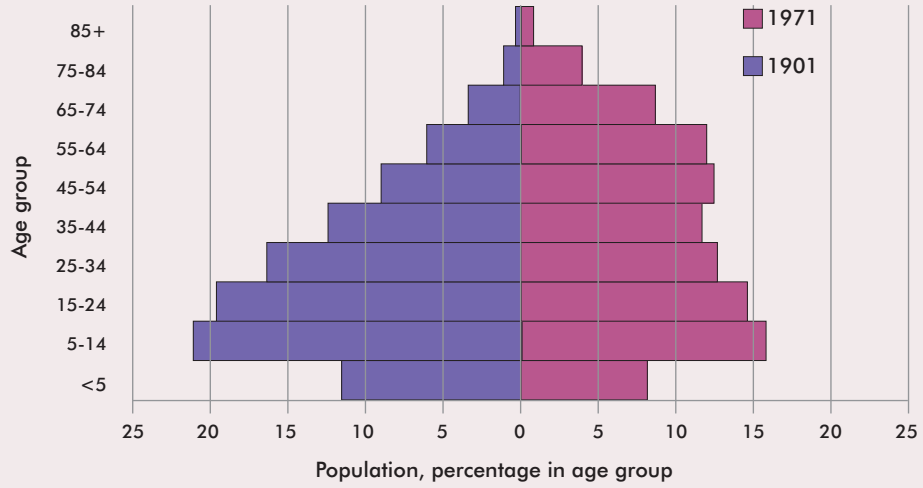
Trends in Overall Mortality

During the 20th century, major improvements in life expectancy were experienced in all industrialised countries. Shortly before the First World War, life expectancy at birth stood at around 50 years (see Figure 2). In 2007, this had increased to around 80 years. Figure 2 shows the similarities in a few selected European countries, with a dramatic increase over the century in the average length of life.

The results described below are standardised to the 1901 population structure in England and Wales, as originally used by McKeown, to enable us to update his seminal analysis. Figure 3 shows that when using the 1901 population structure for standardisation, the falling trend in mortality rates in England and Wales has continued since 1971, but at a slower rate. Similar calculations, but based on the 1971 population structure, demonstrate a similarly dramatic fall in mortality rates between the early 1900s and 2007 (see Figure C1 in Appendix C).

However, there is no suggestion of a slowdown in standardised mortality rates among the males, in Figure C1, as observed in Figure 3, while the slowdown among females (observed around 1950) appears to be less marked than in Figure 3. Much of the improvement in the first half of the 20th century is due to declining childhood mortality rates, which have continued to decline in recent

Figure 1. Comparison of population structure in England and Wales 1901 and 1971



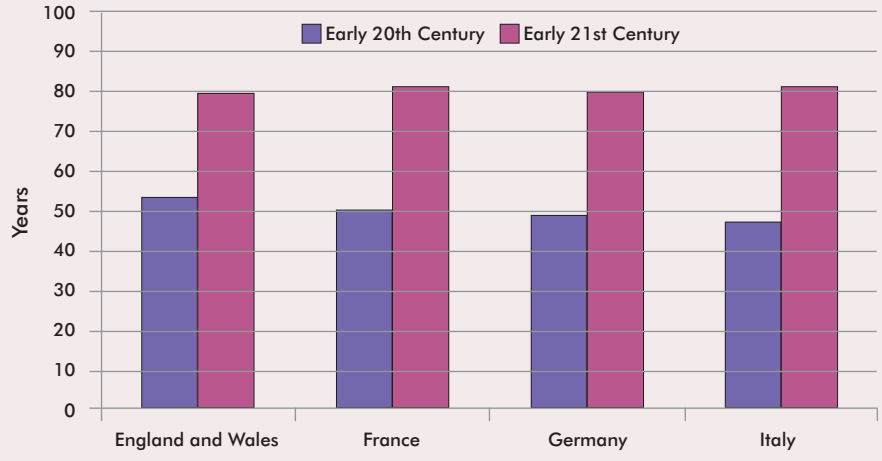
Sources: Sussex and Yuen (2000); ONS (2007a)

decades albeit to a lesser extent. In recent decades, mortality has declined considerably in the elderly. The data underlying Figure 3 indicate the continuing fall in childhood death rates since 1971, although at a slower rate. Basing the data to 1971 rather than 1901 lessens the impact of improvements in mortality rates in childhood observed in the first half of the 20th century, while placing more weight on improvements in mortality rates in recent decades in the elderly.

McKeown (1979) presented his data as deaths per 1,000 conceptions so as to take account of miscarriages and terminations of pregnancies. The first two bars in each of the five age groups in Figure 4 reproduce McKeown's chart. The third bar in each group updates the Sussex and Yuen (2000) calculations for 1997, using updated population data, and the final bar shows our own calculations for 2007. Over the last 170 years, a large fall in mortality rates has occurred, for children especially, but also for people of working age, particularly for those aged under 45 years. People in the age group 45-65 years now have a greater life expectancy than in the past. For example, men aged 45 years in 1971 could expect to live another 27.5 years, but by 2007 men aged 45 in that year could expect to live another 34.6 years. Death is only deferred, of course, which inevitably means that mortality rates in the oldest age groups have risen substantially over time.

As noted in the methods section, we encountered some issues in ensuring a consistent data series for prenatal deaths due to differences in the availability of abortion statistics. That said, age-standardised rates of legal abortions in England and Wales have reportedly increased

Figure 2. Life expectancy at birth for selected European countries, early 20th and early 21st centuries



Notes: England and Wales data for the early 20th century are for 1910-11; France 1908-13; German Empire 1910-11; Italy 1910-12. All these data are taken from Vallin (see Sussex and Yuen, 2000). The borders of Germany and Italy in 1995 differ from those in the early 20th century. The data for the early 21st Century are taken from the UN's *World Population Prospects* (United Nations, 2009) and relate to 2005-2010.
Sources: Sussex and Yuen (2000); United Nations (2009)

between 1970 and 2007 (DH, 2009), as reflected in the increasing prenatal deaths between 1971 and 2007 shown in Figure 4.

The result is a very different population age structure in England and Wales at the beginning of the 21st century compared to that at the beginning of the 20th. In 1901, 32% of the population of England and Wales were aged under 15, compared with 19% today. Conversely, fewer than 5% of the population were aged 65 or over in 1901, compared with 16% in 2007. The proportion of the population in the middle age group has changed little in aggregate over the last 100 years, although it has become older on average (see Appendix B).

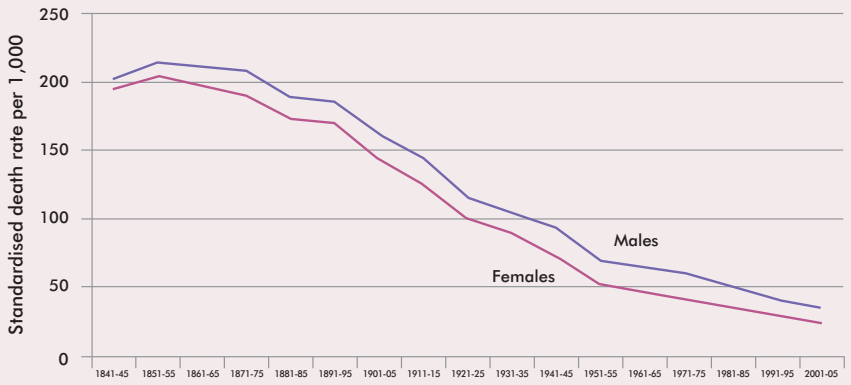
Disease-Specific Mortality

An individual is subject to the risk of death from different causes; the occurrence of one of these will prevent the other from taking place (Crowder, 2001). For the contributions of different groups of diseases to the long-term fall in mortality rates, we follow on from the work of Sussex and Yuen (2000), who explored the reductions in disease-specific mortality rates from 1971 to 1997. We have extended the estimates to 2007. As described in the methods, this *Briefing* considers changes in age-standardised mortality over time.

As can be seen from Table 1, over the period from 1901 to 1971, McKeown's figures show infectious diseases accounting for two thirds of the fall in the standardised death rate in England and Wales. During the later years, 1971-2007, the story looks very different: between 1971 and 1997 approximately one fifth (21%) of the reduction was due to infectious conditions, with a very similar proportion (19%) for 1997-2007.

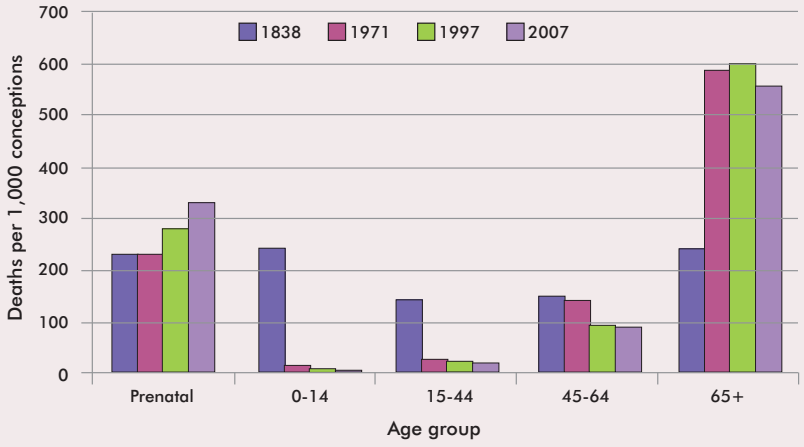
The story after 1971 remains the same when the calculations are based on the 1971 population structure – compare Table C1 in Appendix C with Table 1 below – i.e. fewer deaths from infections, and primarily from airborne

Figure 3. Trends in standardised male and female death rates in England and Wales, per 1,000 (1901 population basis), 1841-2005



Note: Age adjustment to the death rates is by the direct standardisation method: the 1901 age structure of the population of England and Wales has been combined with the age-specific death rates in each period. This separates the decline in mortality from the changes in population structure from the mid-19th century to the start of the 21st century.
Sources: ONS (1997, 2008a)

Figure 4. Deaths per 1,000 conceptions, by age group, England and Wales, 1838-2007



Sources: Data for 1838-54 and 1971 are taken from McKeown, 1979. Figures for 1997 are based on ONS (1997); figures for 2007 are based on ONS (2008a)

diseases, with the drop in deaths from all infections accounting for 21% of the fall in the overall mortality rate from 1971-2007.

Considering the 1971-based calculations presented in Table C1, airborne diseases appear to account for a greater proportion of the fall in overall mortality rates between 1997 and 2007 compared to the period 1971 to 1997, 30% and 17%, respectively. However, the move from ICD-9 to ICD-10 resulted in fewer deaths being attributed to respiratory diseases, particularly for the older age groups (Brock et al., 2006), which receive greater weighting in Table C1. Therefore, as a result of coding changes, the fall in overall mortality rate attributed to airborne diseases between 1997 and 2007 should be interpreted with caution.

For all time periods considered in this analysis, airborne infections have been the largest contributor to the fall in mortality rate from infectious diseases. In contrast, while water- and food-borne diseases contributed to around one sixth of the fall in mortality rates between 1901 and 1971, mortality rates within this disease group increased between 1997 and 2007 (i.e. a negative contribution to the fall in the overall mortality rate). This was due partly to an increase in the number of fatal cases of *clostridium difficile* over this period.

McKeown also calculated mortality rates for a more disaggregated set of disease groupings for airborne diseases for 1901 and 1971. Sussex and Yuen extended these calculations by looking at the period from 1971 to 1997. We have extended the analysis to 2007, replicating the earlier calculations as closely as possible. Table 2 identifies the contribution of different types of airborne diseases.

Over the 1901-1971 period, declining numbers of deaths from bronchitis, pneumonia and influenza represented half of the improvement due to airborne infections. Respiratory tuberculosis accounted for much of the remaining decline. Extending the analysis from 1971 to 2007, death rates from all types of airborne infections have continued to decline. But the only significant impact on overall mortality rate is from the decline in deaths from bronchitis, pneumonia and influenza. Reduced deaths from these causes effectively explain all of the reduced deaths from infectious diseases in total in the 1971-2007 period. Deaths from airborne infections other than respiratory tuberculosis, bronchitis, pneumonia and influenza were already relatively few by 1971 and have remained so. The same 1971-2007 picture is true when standardising to the 1971 population structure – see Table C2 in Appendix C – demonstrating that this is not an artefact of the base population selected.

It is interesting that 3%, 2% and 4% of the reduction in mortality rate between 1901 and 1971 was due to whooping cough, measles and scarlet fever, respectively, but none of the decline in the mortality rate after this period. This is because by 1971 the mortality rate from these diseases already was extremely low.

Tables 3 and 4 demonstrate that declines in the mortality rate from water-borne, food-borne and other infections all occurred in the period 1901-1971, as recorded by McKeown. After 1971, these infections did not contribute further to the overall fall in the mortality rate as deaths from those causes already were relatively few. However, as Table 3 shows, in the decade from 1997-2007, deaths from cholera, diarrhoea and dysentery have increased. One specific infectious intestinal disease, cholera, decreased over the period 1901 to 1971; no deaths were recorded for cholera in 2007. Considering the specific subgroups of diseases within the category of intestinal infectious diseases, the increase in the mortality rate between 1997 and 2007 that is evident in Table 3 has been the result of increases in the number of deaths from *clostridium difficile*. (Tables C3 and C4 show a story similar to those in Tables 3 and 4; using the 1971 population structure rather than the 1901 population structure to calculate the standardised mortality rates does not change them significantly.)

Table 5 shows the impact on the total decline in standardised mortality rates that has been achieved for non-infectious causes of death. These causes accounted for one third of the fall in the mortality rate over the period 1901-1971 and four fifths of the fall after 1971. As the contribution to declining mortality rates from infectious diseases has decreased (as in Table 1), and ultimately all individuals will die from a cause, the share from non-infectious diseases will increase.

Table 1. Share of total fall in standardised mortality rate* in each period attributable to each disease group, England and Wales

	1901-1971	1971-1997	1971-2007	1997-2007
Attributable to micro-organisms				
1. Airborne	39%	20%	20%	21%
2. Water- and food-borne diseases	16%	2%	0%	-2%
3. Other infections	12%	-1%	0%	0%
Total infections	**67%**	**21%**	**20%**	**19%**
Not attributable to micro-organisms	33%	79%	80%	81%

*Age-standardised mortality rate based on 1901 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table 2. Airborne infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1901-1971	1971-1997	1971-2007	1997-2007
Tuberculosis (respiratory)	11%	1%	1%	0%
Bronchitis, pneumonia, influenza	19%	19%	20%	21%
Whooping cough	3%	0%	0%	0%
Measles	2%	0%	0%	0%
Scarlet fever, diphtheria	4%	0%	0%	0%
Smallpox	0%	0%	0%	0%
Infections of ear, pharynx, larynx	1%	0%	0%	0%
Total	**39%**	**20%**	**20%**	**21%**

*Age-standardised mortality rate based on 1901 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table 3. Water- and food-borne infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1901-1971	1971-1997	1971-2007	1997-2007
Cholera, diarrhoea, dysentery	10%	2%	0%	-2%
Tuberculosis (non-respiratory)	4%	0%	0%	0%
Typhoid, typhus	1%	0%	0%	0%
Total	**15%**	**2%**	**0%**	**-2%**

*Age-standardised mortality rate based on 1901 population structure
** In 1997 and 2007 figures relate to intestinal infectious diseases, which include cholera and dysentery. For 1901 and 1971, this group comprised deaths recorded as cholera, diarrhoea and dysentery.
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table 4. Other infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1901-1971	1971-1997	1971-2007	1997-2007
Convulsions, teething	6%	0%	0%	0%
Syphilis	1%	0%	0%	0%
Appendicitis, peritonitis	1%	0%	0%	0%
Puerperal fever	1%	0%	0%	0%
Other infections	4%	-1%	-1%	0%
Total	**12%**	**-1%**	**0%**	**0%**

*Age-standardised mortality rate based on 1901 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

The heading "non-infectious" covers a wide range of disease areas. Looking at the main groups of diseases under that heading, one very striking feature is the large fall in the mortality rate from cardiovascular disease that has only occurred since 1971, and hence after McKeown was writing. This accounted for nearly half (45%) of the total (infectious plus non-infectious) fall in the standardised mortality rate in England and Wales between 1971 and 2007. Although this *Briefing* does not specifically explore the direct role of health care, one explanation for the recent drop in the mortality rate due to cardiovascular disease is the impact of medical innovation (Amiri et al., 2011).

Reductions in rates of mortality from cancer and cerebrovascular disease also have contributed to the decline in mortality rates since 1971. Of potential interest is the increase between 1997 and 2007 in the age-standardised mortality rate from diseases of the digestive system, although this has a comparatively small effect in comparison to the reductions for other disease groups.

Although the share of the total fall in mortality rates standardised to the 1901 population, as shown in Table 5, is similar to the share standardised to the 1971 population, seen in Table C5 in Appendix C, some differences may be observed in the proportion of the decline attributable to specific causes. Using the 1971 population age group weights rather than 1901 heightens the role of cardiovascular disease in falling age-standardised mortality rates for the 1971-2007 period and reduces the role of cancer.

The differences between Tables 5 and C5 are the result of age-specific changes in mortality rates across diseases. The background numbers for the two tables indicate that between 1971 and 2007 larger declines in mortality rates for cancer were observed in the younger and mid-age groups, with a small increase in mortality rates for the 65 and over age group. The greater weight of the older age groups in the 1971 base, compared to the 1901 base, lessens the apparent role of cancer in declining mortality. In contrast, the contribution of cardiovascular disease to the fall in the age-standardised mortality rate between 1971 and 2007 is greater when based on the 1971 population than on the 1901 population because of the considerable fall in mortality rates from cardiovascular disease in the elderly. (Again, these receive greater weighting when using the 1971 population base than the 1901 base.)

The 1971 age-standardised mortality rates for 2007 represent what the population mortality rates would be if the population age structure had not changed between 1971 and 2007. The percentage of the fall in total mortality rates standardised using these rates provides a more representative picture as to what causes have had the greatest impact on the population during that period than would standardising to the 1901 structure. However, to contrast falling mortality rates after 1971 with those over the period 1901 to 1971, using the 1901 weights ensures consistency with McKeown's estimates.

Morbidity

The discussion thus far has been entirely about mortality rates. The reason that McKeown concentrated on mortality was the lack of long time series data for any other aspect of population health. However, much ill health and suffering is caused by conditions that are chronic.

As mortality rates fall and life expectancy increases, the importance of improving the quality of life grows. But it is not just the decline in mortality rates that is making morbidity relatively more important as a focus of health policy. People's perceptions of illness also have changed. Figures from the Great Britain General Household Survey, shown in Table 6, display two main features. First, reported chronic ill health increased considerably in all age groups between the 1970s, when McKeown was writing, and 1990. But, second, since 1990, the percentage of people reporting that they suffer chronic ill health has levelled off and even fell back slightly in 2007. Time series are also available for other measures of morbidity, such as disability-free life expectancy, from ONS, although these series also are based in part on self-perceived health.

Additional information on morbidity is available for a number of selected causes, such as cancer. For all types of cancers combined, the number of new cases being diagnosed each year (the incidence rate) has increased considerably between 1975 and 1997 in Great Britain, from 295.6 to 370.8 per 100,000 population, respectively, but then increased only slightly between 1997 and 2007 to 384.9 per 100,000 in 2007 (Cancer Research UK, 2011). More people are being diagnosed with cancer, but mortality rates for cancer in Great Britain have fallen from 215.5 per 100,000 in 1975 to 198.3 per 100,000 in 1997 to 177.4 per 100,000 in 2007 (Cancer Research UK, 2011). Although more people are getting cancer, fewer are dying from it.

Morbidity may have changed for some diseases where no changes have been observed in mortality rates. For

Table 5. Non-infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1901-1971	1971-1997	1971-2007	1997-2007
Congenital defects	0%	7%	5%	0%
Prematurity, immaturity, other diseases of infancy	9%	7%	8%	10%
Cerebrovascular disease	2%	20%	16%	10%
Cardiovascular disease	-1%	50%	45%	39%
Cancer	-3%	6%	7%	9%
Diseases of digestive system	4%	-2%	-3%	-4%
Other diseases of nervous system	2%	-1%	-2%	-3%
Nephritis and other diseases of the urinary system	3%	2%	0%	-2%
Pregnancy and childbirth (excluding sepsis)	1%	0%	0%	0%
Violence	3%	9%	6%	2%
Other**	5%	-19%	-3%	20%
Total	**33%**	**80%**	**80%**	**81%**

*Age-standardised mortality rate based on 1901 population structure
** Includes blood and blood-forming organs, endocrine, mental illness, musculoskeletal, and skin as well as signs, symptoms and ill-defined conditions
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

example, declines in deaths from tuberculosis (TB) did not contribute significantly to increases in longevity in recent decades because this occurred earlier (e.g. in England and Wales in 2007, 300 deaths were attributed to TB (HPA, 2012)). Mortality rates, however, are only one part of the picture. The number of incident cases of TB has been rising over the past decade. In 2010, there were 8,483 cases of TB reported in the UK, an annual incidence rate of 14.6 per 100,000 population, which compares to a rate of 11.4 in 2000 (HPA, 2012). Morbidity from TB may be growing, then.

Information on the epidemiology of a number of other diseases also is available. Research into stroke incidence and mortality rates based on the General Practice Research Database suggested that, in the 10 years to 2008, stroke incidence (first strokes) decreased by 30% for those over 18 years of age, but observed prevalence of stroke increased by 10%. The same study also reported a decrease in crude mortality rates following incident stroke over the same period. The authors concluded that one factor affecting incidence and mortality rates was better management of vascular risk, both before and following a stroke (Lee et al., 2011).

As seen in Table 5 (and Table C5 in Appendix C), fewer deaths from cardiovascular disease contributed greatly to the overall decline in age-standardised mortality rates between 1971 and 2007. Other sources also have reported improvements in survival rates over the last 50 years, but in parallel with an increasing incidence of heart attacks, both of which are attributed to an ageing population and improvements in survival (Scarborough et al., 2011). The authors of the BHF report noted that, over similar time frames, reduced levels of smoking and, more recently, an increase in the level of obesity (Scarborough et al., 2011).

Table 6. Percentage of GB population reporting chronic ill health

Age group	<16	16-64	65+
1972	6%	20%	53%
1980	12%	30%	60%
1990	17%	33%	63%
1996	16%	34%	62%
2000	20%	32%	62%
2007	14%	30%	63%

Note: Data for 2000 onwards are weighted to compensate for differential non-response thus making the results more representative of the population (see ONS, 2008b).
Sources: ONS (2008b); Sussex and Yuen (2000)

Continued improvements in mortality rates along with an ageing population, as per the examples above, indicate the increasing importance of considering changes in the patterns of morbidity and health related quality of life in addition to mortality rate statistics.

Discussion

Life expectancy increased by around 30 years between 1901 and 1971 in England and Wales, as in many other countries around the world. This positive and welcome trend has continued through to 2007. As well as the obvious benefits this brings, increasing life expectancy may have a considerable upward impact on the costs of providing health services. While it is true that the cost of the NHS has risen enormously since it was established in 1948, debate continues as to how much of this has been driven by the "ageing of the population". How much does an increase in life expectancy per se result in increased costs, or is cost more related to the final years of life regardless of the age at which death occurs (see for example Zweifel et al., 1999 and 2004, and Werblow et al., 2007)?

In this *Briefing* we have not examined the cost of treating diseases. Instead, our focus is on reductions in mortality rates and consequent increases in life expectancy, comparing changes outlined by McKeown for 1901-1971 with those since 1971. Examining declining mortality rates by disease group can in turn provide indications as to what underlying factors have led to the increases observed in life expectancy.

Our extended analysis indicates that whereas a fall in the mortality rates from infectious diseases made the greatest overall contribution to declining mortality for 1901 to 1971, accounting for two thirds of the reduction, this proportion had fallen to just one fifth for 1971 to 2007. McKeown indicated that falling mortality rates from infectious diseases were due mainly to improvements in nutrition, environment and behaviour, although the introduction of antibiotics made a smaller, but still significant, contribution particularly after 1935. Exploring what factors are associated with the recent changes in mortality rates and examining the relative contributions of lifestyle, social and medical care unfortunately are beyond the scope of this *Briefing*.

With respect to specific disease groups, a substantial proportion of the fall in overall mortality rates between 1971 and 2007 is due to a decline in age-standardised mortality rates from cardiovascular disease, which accounted for 45% of the total reduction. Some investigation specifically into the decline in ischaemic heart disease (IHD) mortality concludes that the decline has occurred in all of the countries investigated and, based on past trends, will continue (Amiri, 2011). Accumulating evidence suggests that early declines in IHD mortality rates were due mainly to changes in diet and other lifestyle factors, whereas the more recent declines are due mostly to improvements in cardiovascular disease treatment. However, the precise impact of the various risk factors, and of sociocultural changes and medical care, are unclear and debated (Luepker, 2011).

During the same period, 1971-2007, cerebro-vascular disease accounted for 16% of the total fall in mortality rates. Given that both types of disease are affected by personal behaviours related to health and both can be treated with medicines, it may be hypothesised that over half of the fall in mortality rates between 1971 and 2007 resulted from lifestyle changes – particularly smoking – and better treatment. However, due to the large number of interdependent factors affecting mortality rates from these causes, further research would be required to establish which have contributed the most to increasing life expectancy.

Our extension of the McKeown analysis also highlights a number of specific disease areas where falls in mortality rates have had a considerable impact on the overall fall in mortality rates between 1901 and 1971, but no longer continue to do so. Where this situation occurs, the absolute number of deaths still may be substantial, but a plateau in the rate may have occurred. Alternatively, the absolute number of deaths for these conditions could have declined to the extent that that any further improvements would have a minimal contribution to overall mortality rates. Disease groups that were observed to contribute to the falling mortality rates between 1901 and 1971, but not after 1971, include cholera, diarrhoea, dysentery and respiratory tuberculosis. Together, these accounted for less than 0.5% of all deaths in 1971.

In addition to pointing to factors that may be affecting the overall increase in life expectancy, our research highlights some diseases where the opposite appears – a rise in the age-standardised mortality rate in recent years. This was not observed for 1901-1971 for the groupings considered, but between 1997 and 2007 an increase in the mortality rate occurred in diseases of the digestive system, including fibrosis and cirrhosis of the liver. This may indicate that whereas, in the past, changes in sanitation and other public factors outweighed effects from personal behaviours, in the current day negative personal behaviours can increase the risk for both morbidity and mortality from certain diseases (e.g. obesity and diabetes).

It would be interesting to consider what factors may be expected to affect life expectancy in the future. However, future mortality rates clearly are difficult to predict and must be based on a number of assumptions. Mathers and Loncar (2006) predicted that death rates from a number of causes may be expected to decline in the future (to 2030), but the ageing of the population means that a greater proportion of total deaths will be from conditions of the elderly, such as cardiovascular disease. For high income countries such as the UK, they predicted that IHD, stroke, lung/tracheal cancer and diabetes will be the four leading causes of death in 2030 and that, in future, we also may expect more deaths from specific causes, such as road accident fatalities.

Due to the limitations of the data available over time periods as long as a century or more, we have focused on declines in mortality rates, which imply increasing life expectancy. But some evidence suggests that morbidity rates may paint a different picture. For example, incidence rates for TB (HPA, 2012) have increased over the past decade, while mortality rates have not. Dissecting the factors that contribute to changes in healthy life expectancy and falling morbidity might help uncover the reasons for this.

Several difficulties are inherent in attempting to extend the work by McKeown, the main one being consistent coding of causes of death despite changes in the international classification of diseases that have occurred since 1971. Our analysis points to the need to ensure that the effects of coding changes are understood as far as possible. However, as the coding issues arise mainly between related disease groups, observations gained from examining broad disease groupings, as we have done, are unlikely to be affected substantially.

McKeown stated that the main reasons for declining mortality rates up to 1971 were nutritional, environmental and behavioural, as these affected deaths from infectious diseases. A relationship between a person's health, education and financial situation also is observable (see for example Feinstein et al., 2006 and Marmot, 2000). The factors responsible for mortality rates are so interconnected that it is difficult to determine the exact contribution of each, such as medicine, to changes in mortality rates (Johansson, 2005). Much work remains to be done before the reasons for declining mortality rates can be stated categorically.

Our *Briefing* suggests that the set of factors having the greatest impact on mortality rates is changing. Declines in mortality in England and Wales now are attributable mainly to non-infectious causes, including personal behaviours (stopping smoking) and improvements in health care.

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Appendix A – Unadjusted and Age-Standardised Mortality Rates 1997 and 2007

The following table gives the mortality rates (per 1,000 population) for 1997 and 2007 as well as the age standardised rate (ASR) mortality rate for the same years (based on the 1901 population) for England and Wales.

Table A1. Mortality rates per 1,000

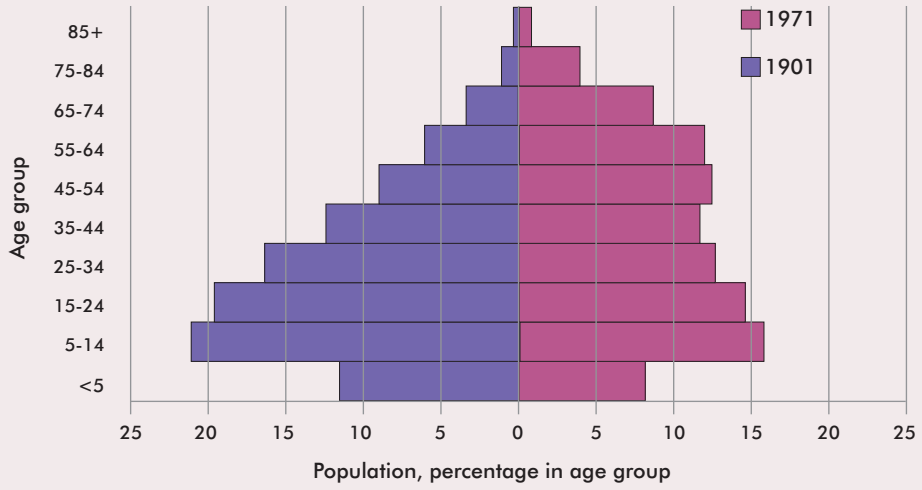
Cause	Mortality rate 1997 (per 1,000 population)	ASR Mortality rate 1997 (per 1,000 population)	Mortality rate 2007 (per 1,000 population)	ASR Mortality rate 2007 (per 1,000 population)
Cholera, etc.	0.1	3.5	<0.05	23.6
TB (respiratory)	0.1	2.3	<0.05	1.8
TB (non-respiratory)	<0.05	0.9	<0.05	0.7
Measles	<0.05	0.1	<0.05	<0.05
Whooping cough	<0.05	<0.05	<0.05	0.1
Streptococcal sore throat and scarlatina	<0.05	<0.05	0.0	0.0
Other infections	0.5	32.4	0.7	31.7
Cancer and benign neoplasms	26.4	1031.1	25.9	947.4
Nervous system	1.9	86.7	3.0	117.4
Cardiovascular and other circulatory	32.7	1122.2	22.9	760.3
Cerebrovascular disease (CVD)	11.1	360.0	8.6	271.3
Bronchitis, influenza and pneumonia	11.5	367.8	5.6	175.5
Other respiratory	6.3	210.2	7.2	231.2
Appendicitis and peritonitis	0.1	4.2	0.1	4.2
Other digestive	3.8	151.0	4.6	184.1
Urinary system	1.3	42.9	2.1	65.1
Pregnancy and childbirth	<0.05	0.7	<0.05	0.9
Premature birth	0.5	98.0	<0.05	6.4
Congenital deformations	0.2	26.8	0.2	22.9
Violence	3.1	227.3	2.0	75.2
Other	6.9	225.2	7.7	278.1
All causes	**106.4**	**4023.6**	**92.8**	**3336.0**

Note: ASR rate is 1901-population based
Sources: ONS (1997); ONS (2008a)

Appendix B – Comparison of England and Wales Population Structures in 1901, 1971 and 2007

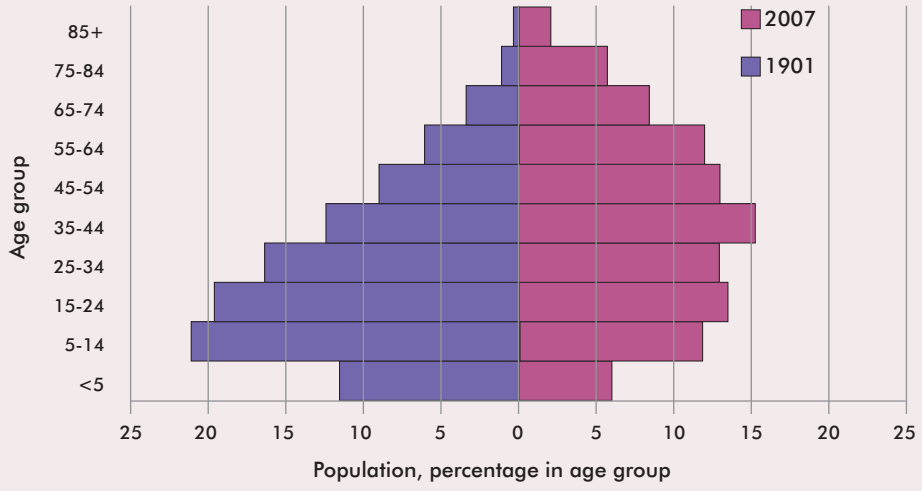
The following two graphs compare the population structure in England and Wales in 1901 with that of 1971 and 2007.

Figure B1. Comparison of population structure in England and Wales 1901 and 1971



Sources: ONS (2007a); Sussex and Yuen (2000)

Figure B2. Comparison of population structure in England and Wales 1901 and 2007



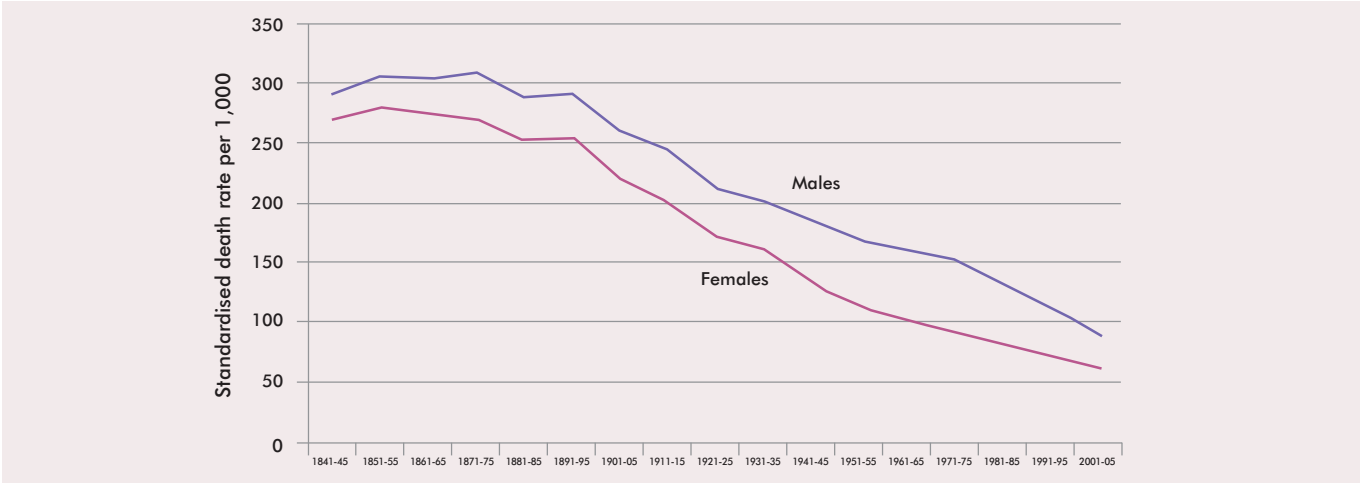
Sources: ONS (2007a); Sussex and Yuen (2000)

Appendix C – Mortality Rates Calculated on the Basis of the 1971 Population Structure

The following figure, based on the 1971 population, demonstrates the falling trend in mortality rates in England and Wales that has continued since 1971. The figure below is to be compared with Figure 3 in the main body of the text.

The following tables illustrate the reductions in mortality rates based on changes in age-standardised mortality rates, standardised to the 1971 population.

Figure C1. Trends in male and female death rates, in England and Wales, per 1,000 (1971 population basis), 1841-2005



Note: Age adjustment to the death rates is by the direct standardisation method: The 1971 age structure of the population of England and Wales has been combined with the age-specific death rates in each period. This separates the decline in mortality from the changes in population structure from the mid-19th century to the start of the 21st century.
Sources: ONS (1997); ONS (2008a)

Table C1. Share of total fall in standardised mortality rate* in each period attributable to each disease group, England and Wales

	1971-1997	1971-2007	1997-2007
Attributable to micro-organisms			
1. Airborne	18%	23%	30%
2. Water- and food-borne diseases	0%	-1%	-3%
3. Other infections	-1%	-1%	-1%
Total infections	**18%**	**21%**	**26%**
Not attributable to micro-organisms	82%	79%	74%

*Age-standardised mortality rate based on 1901 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table C2. Airborne infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1971-1997	1971-2007	1997-2007
Tuberculosis (respiratory)	1%	1%	0%
Bronchitis, pneumonia & influenza	17%	23%	30%
Whooping cough	0%	0%	0%
Measles	0%	0%	0%
Scarlet fever, diphtheria	0%	0%	0%
Smallpox	0%	0%	0%
Infections of ear, pharynx & larynx	0%	0%	0%
Total	**18%**	**23%**	**30%**

*Age-standardised mortality rate based on 1971 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table C3. Water- and food-borne infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1971-1997	1971-2007	1997-2007
Cholera, diarrhoea, dysentery**	0%	-1%	-3%
Tuberculosis (non-respiratory)	0%	0%	0%
Typhoid, typhus	0%	0%	0%
Total	**0%**	**-1%**	**-3 %**

*Age-standardised mortality rate based on 1971 population structure
** In 1997 and 2007 figures relate to intestinal infectious diseases, which include cholera and dysentery. For 1901 and 1971, this group comprised of deaths recorded as cholera, diarrhoea and dysentery.
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table C4. Other infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1971-1997	1971-2007	1997-2007
Convulsions, teething	0%	0%	0%
Syphilis	0%	0%	0%
Appendicitis, peritonitis	0%	0%	0%
Puerperal fever	0%	0%	0%
Other infections	-1%	-1%	-1%
Total	**-1%**	**-1%**	**-1%**

*Age-standardised mortality rate based on 1971 population structure
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

Table C5. Non-infections: Share of total fall in standardised* mortality rates from all causes, England and Wales

	1971-1997	1971-2007	1997-2007
Congenital defects	3%	2%	0%
Prematurity, immaturity, other diseases of infancy	2%	3%	4%
Cerebrovascular disease	27%	21%	13%
Cardiovascular disease	58%	57%	55%
Cancer	1%	4%	8%
Diseases of digestive system	-3%	-3%	-4%
Other diseases of nervous system	-2%	-3%	-5%
Nephritis, and other diseases of urinary system	0%	2%	6%
Pregnancy and childbirth (excluding sepsis)	0%	0%	0%
Violence	7%	4%	0%
Other**	-10%	-8%	-4%
Total	**82%**	**79%**	**74%**

*Age-standardised mortality rate based on 1971 population structure
** Includes blood & blood forming organs, endocrine, mental illness, musculoskeletal, skin and sign, symptoms and ill-defined conditions
Sources: ONS (2008a); ONS (2011); Sussex and Yuen (2000)

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