BMJ Open

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036529
Article Type:	Original research
Date Submitted by the Author:	19-Dec-2019
Complete List of Authors:	Ramsay, Julie; National Records of Scotland, Vital Events Statistics Minton, Jon; NHS Health Scotland, Public Health Observatory Fischbacher, Colin; NHS National Services Scotland, NHS Information Services Division Fenton, Lynda; NHS Health Scotland, Public Health Observatory; NHS Greater Glasgow and Clyde, Public Health Kaye-Bardgett, Maria; National Records of Scotland, Vital Events Statistics Wyper, Grant; NHS Health Scotland, Public Health Observatory Richardson, Elizabeth; NHS Health Scotland, Public Health Observatory McCartney, Gerry; NHS Health Scotland, Public Health Science Directorate
Keywords:	PUBLIC HEALTH, Dementia < NEUROLOGY, Substance misuse < PSYCHIATRY, Ischaemic heart disease < CARDIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Julie Ramsay[1] MSc,*, Jon Minton[2] PhD, Colin Fischbacher[3] FFPH, Lynda Fenton[2 4] MPH, Maria Kaye-Bardgett[1] PhD, Grant MA Wyper[2] MSc, Elizabeth Richardson[2] PhD, Gerry McCartney[2] MD.

* Corresponding author. Email: julie.ramsay@nrscotland.gov.uk . Telephone: 0131 314 4330

[1] National Records of Scotland, Ladywell House, Ladywell Road, Edinburgh, Scotland, EH12 7TF.

[2] Public Health Observatory, NHS Health Scotland, 5 Cadogan Street, Glasgow, Scotland, G2 6QE.

[3] Information Services Division, NHS National Services Scotland, Gyle Square, 1 South Gyle Crescent, Edinburgh, EH12 9EB.

[4] Public Health Department, NHS Greater Glasgow & Clyde, West House, Gartnavel Royal Hospital Campus, 1055 Great Western Road, Glasgow, G12 0XH.

Abstract

Objective
Annual gains in life expectancy in Scotland were slower in recent years than in the previous two decades. This analysis investigates how deaths in different age-groups and from different causes have contributed to annual average change in life expectancy across two time periods: 2000-02 to 2012-14 and 2012-14 to 2015-17.

Setting
Scotland.

Methods
Life expectancy at birth was calculated from death and population counts, disaggregated by five-year age-group and by underlying cause of death. Arriaga's method of life expectancy decomposition was applied to produce estimates of the contribution of different age-groups and underlying causes to changes in life expectancy at birth for the two periods.

Results
Average annual life expectancy gains between 2012-14 to 2015-17 were markedly smaller than in the earlier period. Almost all age-groups saw worsening mortality trends, which deteriorated for most cause of death groups between 2012-14 and 2015-17. In particular, the previously observed substantial life expectancy gains due to reductions in mortality from circulatory causes, which most benefited those aged 55-84 years, more than halved. Mortality rates for those aged 30-54 years and 90+ years worsened, due in large part to increases in drug-related deaths, and dementia and Alzheimer's disease respectively.

Conclusion
Future research should seek to explain the changes in mortality trends for all age-groups and causes. More investigation is required to establish to what extent shortcomings in the social security system and public services may be contributing to the adverse trends and preventing mitigation of the impact of other contributing factors, such as influenza outbreaks.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. JR and MK-B are salaried by NRS and GM, LF, JM, GW, CF and ER are salaried by the NHS.

Keywords
Life expectancy, decomposition, Scotland, mortality.

Article summary

Strengths and limitations of this study

- This is the first paper to describe the contribution of specific age-groups and causes of death to recent changes in life expectancy in Scotland.
- It uses a high quality dataset of deaths in which very few death registrations are missing and where less than 10% of deaths are coded using ill-defined causes.
- The results are limited to describing trends rather than explaining causal social and biological processes.
- The analysis does not identify the mechanism by which a given cause of death exerts an effect on life expectancy
- The analysis of cause of death within age-group required broad groupings of causes of death, which is likely to conflate diverse causal mechanisms

Introduction

Life expectancy improvement rates in Scotland have been slower since 2012-14 than in previous decades, the inequalities gradient across the deprivation scale has steepened, and age-standardised mortality rates have increased for those living in the most deprived areas, leading to widening health inequalities.[1,2] This comes against a background of consistently lower life expectancy in Scotland compared with the rest of Western Europe since the 1980s, and consistently worse socioeconomic inequalities in mortality.[3]

A similar slow-down since around 2012 in the long term trend of life expectancy has been observed across many high income countries.[2,4,5] Amongst 20 high-income countries, only the USA had a slower improvement in life expectancy than the UK in the most recent six years compared with the previous six years.[6] Continued improvements have been seen in some of the countries with the highest life expectancies, and amongst people living in more affluent areas, both of which undermine suggestions that the recent trends are due to a 'natural ceiling' being reached. [2,5]

Other explanations for the recent trends have included: that the UK, along with much of the rest of Western Europe, has experienced exceptionally high winter mortality; [7–9] that an increase in 'deaths of despair' – those from alcohol, drugs, and suicides – have offset broader health improvements;[10] that funding for health and social care services has not kept up with demand; [11,12] and, relatedly, that austerity policies have impacted on health through mechanisms such as reduced social security payments and underemployment. [13,14] Such explanations are likely neither mutually exclusive nor exhaustive, and some (such as additional winter deaths and slowing improvements in ischaemic heart disease mortality) may plausibly result from other causes, such as increased pressure on healthcare services and associated unmet need.[15]

Many of the above explanations differ about how mortality changes for specific age-groups, and causes, have contributed to the overall slow-down in life expectancy growth. This includes increases in several countries in mortality from dementia/Alzheimer's disease, drug-related deaths and suicide and marked slow-downs in the previous rapid improvements in cardiovascular mortality.[9,10]

We aimed to explore the reasons for these recent changes by describing the contribution of specific age-groups and causes of death to the slow-down in life expectancy growth in Scotland in two successive time periods (2000-02 to 2012-14 and 2012-14 to 2015-17).

Methods

Period life expectancy at birth was calculated from abridged life tables for males and females separately, using three-years combined data to allow robust breakdowns by cause of death and age-group.[16] For the age-group decomposition, death counts and population data in five year age-groups were used, separating <1 year from 1-4 year olds and using 90+ as the oldest age category. For the cause of death decomposition, International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) categories were grouped into 26 categories . These groupings are exclusive and exhaustive, and were developed on the basis that: at least the five leading causes of death should be separate categories; proposed and plausible contributory causes to life expectancy changes should be independent categories; and that the residual group should overall make a small contribution to life expectancy changes. The leading causes of death categorisation used by the Office for National Statistics (ONS) was employed as the basis to determine groupings where appropriate.[17] Due to the overlaps between drug-related deaths and other causes (mental

and behavioural excluding dementia, suicides, accidents and other external), for the purposes of this analysis these four causes exclude drug-related deaths (Web table 1).

We calculated the changes in life expectancy between three-year rolling periods for males and females for the whole time series from 1980 before focusing on two time periods from 2000 onwards. (The tenth revision of ICD was implemented in 2000 in Scotland and data prior to this period is not consistent across the cause of death categories examined.) Life expectancy growth between 2000-02 and 2012-14 and between 2012-14 and 2015-17 was decomposed into age and cause components using Arriaga's method with the aid of syntax developed by Auger et al. [18,19] The break between the two periods was selected on the basis of the previously identified change in mortality trend (around 2012-14).[2] Life expectancy change and decomposition results are presented as average annual change in life expectancy (in weeks) to account for the different length of the two time periods. For the analysis of cause of death within age-group, the age and cause of death categories were aggregated into five mutually exclusive age-groups, and eight mutually exclusive cause-of-death groupings (40 age-cause groupings). A more detailed disaggregation (20 age-groups and 26 cause-of-death groups) is presented in Web figures 3 and 4.

Patient and public involvement

This research was done without direct patient or public involvement

Results

Rate of improvement in life expectancy

Life expectancy in Scotland has increased steadily in recent decades, but improvements have stalled and life expectancy has decreased in recent years (Web figure 1). Although the rate of growth has fluctuated over time, it has rarely been as low as in the last few years (Web figure 2).

Decomposition of life expectancy changes by age and sex

In the earlier period (2000-02 to 2012-14) the average annual increase in male life expectancy was 16.3 weeks/year. However, during the later period (2012-14 to 2015-17) male life expectancy fell by an average of 1.1 weeks/year. During the earlier period, all age-groups contributed to increases in life expectancy (Figure 1) though the greatest contribution (61% of the increase) came from the 55-79 year age-group. During the later period, males aged 40-54 years and 90+ years made substantial negative contributions to overall changes in life expectancy. Although still contributing positively to life expectancy growth in the later period, mortality improvement among 55-84 year old males declined markedly and contributed considerably to the slowing of life expectancy growth. There was a notable reduction in the rate of improvement for males aged 15-34 years, although the smaller number of deaths at these ages meant that this made a smaller contribution to the overall change in life expectancy. There were also small but noticeable declines in the rate of improvement for infants and children aged 1-4 years.

Patterns across age-groups were similar for females, although both the rates of improvement and the scale of change were smaller than for males (Figure 1). During the earlier period female life expectancy grew by 10.0 weeks/year, with mortality improvements in all age-groups. The largest contributions to the increase (64%) came from the 60-84 year age-group. During the later period the average annual improvement in life expectancy declined to less than 0.1 weeks/year. For those aged 30-49 years and 85+ years, mortality rates worsened. Mortality improvements amongst those aged 60-84 years were very much reduced compared to the earlier period. There was also slowing in improvements for infants, children aged 1-4 years and 10-14 year olds.

Figure 1 – Decomposition of changes in life expectancy between 2002-02 to 2012-14, and from 2012-14 to 2015-17, by sex, Scotland

Decomposition by detailed cause of death

For males, the single largest cause of the slow-down in life expectancy growth was slower improvements in ischaemic heart disease (IHD) mortality (Figure 2). In the earlier period reductions in IHD mortality added 5.8 weeks/year to male life expectancy; in the later period they added only 2.2 weeks per year. Drug-related deaths made the second biggest contribution for males, changing from a small negative impact (-0.4 weeks/year) in the earlier period to a much larger negative impact (-2.4 weeks/year) afterwards. Other circulatory diseases, cerebrovascular disease, dementia and Alzheimer's disease also made substantial contributions to the slow-down. Only two causes, 'other respiratory' and genitourinary, contributed more to male life expectancy growth after 2012-14 than before.

For females, the same broad causes had the largest impact on life expectancy growth, although again the scale of change was smaller than for males. The single largest cause of the slow-down in life expectancy growth was IHD mortality. As in males, drug-related deaths had the second biggest impact on life expectancy, changing from a small negative impact in the earlier period to a much larger negative impact in the later one. Improvements in mortality from other circulatory causes reversed in the later time period. For cerebrovascular disease there was a marked decline in the rate of improvement between the two time periods. Dementia and Alzheimer's disease mortality worsened from the earlier period. For some causes female mortality improved after 2012-14, making a positive contribution to life expectancy growth; these included lung cancer, other respiratory causes, other cancers, genitourinary, ill-defined causes and breast cancer.

Figure 2 – Decomposition of the contribution of specific causes of death to changes in life expectancy between 2000-02 and 2012-14 and between 2012-14 and 2015-17, by sex, Scotland

*Excluding causes that are included under drug-related deaths.

Decomposition by age and broad causes of death

The contributions of different causes of death to life expectancy trends varied across age-groups but were generally similar between males and females. For those aged <35 years, improvements in mortality from external causes made the greatest single contribution to the positive trend in the earlier period (2000-02 to 2012-14). In the later period (2012-14 to 2015-17) this fell to 0.3 weeks/year for males and disappeared for females. Mortality rates for drug-related deaths and cancers increased slightly in the later time period for those aged <35 years (Figure 3).

For those aged 35-54 years, the overall negative contribution to life expectancy changes was due both to substantial reductions in the rate of improvement for some causes of death (including circulatory causes) and absolute increases in mortality for others (such as drug-related deaths, cancers and other causes; Figures 3 and 4).

Although the overall contribution to life expectancy of those aged 55-74 years remained positive in the later period, the dramatic decline in the positive contribution of this age-group is important in explaining overall trends (Figure 1). Much of this decline was explained by the much slower improvement in deaths from circulatory causes in the later compared with the earlier period. Improvements in cancer mortality slowed among males but increased markedly among females. For both males and females, deaths due to dementia, drugs and other causes all made negative contributions in the later time period to life expectancy growth (Figures 3 and 4).

The contributions of broad causes of death to trends in life expectancy amongst those aged 75-89 years was similar to that of those aged 55-74 years, but the negative contribution of dementia and Alzheimer's disease increased in the later period. Improvements in mortality from circulatory causes fell substantially. Positive trends in cancer mortality improved further for both males and females between the earlier and later periods (Figures 3 and 4).

Amongst the oldest age-group (90+ years), the small overall contribution to life expectancy growth changed from positive to negative between the earlier and later time periods (Figure 1). This was due to worsening mortality due to dementia as well as a slowing in the rate of improvement due to circulatory causes (Figures 3 and 4).

More detailed age-groups and causes of death are presented in Web figures 3 and 4. These show that mortality in the first year of life from causes of death originating in the perinatal period has improved at a slower rate since 2012-14 for males and has worsened slightly for females (although given the relatively small numbers and the fact that this has not occurred for both sexes, this finding should be treated with caution). The detailed findings also indicate that the increasingly negative contribution of drug-related deaths to life expectancy trends is mainly concentrated among 35-44 year olds for females and 40-49 year olds for males. The slow-down of improvements in IHD mortality is mainly concentrated in 60-69 year old males and 65-74 year old females; the negative contribution of suicides is concentrated in 25-29 year old males, and the rising contribution of dementia and Alzheimer's disease is concentrated in the oldest age-groups.

Figure 3 - Decomposition of changes in life expectancy by grouped age and cause of death, 2000-02 to 2012-14 and 2012-14 to 2015-17, by sex, Scotland

Note: values in cells indicate contribution to life expectancy change in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Figure 4 - Decomposition of change in life expectancy growth pre and post 2012-14 by grouped age and cause of death, by sex, Scotland

Note: values in cells indicate the difference in contribution to life expectancy change between the two periods, in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Discussion

Main results

Life expectancy in Scotland steadily improved from the early 1980s until 2012-14, after which the rate of improvement slowed, followed by declines in life expectancy between 2014-16 and 2015-17. Between 2000-02 and 2012-14, average annual increases in male and female life expectancy were 16.3 and 10.0 weeks/year respectively, but this changed to a decline of 1.1 weeks/year for males and to a very small increase of less than 0.1 weeks/year for females between 2012-14 and 2015-17. In the earlier period most of the increases in life expectancy were due to falling mortality amongst those aged 55-84 years, although mortality rates declined for all age-groups. In the later period declines in mortality were slower for all age-groups, particularly those aged 55-84 years. Mortality increased for males aged 30-54 years, females aged 35-49 years and both males and females aged 90+ years.

A wide range of causes of death were responsible for this slowing in life expectancy growth. Although mortality due to IHD and cerebrovascular disease continued to decline in the later period, life expectancy gains due to these conditions were less than half of those in the earlier period. This affected all age-groups, but was particularly important in explaining the slowing in improvement for those aged 55-74 years, and to a lesser extent those aged 35-54 years. Mortality from drug-related causes and from dementia and Alzheimer's disease, which were already making negative contributions to life expectancy in the earlier period, made larger negative contributions after 2012-14. The previous favourable trends in mortality from other circulatory causes reversed. The increase in drug-related deaths was particularly important in explaining increasing mortality amongst those aged 35-54 years, whilst increases in dementia and Alzheimer's disease mortality substantially explained trends among those aged 90+ years.

How this compares with existing research

Much of the initial research describing recent slowing in life expectancy gains has focused on the role of influenza and mortality amongst the oldest age-groups.[9,20] Although we report increases in deaths due to influenza and respiratory causes, and rising mortality amongst those aged 90+ years, these results show that the contribution they make to explaining the overall slowing in life expectancy growth in Scotland is small. This is consistent with other studies in England & Wales and the USA which report that slowing improvements for IHD and cerebrovascular disease and increases in mortality for other circulatory causes among 55-84 year olds and drug-related deaths for adults aged 35-49 years, all make substantial contributions to the overall trends.[21–25]

There is evidence that the increase in drug-related deaths in Scotland is due in part to a cohort effect amongst males who were young adults during the 1980s.[26] Some recent trends may therefore be attributable to historical exposures to political and social change at that time and before. [3]

The reasons for slowing improvements in cardiovascular disease mortality is not clear. Possible explanations might include slowing of progress in reducing exposure to tobacco, increases in the prevalence of obesity, changes in psychosocial risk factors related to economic insecurity or deterioration in access to, or the quality of, health and social care services.

The increase in mortality from dementia and Alzheimer's disease has been attributed to a number of factors, including: people living longer and surviving other illnesses;[27] increased awareness of dementia, making it more likely to be diagnosed and recorded;[9,25] and NHS policies encouraging dementia diagnosis. [25] Changes in death certification practices have also been cited as one of the reasons for increase in deaths from dementia and Alzheimer's disease,[6] although it should be

noted that these changes did not occur in Scotland until 2017 so will have had a limited impact on these results.

Implications

Several hypotheses have been proposed to explain recent life expectancy trends in Scotland and other high income countries. [15] Further research should include work to understand the mechanisms and processes underlying the changes at different life-course stages: the considerable rise in drug-related deaths among working-age adults; the substantial slow-down in improvements for IHD, cerebrovascular disease and other circulatory causes; and the rise in mortality from dementia and Alzheimer's disease amongst those aged 90+ years.

The recent change in life expectancy trends represents a very substantial mortality impact which needs to be reflected in the level of priority given to understanding this further. Mortality has worsened (through slowing improvements or mortality increases) across many age-groups and causes, so it is unlikely that any single factor provides sufficient explanation. The extent to which there is a common underlying cause or exposure affecting each of these age-groups should be prioritised for further investigation.

Contributorship statement

LF and GM conceived the idea for this study. JR, MK-B and JM undertook the analyses. GM and JR drafted the manuscript. CF, GW and ER along will all other authors made substantial contributions to interpretation of results and editing the manuscript, and all approved the final draft.

Data availability statement

Life expectancy data and mortality breakdowns by cause of death and age are available on the National Records of Scotland website (www.nrscotland.gov.uk). Breakdowns by detailed cause of death are available on request from Julie.ramsay@nrscotland.gov.uk

Declaration of Interests

The authors declare that they have no competing interests. No funding was received for this work.

Ethics

No new data were collected in this study and there was no public or patient involvement. We used mortality data made available to us by National Records of Scotland and adhered to our standard procedures to protect against disclosure.

References

1 Fenton L, Wyper GM, McCartney G, *et al.* Socioeconomic inequality in recent adverse all-cause mortality trends in Scotland. *J Epidemiol Community Health* 2019;**73**:971–4. doi:10.1136/jech-2019-212300

2 Fenton L, Minton J, Ramsay J, *et al.* Recent adverse mortality trends in Scotland: comparison with other high-income countries. *bioRxiv* 2019;:542449. doi:10.1101/542449

3 Walsh D, McCartney G, Collins C, *et al.* History, politics and vulnerability: explaining excess mortality in Scotland and Glasgow. Glasgow: 2106.

4 Ho JY, Hendi AS. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ* 2018;:k2562. doi:10.1136/bmj.k2562

5 Raleigh V. Stalling life expectancy in the UK | The King's Fund. 2018.https://www.kingsfund.org.uk/publications/stalling-life-expectancy-uk (accessed 20 Feb 2019).

6 Office for National Statistics. Changing trends in mortality: an international comparison: 2011 to 2016. 2018. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/changingtrendsinmortalityaninternationalcomparison/2000to2016

7 Molbak K, Espenhain L, Nielsen J, *et al.* Excess mortality among the elderly in European countries, December 2014 to February 2015. *Euro Surveill* 2015;**20**.http://www.ncbi.nlm.nih.gov/pubmed/25811643

8 Vestergaard LS, Nielsen J, Krause TG, *et al.* Excess all-cause and influenza-attributable mortality in Europe, December 2016 to February 2017. *Euro Surveill* 2017;**22**. doi:https://doi.org/10.2807/1560-7917.ES.2017.22.14.30506

9 PHE. A review of recent trends in mortality in England. London: : Public Health England 2018.

10 Steel N, Ford JA, Newton JN, *et al.* Changes in health in the countries of the UK and 150 English Local Authority areas 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2018;**392**:1647–61. doi:10.1016/S0140-6736(18)32207-4

11 Watkins J, Wulaningsih W, Da Zhou C, *et al.* Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017;**7**:e017722. doi:10.1136/bmjopen-2017-017722

12 Currie J, Guzman Castillo M, Adekanmbi V, *et al.* Evaluating effects of recent changes in NHS resource allocation policy on inequalities in amenable mortality in England, 2007–2014: time-series analysis. *J Epidemiol Community Health* 2019;**73**:162–7. doi:10.1136/jech-2018-211141

13 Hiam L, Dorling D, McKee M. Rise in mortality—when will the government take note? *BMJ* 2018;:k2747. doi:10.1136/bmj.k2747

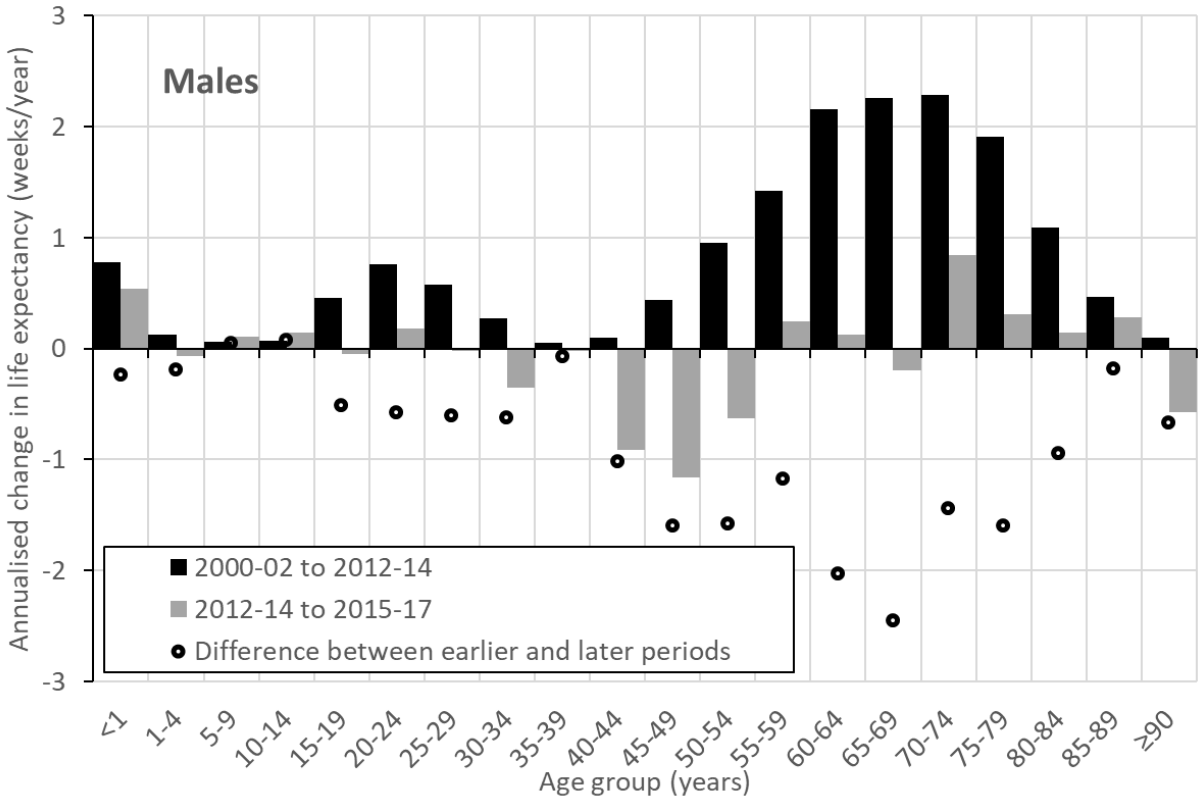
14 Taulbut M, Agbato D, McCartney NHS Health Scotland G. Working and hurting? Monitoring the health and health inequalities impacts of the economic downturn and changes to the social security system. 2018. http://www.healthscotland.scot/media/2147/working-and-hurting-sep-2018-english.pdf (accessed 25 Sep 2018).

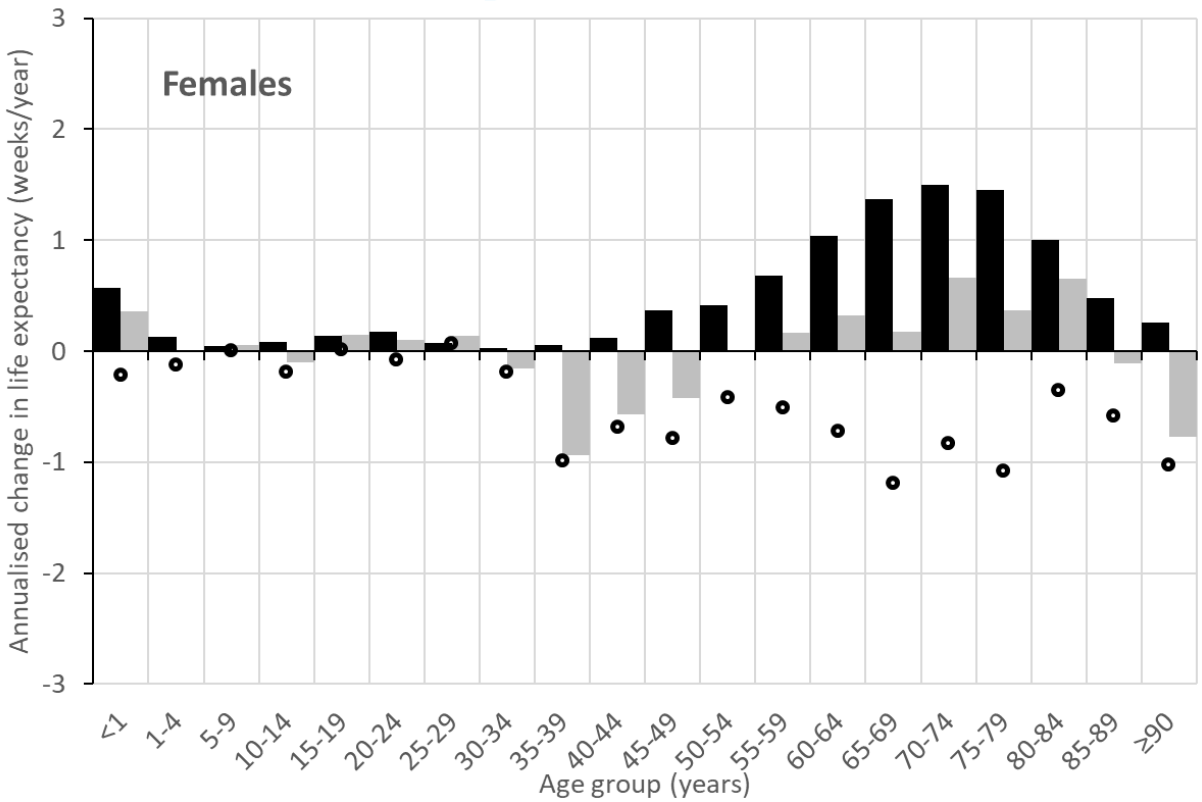
15 Fenton L. Mortality trends workshop 13th November 2018 – short report and presentations. ScotPHO. 2018.https://www.scotpho.org.uk/publications/reports-and-papers/mortality-trends-workshop-13th-november-2018-short-report-and-presentations/

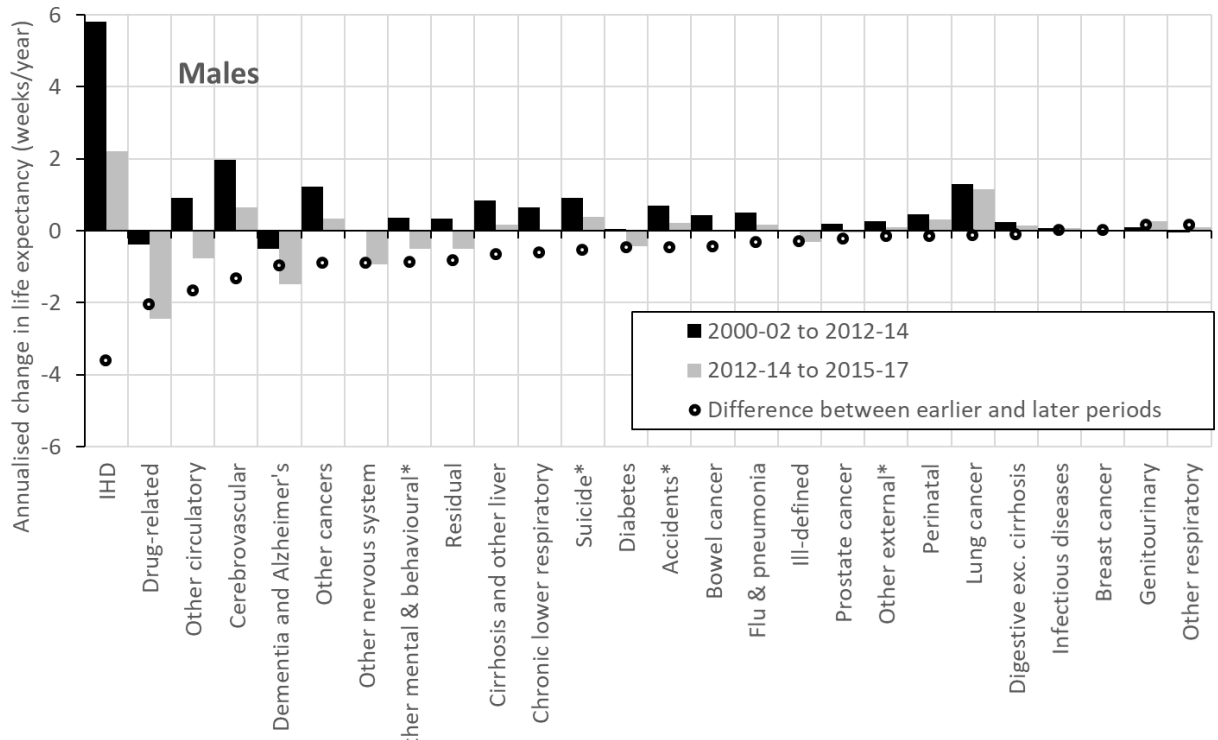
16 National Records of Scotland. Life Tables for Scotland 2015-2017. Natl. Rec. Scotl. 2018.https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/life-expectancy/life-expectancy-at-scotland-level/scottish-national-life-tables/2015-2017 (accessed 1 Oct 2018).

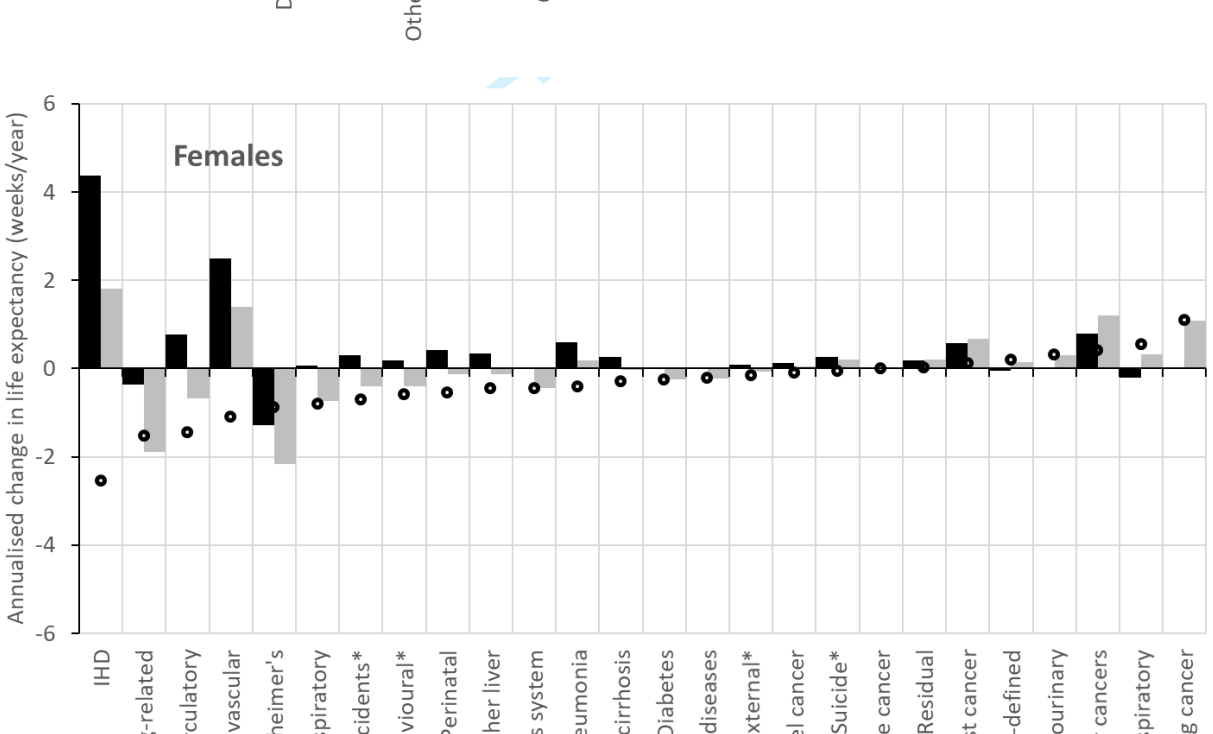
17 Office for National Statistics. Leading causes of death in England and Wales (revised 2016) - Office for National Statistics. 2016.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/methodologies/userguidetomortalitystatistics/leadingcausesofdeathinenglandandwale

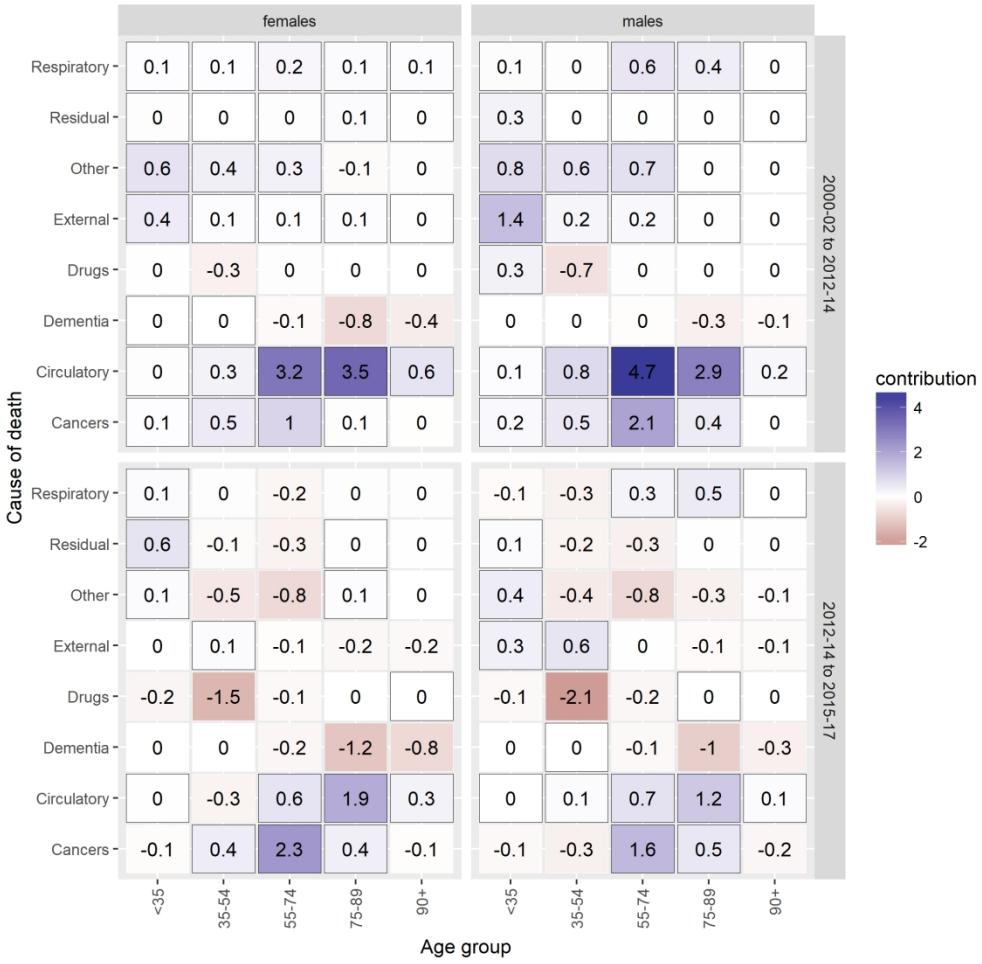
srevised2016 (accessed 23 Oct 2018).
18 Arriaga EE. Measuring and Explaining the Change in Life Expectancies. *Demography* 1984;**21**:83. doi:10.2307/2061029
19 Auger N, Feuillet Msc P, Martel Msc S, *et al.* Mortality inequality in populations with equal life expectancy: Arriaga's decomposition method in SAS, Stata, and Excel. *Ann Epidemiol* 2014;**24**:575-580.e1. doi:10.1016/j.annepidem.2014.05.006
20 Pebody RG, Green HK, Warburton F, *et al.* Significant spike in excess mortality in England in winter 2014/15 - influenza the likely culprit. *Epidemiol Infect* 2018;**146**:1106–13. doi:10.1017/S0950268818001152
21 Acciai F, Firebaugh G. Why did life expectancy decline in the United States in 2015? A gender-specific analysis. *Soc Sci Med* 2017;**190**:174–80. doi:10.1016/j.socscimed.2017.08.004
22 Bennett JE, Pearson-Stuttard J, Kontis V, *et al.* Contributions of diseases and injuries to widening life expectancy inequalities in England from 2001 to 2016: a population-based analysis of vital registration data. *Lancet Public Heal* 2018;**3**:e586–97. doi:10.1016/S2468-2667(18)30214-7
23 Duffy M, Robinson A, Laverty C. Health Inequalities - Life Expectancy Decomposition 2017. 2012. http://www.health-ni.gov.uk/topics/dhssps-statistics-and-research/health-inequalities-statisticswww.nisra.gov.uk (accessed 25 Sep 2018).
24 Remund A, Camarda CG, Riffe T. A Cause-of-Death Decomposition of Young Adult Excess Mortality. *Demography* 2018;**55**:957–78. doi:10.1007/s13524-018-0680-9
25 Public Health England. Recent trends in mortality in England: review and data packs - GOV.UK. 2018.
26 Parkinson J, Minton J, Lewsey J, *et al.* Drug-related deaths in Scotland 1979-2013: Evidence of a vulnerable cohort of young men living in deprived areas. *BMC Public Health* 2018;**18**. doi:10.1186/s12889-018-5267-2
27 ONS. Changing trends in mortality: a cross-UK comparison, 1981 to 2016. Analysis of age-specific and age-standardised mortality rates for the UK, England, Wales, Scotland and Northern Ireland from 1981 to 2016. London: : Office for National Statistics 2018.
28 NRS. Quality of National Records of Scotland (NRS) Data on Deaths. 2019.https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/deaths/deaths-background-information/quality-of-nrs-data-on-deaths (accessed 14 Mar 2019).
29 Mesalles-Naranjo O, Grant I, Wyper GMA, *et al.* Trends and inequalities in the burden of mortality in Scotland 2000–2015. *PLoS One* 2018;**13**:e0196906. doi:10.1371/journal.pone.0196906

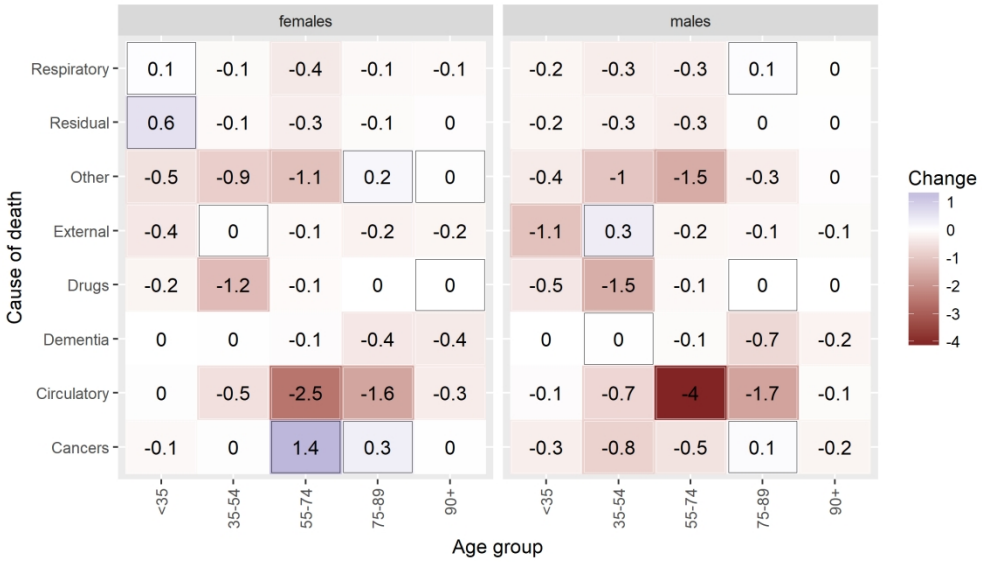

Males
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

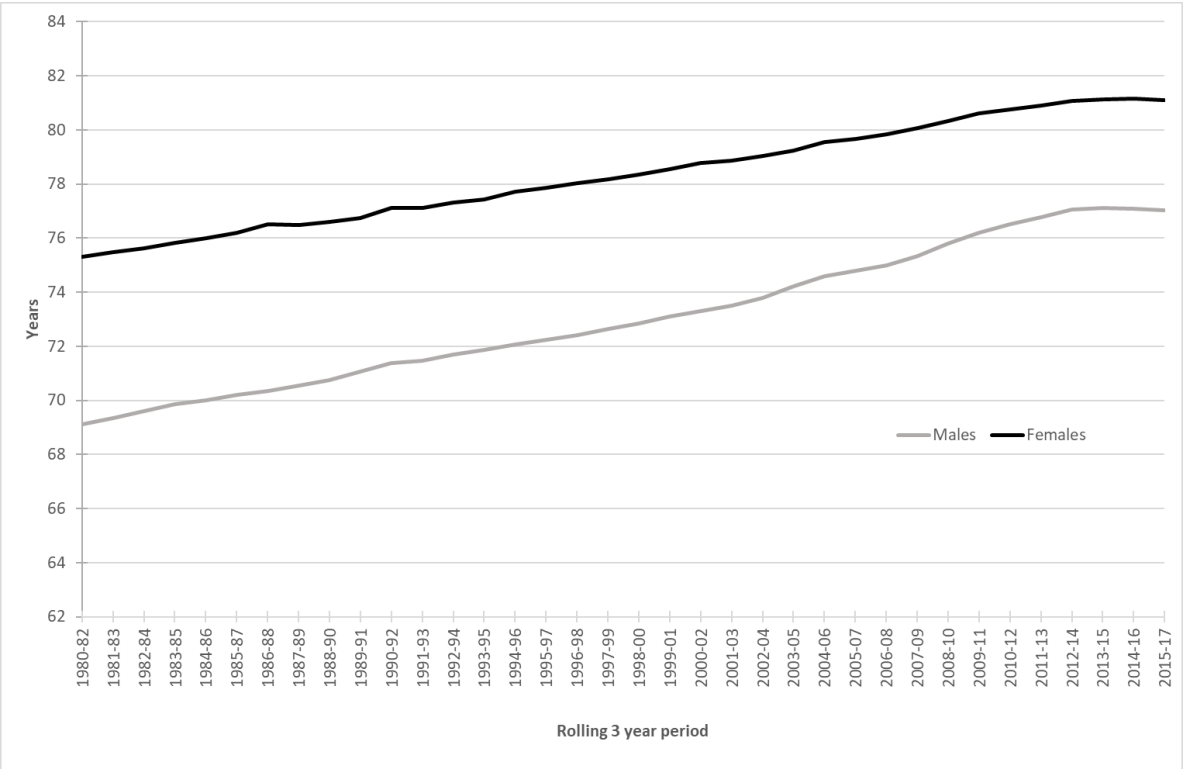

Females
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

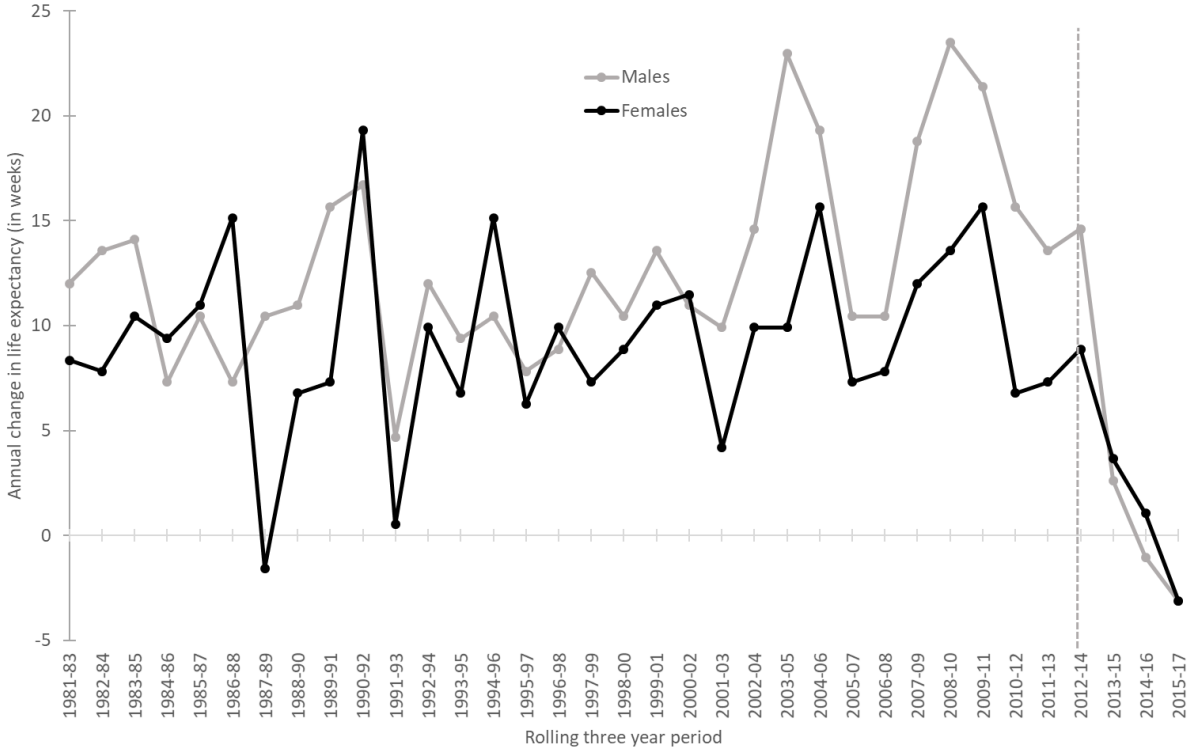

Males
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Other cancers
Other nervous system
Other mental & behavioural*
Residual
Cirrhosis and other liver
Chronic lower respiratory
Suicide*
Diabetes
Accidents*
Bowel cancer
Flu & pneumonia
Ill-defined
Prostate cancer
Other external*
Perinatal
Lung cancer
Digestive exc. cirrhosis
Infectious diseases
Breast cancer
Genitourinary
Other respiratory

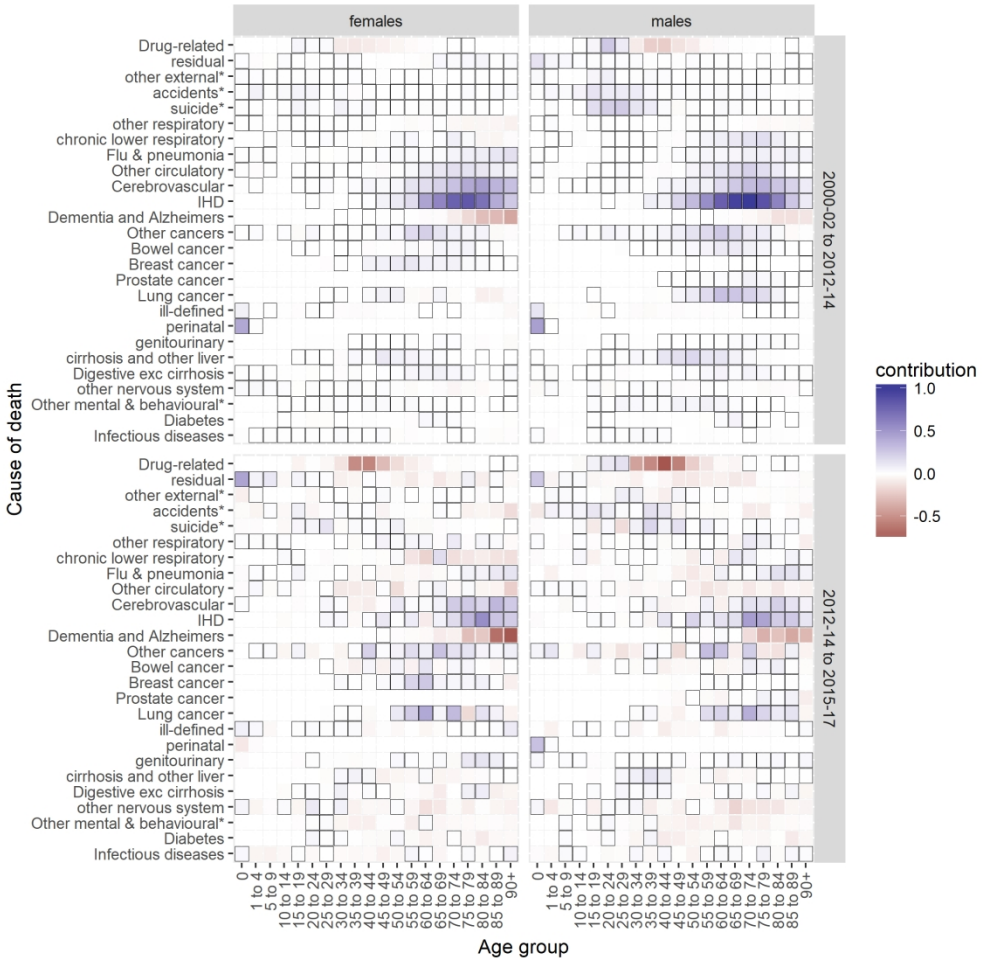

Females
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Chronic lower respiratory
Accidents*
Other mental & behavioural*
Perinatal
Cirrhosis and other liver
Other nervous system
Flu & pneumonia
Digestive exc. cirrhosis
Diabetes
Infectious diseases
Other external*
Bowel cancer
Suicide*
Prostate cancer
Residual
Breast cancer
Ill-defined
Genitourinary
Other cancers
Other respiratory
Lung cancer

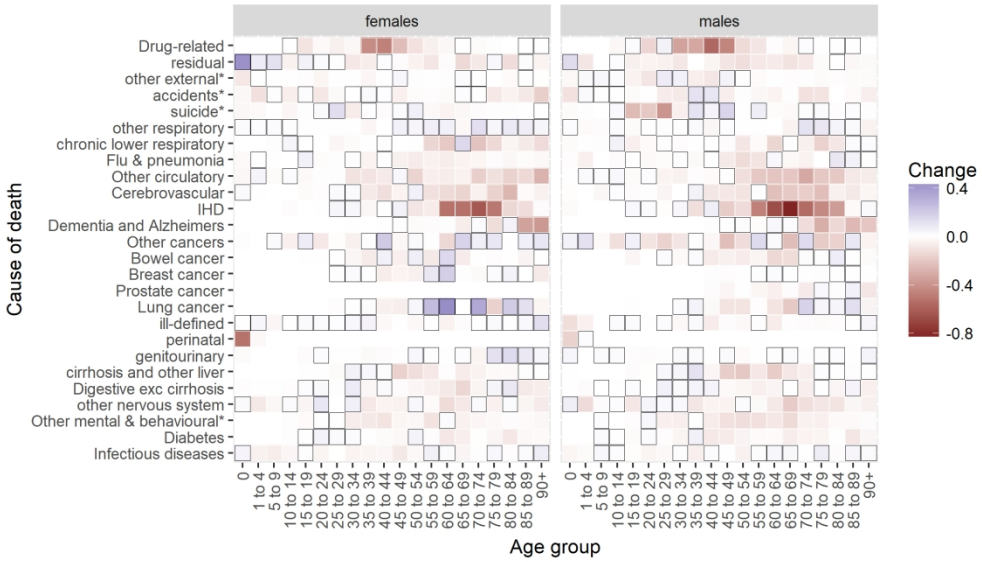












Web table 1: Categorisation of Causes of Death

#	Detailed Category (26)	ICD-10	Grouped Category (8)
1	Infectious diseases	A00-B99	Other
2	Lung cancer	C33-C34	Cancers
3	Prostate cancer	C61	Cancers
4	Breast cancer	C50	Cancers
5	Bowel cancer	C18-C21	Cancers
6	Other cancers	All other C codes	Cancers
7	Diabetes	E10-E14	Other
8	Dementia and Alzheimer's	F00, F01, F03, G30	Dementia and Alzheimer's
9	Mental and behavioural disorders excluding dementia *	All other F codes	Other
10	Nervous system diseases excluding Alzheimer's	All other G codes	Other
11	Ischaemic heart disease	I20-I25	Circulatory
12	Cerebrovascular	I60-I69	Circulatory
13	Other circulatory	All other I codes	Circulatory
14	Influenza and pneumonia	J09-J18	Respiratory
15	Chronic lower respiratory diseases	J40-J47	Respiratory
16	Other respiratory	All other J codes	Respiratory
17	Digestive excluding cirrhosis	K00-K69 K77-K99	Other
18	Cirrhosis and other diseases of the liver	K70-K76	Other
19	Genitourinary	N00-N99	Other
20	Perinatal conditions	P00-P96	Other
21	Ill-defined	R00-R99	Other
22	Suicide and injury/poisoning of undetermined intent *	X60-X84, Y10-Y34, Y87.0, Y87.2	External
23	Accidents *	V01-X59, Y85-Y86	External
24	Other external *	All other X&Y codes	External
25	Residual	All D Residual E codes All H, All L, All O All M, All Q	Residual
26	Drug-related	F11-F15, F19, Plus X40-X44, X60-X64, X85, Y10-Y14 where an illegal drug was present in the body.	Drug-related

* excluding deaths which are also classified as drug-related.

As the drug-related codes overlap with mental and behavioural causes (exc. dementia) and external causes (suicides, accidents and other external), where a death would appear in both categories, we

included it in the drug-related category only, and therefore the other 4 categories exclude drug-related deaths. This was done for two reasons: firstly, the interest in the impact of recent drug-related death trends; and secondly, because of ICD coding changes in 2011[1] there is a discontinuity in the figures for external causes and mental and behavioural causes. This change caused deaths which would previously have been coded as mental and behavioural causes to be coded as external causes. As this change occurred at a key point in the time period we are analysing, it would give misleading results on the relative impact of these causes on life expectancy growth. The coding change did not affect the figures for drug-related deaths, so by selecting these as a separate category, the discontinuity is avoided.

[1] https://www.nrscotland.gov.uk/files/statistics/vital-events/changes-to-coding-of-causes-of-death-between-2010-2011.pdf.

BMJ Open

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036529.R1
Article Type:	Original research
Date Submitted by the Author:	25-May-2020
Complete List of Authors:	Ramsay, Julie; National Records of Scotland, Vital Events Statistics Minton, Jon; NHS Health Scotland, Public Health Observatory Fischbacher, Colin; NHS National Services Scotland, NHS Information Services Division Fenton, Lynda; NHS Health Scotland, Public Health Observatory; NHS Greater Glasgow and Clyde, Public Health Kaye-Bardgett, Maria; National Records of Scotland, Vital Events Statistics Wyper, Grant; NHS Health Scotland, Public Health Observatory Richardson, Elizabeth; NHS Health Scotland, Public Health Observatory McCartney, Gerry; NHS Health Scotland, Public Health Science Directorate
Primary Subject Heading:	Public health
Secondary Subject Heading:	Health policy
Keywords:	PUBLIC HEALTH, Dementia < NEUROLOGY, Substance misuse < PSYCHIATRY, Ischaemic heart disease < CARDIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Julie Ramsay[1] MSc,*, Jon Minton[2] PhD, Colin Fischbacher[3] FFPH, Lynda Fenton[2 4] MPH, Maria Kaye-Bardgett[1] PhD, Grant MA Wyper[2] MSc, Elizabeth Richardson[2] PhD, Gerry McCartney[2] MD.

* Corresponding author. Email: julie.ramsay@nrscotland.gov.uk . Telephone: 0131 314 4330

[1] National Records of Scotland, Ladywell House, Ladywell Road, Edinburgh, Scotland, EH12 7TF.

[2] Public Health Observatory, NHS Health Scotland, 5 Cadogan Street, Glasgow, Scotland, G2 6QE.

[3] Information Services Division, NHS National Services Scotland, Gyle Square, 1 South Gyle Crescent, Edinburgh, EH12 9EB.

[4] Public Health Department, NHS Greater Glasgow & Clyde, West House, Gartnavel Royal Hospital Campus, 1055 Great Western Road, Glasgow, G12 0XH.

Abstract

Objective
Annual gains in life expectancy in Scotland were slower in recent years than in the previous two decades. This analysis investigates how deaths in different age-groups and from different causes have contributed to annual average change in life expectancy across two time periods: 2000-02 to 2012-14 and 2012-14 to 2015-17.

Setting
Scotland.

Methods
Life expectancy at birth was calculated from death and population counts, disaggregated by five-year age-group and by underlying cause of death. Arriaga's method of life expectancy decomposition was applied to produce estimates of the contribution of different age-groups and underlying causes to changes in life expectancy at birth for the two periods.

Results
~~Average annual~~Annualised gains in life expectancy ~~gains~~ between 2012-14 and~~to~~ 2015-17 were markedly smaller than in the earlier period. Almost all age-groups saw worsening mortality trends, which deteriorated for most cause of death groups between 2012-14 and 2015-17. In particular, the previously observed substantial life expectancy gains due to reductions in mortality from circulatory causes, which most benefited those aged 55-84 years, more than halved. Mortality rates for those aged 30-54 years and 90+ years worsened, due in large part to increases in drug-related deaths, and dementia and Alzheimer's disease respectively.

Conclusion
Future research should seek to explain the changes in mortality trends for all age-groups and causes. More investigation is required to establish to what extent shortcomings in the social security system and public services may be contributing to the adverse trends and preventing mitigation of the impact of other contributing factors, such as influenza outbreaks.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. JR and MK-B are salaried by NRS and GM, LF, JM, GW, CF and ER are salaried by the NHS.

Keywords
Life expectancy, decomposition, Scotland, mortality.

Article summary

Strengths and limitations of this study

- This is the first paper to describe the contribution of specific age-groups and causes of death to recent changes in life expectancy in Scotland.
- It uses a high quality dataset of deaths in which very few death registrations are missing and where less than 10% of deaths are coded using ill-defined causes.
- The results are limited to describing trends rather than explaining causal social and biological processes.
- The analysis does not identify the mechanism through~~by~~ which a given cause of death exerts an effect on life expectancy
- The analysis of cause of death within age-group required broad groupings of causes of death, which is likely to conflate diverse causal mechanisms

Introduction

Life expectancy improvement rates in Scotland have been slower since 2012-14 than in previous decades, the inequalities gradient across the deprivation scale has steepened, and age-standardised mortality rates have increased for those living in the most deprived areas, leading to widening health inequalities.[1,2] This comes against a background of consistently lower life expectancy in Scotland compared with the rest of Western Europe since the 1980s, and consistently worse socioeconomic inequalities in mortality.[3]

A similar slow-down since around 2012 in the long term trend of life expectancy has been observed across many high income countries.[2,4,5] Amongst 20 high-income countries, only the USA had a slower improvement in life expectancy than the UK in the most recent six years compared with the previous six years.[6] Continued improvements have been seen in some of the countries with the highest life expectancies, and amongst people living in more affluent areas, both of which undermine suggestions that the recent trends are due to a 'natural ceiling' being reached.[2,5]

Other explanations for the recent trends have included: that the UK, along with much of the rest of Western Europe, has experienced exceptionally high winter mortality;[7–9] that an increase in 'deaths of despair' – those from alcohol, drugs, and suicides – have offset broader health improvements;[10] that funding for health and social care services has not kept up with demand; [11,12]; and, relatedly, that austerity policies have impacted on health through mechanisms such as reduced social security payments and underemployment.[13,14] Such explanations are likely neither mutually exclusive nor exhaustive, and some (such as additional winter deaths and slowing improvements in ischaemic heart disease mortality) may plausibly result from other causes, such as increased pressure on healthcare services and associated unmet need.[15]

Many of the above explanations differ about how mortality changes for specific age-groups, and causes, have contributed to the overall slow-down in life expectancy growth. This includes increases in several countries in mortality from dementia/Alzheimer's disease, drug-related deaths and suicide and marked slow-downs in the previous rapid improvements in cardiovascular mortality.[9,10]

We aimed to explore the reasons for these recent changes by describing the contribution of specific age-groups and causes of death to the slow-down in life expectancy growth in Scotland in two successive time periods (2000-02 to 2012-14 and 2012-14 to 2015-17).

Methods

We used repeat cross-sectional data to undertake comparative decomposition analyses of life expectancy over time. The data used includes all deaths which occurred in Scotland from 2000 to 2017 (inclusive) as held by National Records of Scotland.

Period life expectancy at birth was calculated from abridged life tables available from National Records of Scotland for males and females separately, using three-years combined data to allow robust breakdowns by cause of death and age-group.[16] For the age-group decomposition, death counts and population data in five year age-groups were used, separating <1 year from 1-4 year olds and using 90+ years as the oldest age category. For the cause of death decomposition, International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) categories were grouped into 26 categories. These groupings are exclusive and exhaustive, and were developed on the basis that: at least the five leading causes of death should be separate categories; proposed and plausible contributory causes to life expectancy changes should be independent

categories; and that the residual group should overall make a small contribution to life expectancy changes. The leading causes of death categorisation used by the Office for National Statistics (ONS) was employed as the basis to determine groupings where appropriate.[17] Due to the overlaps between drug-related deaths and other causes (mental and behavioural excluding dementia, suicides, accidents and other external), for the purposes of this analysis these four causes exclude drug-related deaths (Supplementary file 3)~~Web table 1)~~.

We calculated the changes in life expectancy between three-year rolling periods for males and females for the whole time series from 1980 before focusing on two time periods from 2000 onwards. (The tenth revision of ICD was implemented in 2000 in Scotland and data prior to this period is not consistent across the cause of death categories examined.) Life expectancy growth between 2000-02 and 2012-14 and between 2012-14 and 2015-17 was decomposed into age and cause components using Arriaga's method with the aid of syntax developed by Auger et al.[18,19] The break between the two periods was selected on the basis of the previously identified change in mortality trend which showed that the best estimate of when mortality rates changed to a slower rate of improvement was the year to 2012 quarter 4 for men and the year to 2014 quarter 2 for women ~~(around 2012-14)~~.[2] As life expectancy data is based on three-year rolling periods, 2012-2014 was chosen to most accurately reflect this breakpoint. Life expectancy change and decomposition results are presented as ~~average annual~~annualised change in life expectancy (in weeks) to account for the different length of the two time periods. For the analysis of cause of death within age-group, the age and cause of death categories were aggregated into five mutually exclusive age-groups, and eight mutually exclusive cause-of-death groupings (40 age-cause groupings). A more detailed disaggregation (20 age-groups and 26 cause-of-death groups) is presented in ~~Web figures~~Supplementary files ~~1~~3 and ~~4~~2.

Patient and public involvement

This research was done without direct patient or public involvement

Results

Rate of improvement in life expectancy

Life expectancy in Scotland has increased steadily ~~in recent decades~~until around 2012, but improvements have since stalled and life expectancy has decreased in recent years ~~(Web figure 1)~~. Although the rate of growth has fluctuated over time, it has rarely been as low as in the last few years, and any slower periods have not been sustained (~~Web figure 2~~1Supplementary file 2).

Decomposition of life expectancy changes by age and sex

In the earlier period (2000-02 to 2012-14) the ~~average annual~~annualised increase in male life expectancy was 16.3 weeks/year. However, during the later period (2012-14 to 2015-17) male life expectancy fell by an average of 1.1 weeks/year. During the earlier period, all age-groups contributed to increases in life expectancy (Figure ~~1~~2) though the greatest contribution (61% of the increase) came from the 55-79 year age-group. During the later period, males aged 40-54 years and 90+ years made substantial negative contributions to overall changes in life expectancy. Although still contributing positively to life expectancy growth in the later period, mortality improvement among 55-84 year old males declined markedly and contributed considerably to the slowing of life expectancy growth. There was a notable reduction in the rate of improvement for males aged 15-34 years, although the smaller number of deaths at these ages meant that this made a smaller contribution to the overall change in life expectancy. There were also small but noticeable declines in the rate of improvement for infants and children aged 1-4 years.

Patterns across age-groups were similar for females, although both the rates of improvement and the scale of change were smaller than for males (Figure ~~1~~2). During the earlier period female life expectancy grew by 10.0 weeks/year, with mortality improvements in all age-groups. The largest contributions to the increase (64%) came from the 60-84 year age-group. During the later period the ~~average annual~~annualised improvement in life expectancy declined to less than 0.1 weeks/year. For those aged 30-49 years and 85+ years, mortality rates worsened. Mortality improvements amongst those aged 60-84 years were very much reduced compared to the earlier period. There was also slowing in improvements for infants, children aged 1-4 years and 10-14 year olds.

~~Figure 1 – Decomposition of changes in life expectancy between 2002-02 to 2012-14, and from 2012-14 to 2015-17, by sex, Scotland~~

Decomposition by detailed cause of death

For males, the single largest cause of the slow-down in life expectancy growth was slower improvements in ischaemic heart disease (IHD) mortality (Figure ~~2~~3). In the earlier period reductions in IHD mortality added 5.8 weeks/year to male life expectancy; in the later period they added only 2.2 weeks per year. Drug-related deaths made the second biggest contribution for males, changing from a small negative impact (-0.4 weeks/year) in the earlier period to a much larger negative impact (-2.4 weeks/year) afterwards. Other circulatory diseases, cerebrovascular disease, dementia and Alzheimer's disease also made substantial contributions to the slow-down. Only two causes, 'other respiratory' and genitourinary, contributed more to male life expectancy growth after 2012-14 than before.

For females, the same broad causes had the largest impact on life expectancy growth, although again the scale of change was smaller than for males. The single largest cause of the slow-down in life expectancy growth was IHD mortality. As in males, drug-related deaths had the second biggest impact on life expectancy, changing from a small negative impact in the earlier period to a much larger negative impact in the later one. Improvements in mortality from other circulatory causes reversed in the later time period. For cerebrovascular disease there was a marked decline in the rate of improvement between the two time periods. Dementia and Alzheimer's disease mortality worsened from the earlier period. For some causes female mortality improved after 2012-14, making a positive contribution to life expectancy growth; these included lung cancer, other respiratory causes, other cancers, genitourinary, ill-defined causes and breast cancer.

~~Figure 2 – Decomposition of the contribution of specific causes of death to changes in life expectancy between 2000-02 and 2012-14 and between 2012-14 and 2015-17, by sex, Scotland~~

~~*Excluding causes that are included under drug-related deaths.~~

Decomposition by age and broad causes of death

The contributions of different causes of death to life expectancy trends varied across age-groups but were generally similar between males and females. For those aged <35 years, improvements in mortality from external causes made the greatest single contribution to the positive trend in the earlier period (2000-02 to 2012-14). In the later period (2012-14 to 2015-17) this fell to 0.3 weeks/year for males and disappeared for females. Mortality rates for drug-related deaths and cancers increased slightly in the later time period for those aged <35 years (Figure ~~3~~4).

For those aged 35-54 years, the overall negative contribution to life expectancy changes was due both to substantial reductions in the rate of improvement for some causes of death (including circulatory causes) and absolute increases in mortality for others (such as drug-related deaths, cancers and other causes; Figures ~~4~~3 and ~~4~~5).

Although the overall contribution to life expectancy of those aged 55-74 years remained positive in the later period, the dramatic decline in the positive contribution of this age-group is important in explaining overall trends (Figure ~~1~~2). Much of this decline was explained by the much slower improvement in deaths from circulatory causes in the later compared with the earlier period. Improvements in cancer mortality slowed among males but increased markedly among females. For both males and females, deaths due to dementia, drugs and other causes all made negative contributions in the later time period to life expectancy growth (Figures ~~3~~4 and ~~4~~5).

The contributions of broad causes of death to trends in life expectancy amongst those aged 75-89 years was similar to that of those aged 55-74 years, but the negative contribution of dementia and Alzheimer's disease increased in the later period. Improvements in mortality from circulatory causes fell substantially. Positive trends in cancer mortality improved further for both males and females between the earlier and later periods (Figures ~~3~~4 and ~~4~~5).

Amongst the oldest age-group (90+ years), the small overall contribution to life expectancy growth changed from positive to negative between the earlier and later time periods (Figure ~~1~~2). This was due to worsening mortality due to dementia as well as a slowing in the rate of improvement due to circulatory causes (Figures ~~4~~3 and ~~4~~5).

More detailed age-groups and causes of death are presented in ~~Web F~~figures~~s~~supplementary files ~~3~~2~~1~~1 and ~~4~~2~~3~~3. These show that mortality in the first year of life from causes of death originating in the perinatal period has improved at a slower rate since 2012-14 for males and has worsened slightly for females (although given the relatively small numbers and the fact that this has not occurred for both sexes, this finding should be treated with caution). The detailed findings also indicate that the increasingly negative contribution of drug-related deaths to life expectancy trends is mainly concentrated among 35-44 year olds for females and 40-49 year olds for males. The slow-down of improvements in IHD mortality is mainly concentrated in 60-69 year old males and 65-74 year old females; the negative contribution of suicides is concentrated in 25-29 year old males, and the rising contribution of dementia and Alzheimer's disease is concentrated in the oldest age-groups.

Figure 3 - Decomposition of changes in life expectancy by grouped age and cause of death, 2000-02 to 2012-14 and 2012-14 to 2015-17, by sex, Scotland

Note: values in cells indicate contribution to life expectancy change in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Figure 4 - Decomposition of change in life expectancy growth pre and post 2012-14 by grouped age and cause of death, by sex, Scotland

Note: values in cells indicate the difference in contribution to life expectancy change between the two periods, in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Discussion

Main results

Life expectancy in Scotland steadily improved from the early 1980s until 2012-14, after which the rate of improvement slowed, followed by declines in life expectancy between 2014-16 and 2015-17. Between 2000-02 and 2012-14, ~~average annual~~annualised increases in male and female life expectancy were 16.3 and 10.0 weeks/year respectively, but this changed to a decline of 1.1 weeks/year for males and to a very small increase of less than 0.1 weeks/year for females between 2012-14 and 2015-17. In the earlier period most of the increases in life expectancy were due to falling mortality amongst those aged 55-84 years, although mortality rates declined for all age-groups. In the later period declines in mortality were slower for all age-groups, particularly those aged 55-84 years. Mortality increased for males aged 30-54 years, females aged 35-49 years and both males and females aged 90+ years.

Almost all ~~wide range of~~ causes of death demonstrated a change in trend in the recent period~~were responsible for this slowing in life expectancy growth~~. Although mortality due to IHD and cerebrovascular disease continued to decline in the later period, life expectancy gains due to these conditions were less than half of those in the earlier period. This affected all age-groups, but was particularly important in explaining the slowing in improvement for those aged 55-74 years, and to a lesser extent those aged 35-54 years. Mortality from drug-related causes and from dementia and Alzheimer's disease, which were already making negative contributions to life expectancy in the earlier period, made larger negative contributions after 2012-14. The previous favourable trends in mortality from other circulatory causes reversed. The increase in drug-related deaths was particularly important in explaining increasing mortality amongst those aged 35-54 years, whilst increases in dementia and Alzheimer's disease mortality substantially explained trends among those aged 90+ years.

Strengths and limitations

The key strengths of this analysis are the use of a complete mortality dataset for the whole population which reduces the risk of bias from missing data or selection biases. Less than 10% of deaths in Scotland are coded using ill-defined causes. We also use standard decomposition analysis (Arriaga) methods that are thereby comparable to estimates produced for other populations. The analysis is limited to the use of cause of death codes which do not illuminate the overall social causation and mechanisms leading to mortality – this is the subject of other work. We also had to use broad grouping of death codes within age groups to improve the precision of our estimates which is likely to conflate diverse causal mechanisms.

How this compares with existing research

The stalling in life expectancy trends in Scotland is of a similar magnitude to the rest of the UK and USA, but greater than in some other parts of Europe.[2,4,5]~~[2,4,6]~~ Much of the initial research describing recent slowing in life expectancy gains has focused on the role of influenza and mortality amongst the oldest age-groups.[9,20] Although we report increases in deaths due to influenza and respiratory causes, and rising mortality amongst those aged 90+ years, these results show that the contribution they make to explaining the overall slowing in life expectancy growth in Scotland is small. This is consistent with other studies in England & Wales and the USA which report that slowing improvements for IHD and cerebrovascular disease and increases in mortality for other circulatory causes among 55-84 year olds and drug-related deaths for adults aged 35-49 years, all make substantial contributions to the overall trends.[21–25] The slightly slower rate of improvement in the most recent period for women compared to men indicates that the long-term closing of the sex gap seems to be continuing.

There is evidence that the increase in drug-related deaths in Scotland is due in part to a cohort effect amongst males who were young adults during the 1980s.[26] Some recent trends may therefore be attributable to historical exposures to political and social change at that time and before, whereby risk of mortality accumulates over time within that cohort.~~[3, 26]~~ [3,26]

The reasons for slowing improvements in cardiovascular disease mortality is not clear. Possible explanations might include slowing of progress in reducing exposure to tobacco, increases in the prevalence of obesity, changes in psychosocial risk factors related to economic insecurity or deterioration in access to, or the quality of, health and social care services.[27] This should be the focus of further specific work to understand the timing and reasons for the stalling.

The increase in mortality from dementia and Alzheimer's disease has been attributed to a number of factors, including: people living longer and surviving other illnesses;[28] increased awareness of dementia, making it more likely to be diagnosed and recorded;[9,25] and NHS policies encouraging dementia diagnosis.~~[25]~~ Changes in death certification practices have also been cited as one of the reasons for increase in deaths from dementia and Alzheimer's disease,[6] although it should be noted that these changes did not occur in Scotland until 2017 so will have had a limited impact on these results.

Implications

Several hypotheses have been proposed to explain recent life expectancy trends in Scotland and other high income countries.~~[15]~~ Further research should include work to understand the mechanisms and processes underlying the changes at different life-course stages: the considerable rise in drug-related deaths among working-age adults; the substantial slow-down in improvements for IHD, cerebrovascular disease and other circulatory causes; and the rise in mortality from dementia and Alzheimer's disease amongst those aged 90+ years.

The recent change in life expectancy trends represents a very substantial mortality impact which needs to be reflected in the level of priority given to understanding this further. Mortality has worsened (through slowing improvements or mortality increases) across many age-groups and causes, so it is unlikely that any single factor provides sufficient explanation. The extent to which there is a common underlying cause or exposure affecting each of these age-groups should be prioritised for further investigation.

Figure 1 – Life Expectancy and annual change in life expectancy, 1980-82 to 2015-17, by sex, Scotland

Figure ~~1~~2 – Decomposition of changes in life expectancy between 2002-02 to 2012-14, and from 2012-14 to 2015-17, by sex, Scotland

Figure ~~2~~3 – Decomposition of the contribution of specific causes of death to changes in life expectancy between 2000-02 and 2012-14 and between 2012-14 and 2015-17, by sex, Scotland

*Excluding causes that are included under drug-related deaths. ~~s.~~

Figure 43 - Decomposition of changes in life expectancy by grouped age and cause of death, 2000-02 to 2012-14 and 2012-14 to 2015-17, by sex, Scotland

Note: values in cells indicate contribution to life expectancy change in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Figure 54 - Decomposition of change in life expectancy growth pre and post 2012-14 by grouped age and cause of death, by sex, Scotland

Note: values in cells indicate the difference in contribution to life expectancy change between the two periods, in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Contributorship statement

LF and GM conceived the idea for this study. JR, MK-B and JM undertook the analyses. GM and JR drafted the manuscript. CF, GW and ER -along will all other authors made substantial contributions to interpretation of results and editing the manuscript, and all approved the final draft.

Data availability statement

Life expectancy data and mortality breakdowns by cause of death and age are available on the National Records of Scotland website (www.nrscotland.gov.uk). Breakdowns by detailed cause of death are available on request from Julie.ramsay@nrscotland.gov.uk

Funding statement

No specific funding was received for this work. All authors are salaried employees of National Records of Scotland or the NHS.

Declaration of Interests

The authors declare that they have no competing interests. No funding was received for this work.

Ethics

No new data were collected in this study and there was no public or patient involvement. We used mortality data made available to us by National Records of Scotland and adhered to our standard procedures to protect against disclosure.

References

1 Fenton L, Wyper GM, McCartney G, *et al.* Socioeconomic inequality in recent adverse all-cause mortality trends in Scotland. *J Epidemiol Community Health* 2019;**73**:971–4. doi:10.1136/jech-2019-212300

2 Fenton L, Minton J, Ramsay J, *et al.* Recent adverse mortality trends in Scotland: comparison with other high-income countries. *BMJ Open* 2019;**9**:e029936. doi:10.1136/bmjopen-2019-029936

3 Walsh D, McCartney G, Collins C, *et al.* History, politics and vulnerability: explaining excess mortality in Scotland and Glasgow. Glasgow: 2106.

4 Ho JY, Hendi AS. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ* 2018;:k2562. doi:10.1136/bmj.k2562

5 Raleigh V. Stalling life expectancy in the UK | The King's Fund. 2018.https://www.kingsfund.org.uk/publications/stalling-life-expectancy-uk (accessed 20 Feb 2019).

6 Office for National Statistics. Changing trends in mortality: an international comparison: 2011 to 2016. 2018. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/changingtrendsinmortalityaninternationalcomparison/2000to2016

7 Molbak K, Espenhain L, Nielsen J, *et al.* Excess mortality among the elderly in European countries, December 2014 to February 2015. *Euro Surveill* 2015;**20**.http://www.ncbi.nlm.nih.gov/pubmed/25811643

8 Vestergaard LS, Nielsen J, Krause TG, *et al.* Excess all-cause and influenza-attributable mortality in Europe, December 2016 to February 2017. *Euro Surveill* 2017;**22**. doi:https://doi.org/10.2807/1560-7917.ES.2017.22.14.30506

9 PHE. A review of recent trends in mortality in England. London: : Public Health England 2018.

10 Steel N, Ford JA, Newton JN, *et al.* Changes in health in the countries of the UK and 150 English Local Authority areas 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2018;**392**:1647–61. doi:10.1016/S0140-6736(18)32207-4

11 Watkins J, Wulaningsih W, Da Zhou C, *et al.* Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017;**7**:e017722. doi:10.1136/bmjopen-2017-017722

12 Currie J, Guzman Castillo M, Adekanmbi V, *et al.* Evaluating effects of recent changes in NHS resource allocation policy on inequalities in amenable mortality in England, 2007–2014: time-series analysis. *J Epidemiol Community Health* 2019;**73**:162–7. doi:10.1136/jech-2018-211141

13 Hiam L, Dorling D, McKee M. Rise in mortality—when will the government take note? *BMJ* 2018;:k2747. doi:10.1136/bmj.k2747

14 Taulbut M, Agbato D, McCartney NHS Health Scotland G. Working and hurting? Monitoring the health and health inequalities impacts of the economic downturn and changes to the social security system. 2018. http://www.healthscotland.scot/media/2147/working-and-hurting-sep-2018-english.pdf (accessed 25 Sep 2018).

15 Fenton L. Mortality trends workshop 13th November 2018 – short report and presentations. ScotPHO. 2018.https://www.scotpho.org.uk/publications/reports-and-papers/mortality-trends-workshop-13th-november-2018-short-report-and-presentations/

16 National Records of Scotland. Life Tables for Scotland 2015-2017. Natl. Rec. Scotl. 2018.https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/life-expectancy/life-expectancy-at-scotland-level/scottish-national-life-tables/2015-2017 (accessed 1 Oct 2018).

17 Office for National Statistics. Leading causes of death in England and Wales (revised 2016) - Office for National Statistics. 2016.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/d

eaths/methodologies/userguidetomortalitystatistics/leadingcausesofdeathinenglandandwalesrevised2016 (accessed 23 Oct 2018).

18 Arriaga EE. Measuring and Explaining the Change in Life Expectancies. *Demography* 1984;**21**:83. doi:10.2307/2061029

19 Auger N, Feuillet Msc P, Martel Msc S, *et al.* Mortality inequality in populations with equal life expectancy: Arriaga's decomposition method in SAS, Stata, and Excel. *Ann Epidemiol* 2014;**24**:575-580.e1. doi:10.1016/j.annepidem.2014.05.006

20 Pebody RG, Green HK, Warburton F, *et al.* Significant spike in excess mortality in England in winter 2014/15 - influenza the likely culprit. *Epidemiol Infect* 2018;**146**:1106–13. doi:10.1017/S0950268818001152

21 Acciai F, Firebaugh G. Why did life expectancy decline in the United States in 2015? A gender-specific analysis. *Soc Sci Med* 2017;**190**:174–80. doi:10.1016/j.socscimed.2017.08.004

22 Bennett JE, Pearson-Stuttard J, Kontis V, *et al.* Contributions of diseases and injuries to widening life expectancy inequalities in England from 2001 to 2016: a population-based analysis of vital registration data. *Lancet Public Heal* 2018;**3**:e586–97. doi:10.1016/S2468-2667(18)30214-7

23 Duffy M, Robinson A, Laverty C. Health Inequalities - Life Expectancy Decomposition 2017. 2012. http://www.health-ni.gov.uk/topics/dhssps-statistics-and-research/health-inequalities-statisticswww.nisra.gov.uk (accessed 25 Sep 2018).

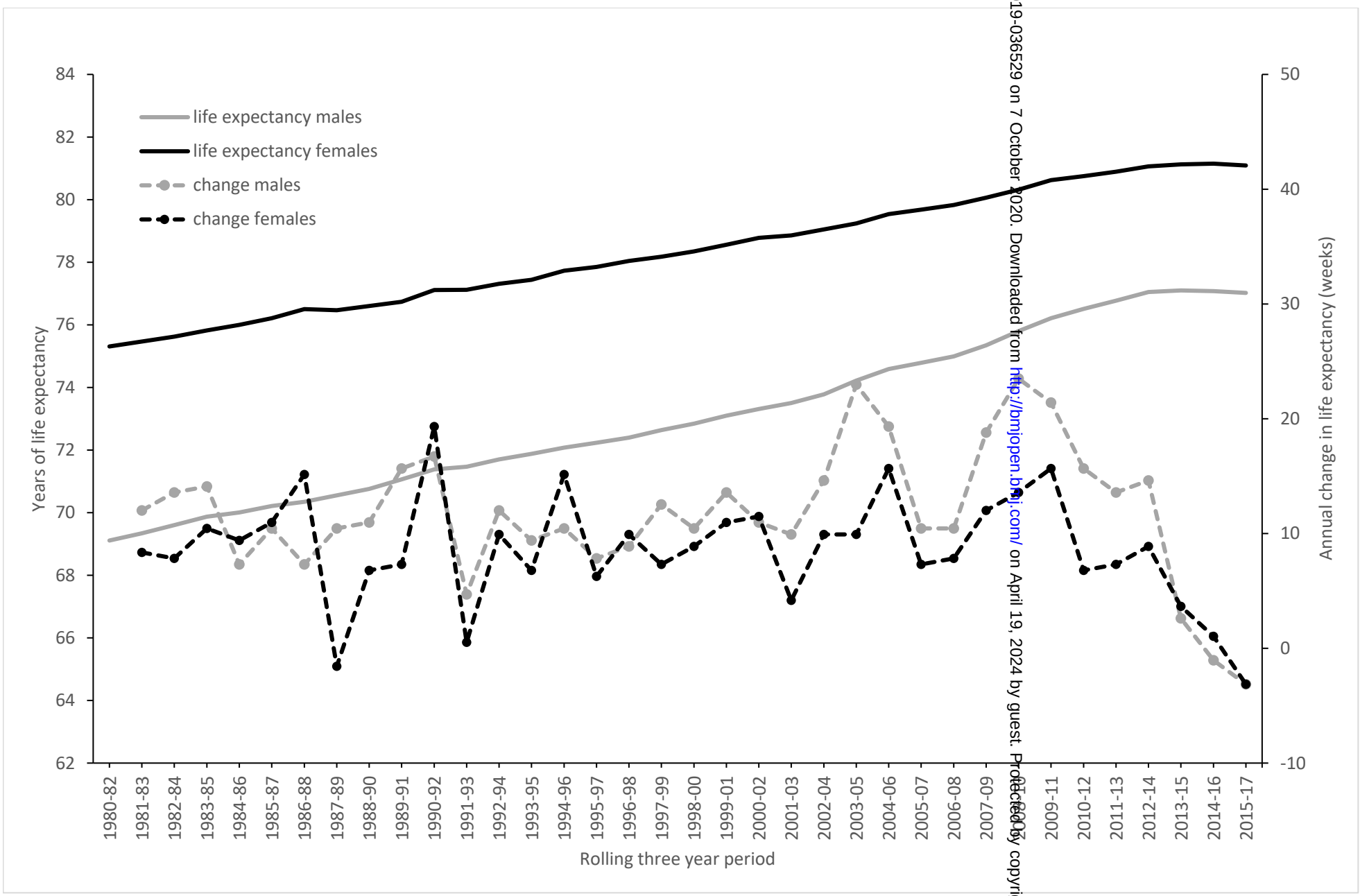
24 Remund A, Camarda CG, Riffe T. A Cause-of-Death Decomposition of Young Adult Excess Mortality. *Demography* 2018;**55**:957–78. doi:10.1007/s13524-018-0680-9

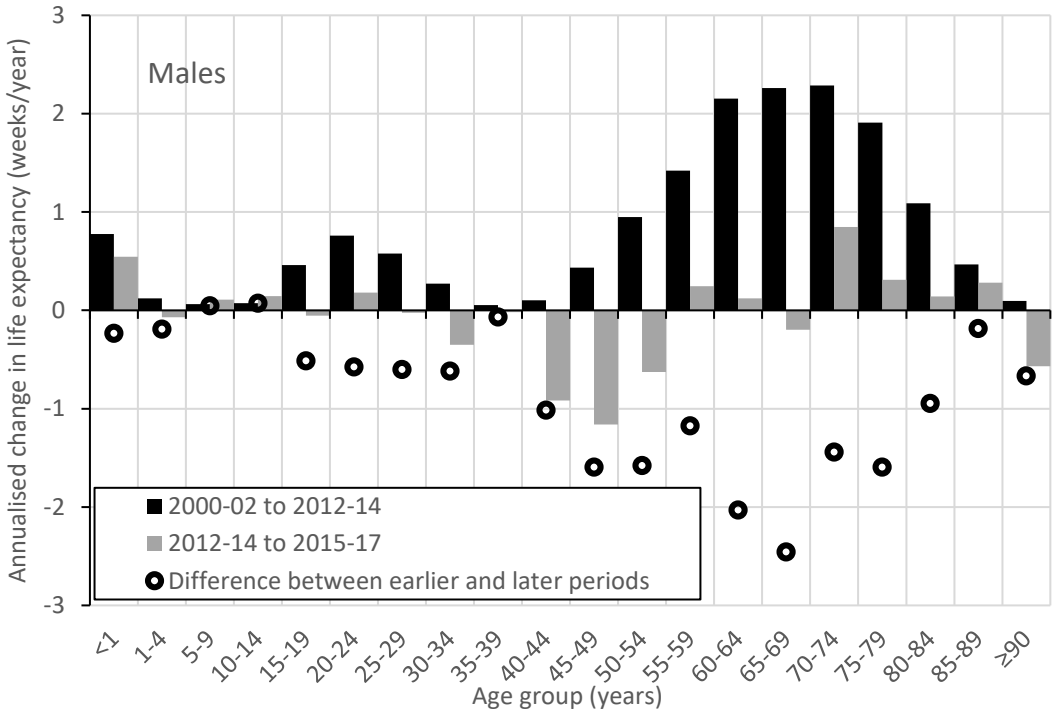
25 Public Health England. Recent trends in mortality in England: review and data packs - GOV.UK. 2018.

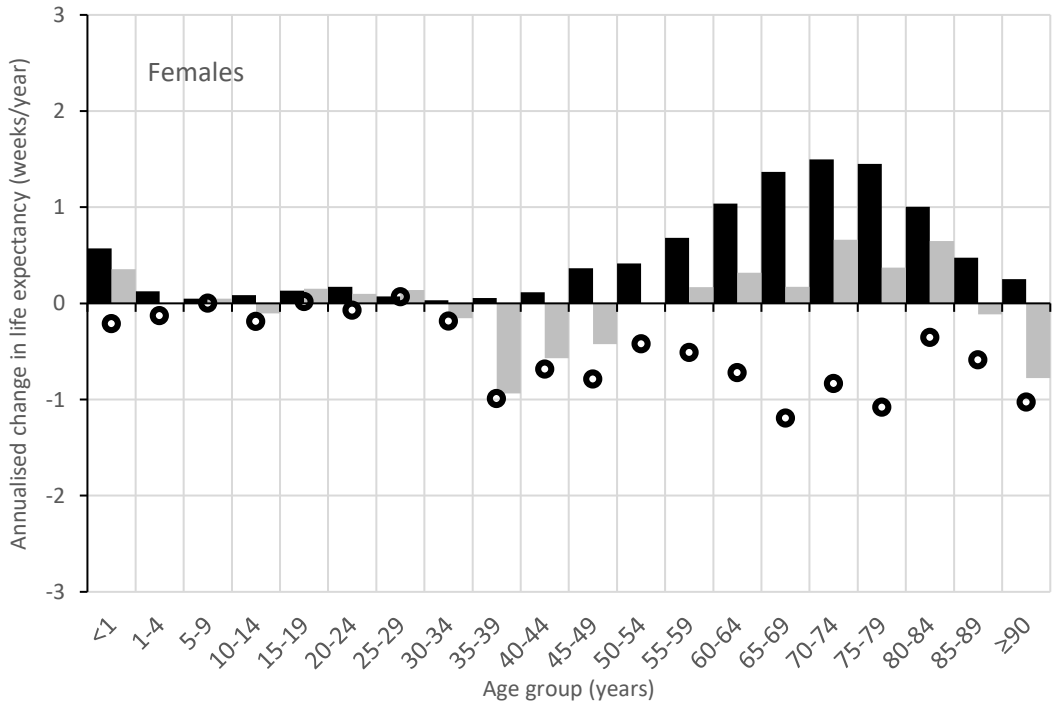
26 Parkinson J, Minton J, Lewsey J, *et al.* Drug-related deaths in Scotland 1979-2013: Evidence of a vulnerable cohort of young men living in deprived areas. *BMC Public Health* 2018;**18**. doi:10.1186/s12889-018-5267-2

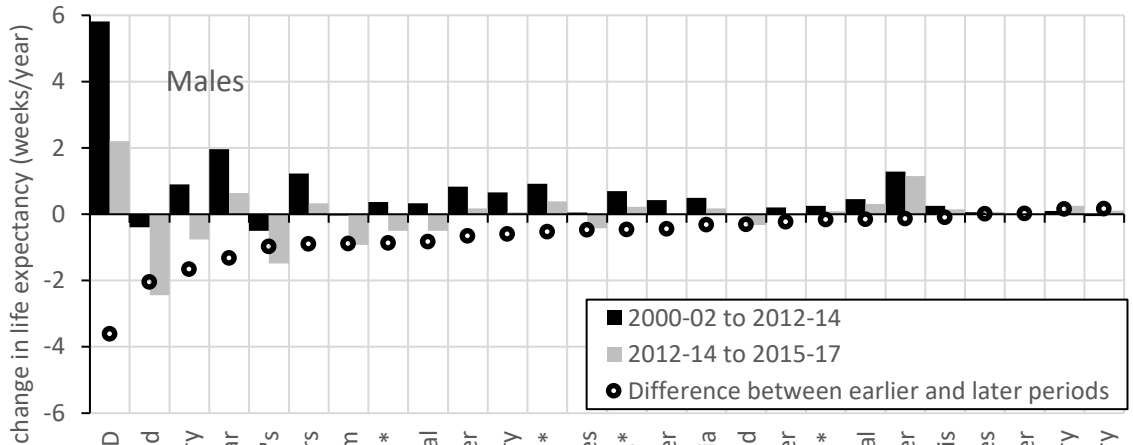
27 Sidney S, Quesenberry CP, Jaffe MG, *et al.* Recent trends in cardiovascular mortality in the United States and public health goals. *JAMA Cardiol* 2016;**1**:594–9. doi:10.1001/jamacardio.2016.1326

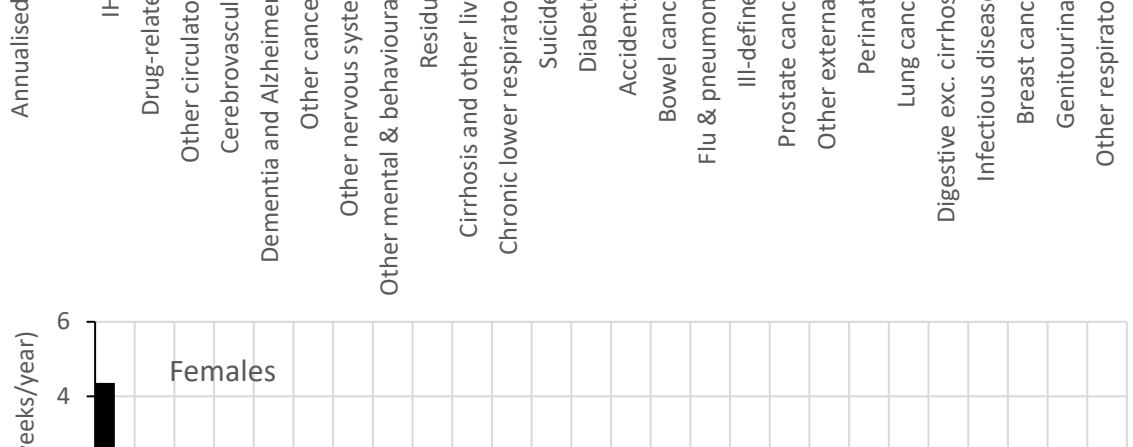
28 ONS. Changing trends in mortality: a cross-UK comparison, 1981 to 2016. Analysis of age-specific and age-standardised mortality rates for the UK, England, Wales, Scotland and Northern Ireland from 1981 to 2016. London: : Office for National Statistics 2018.

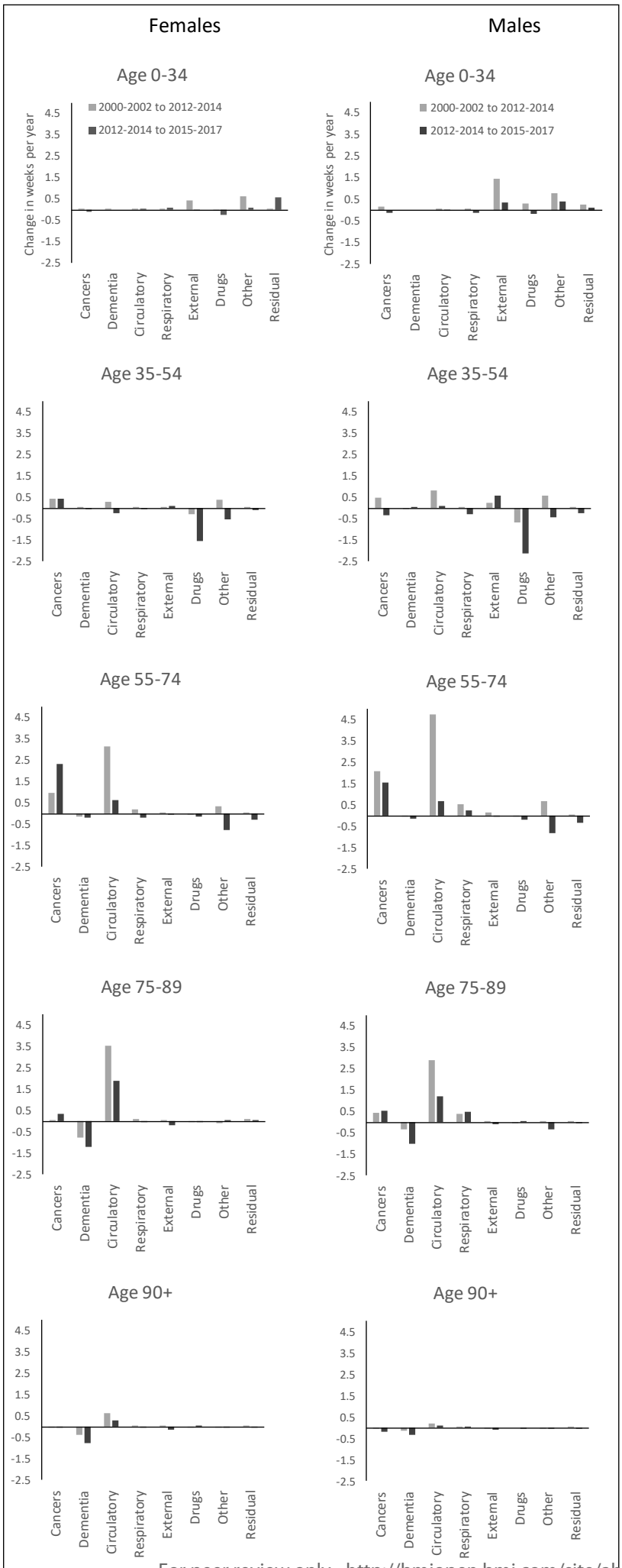


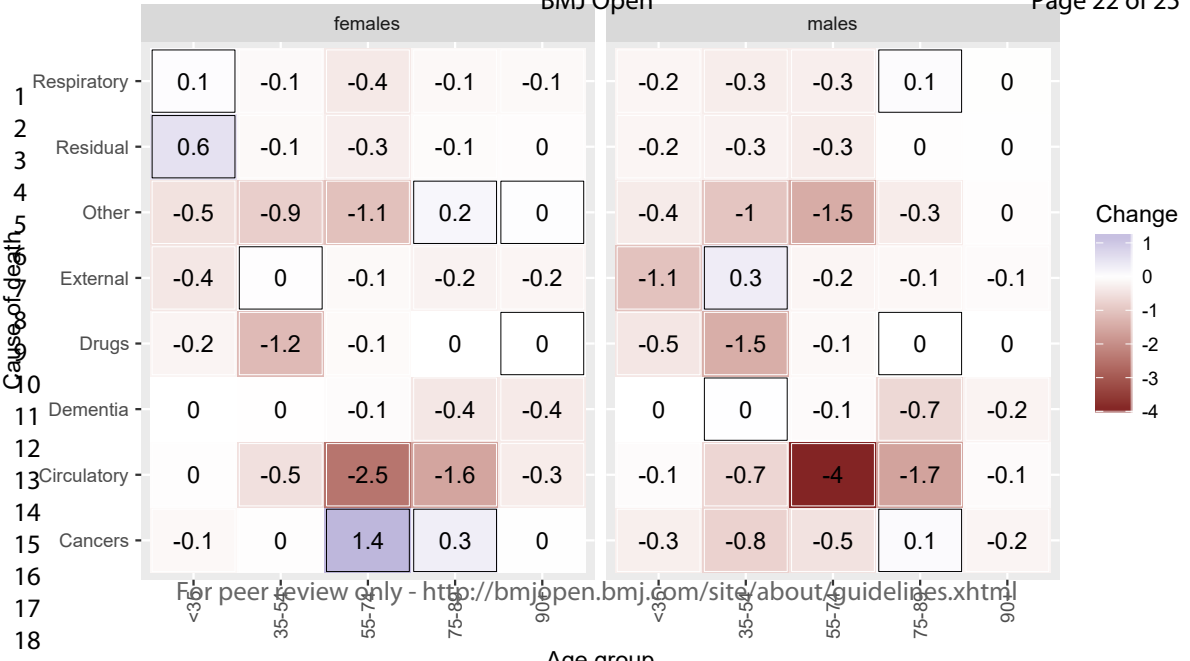

Males
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

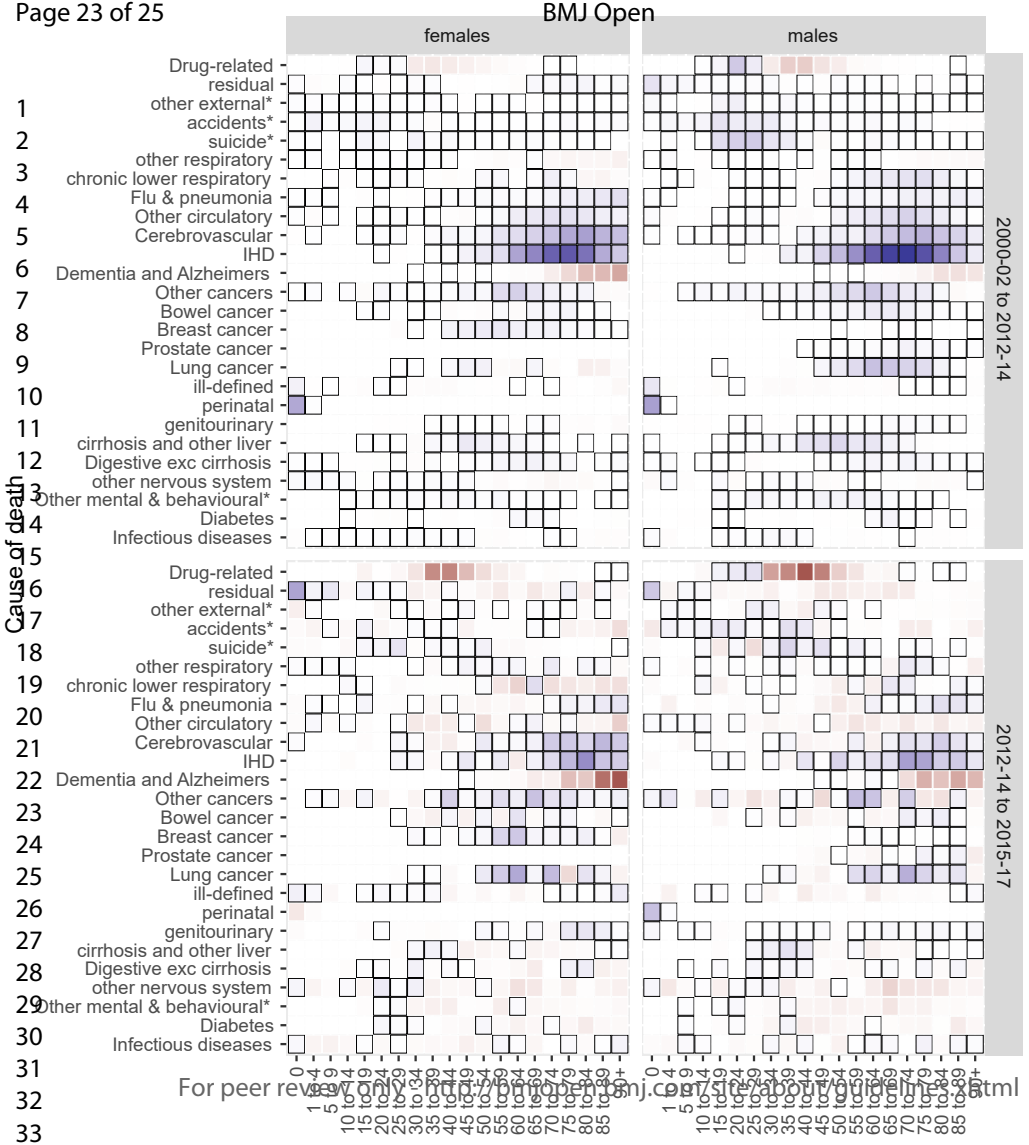

Females
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

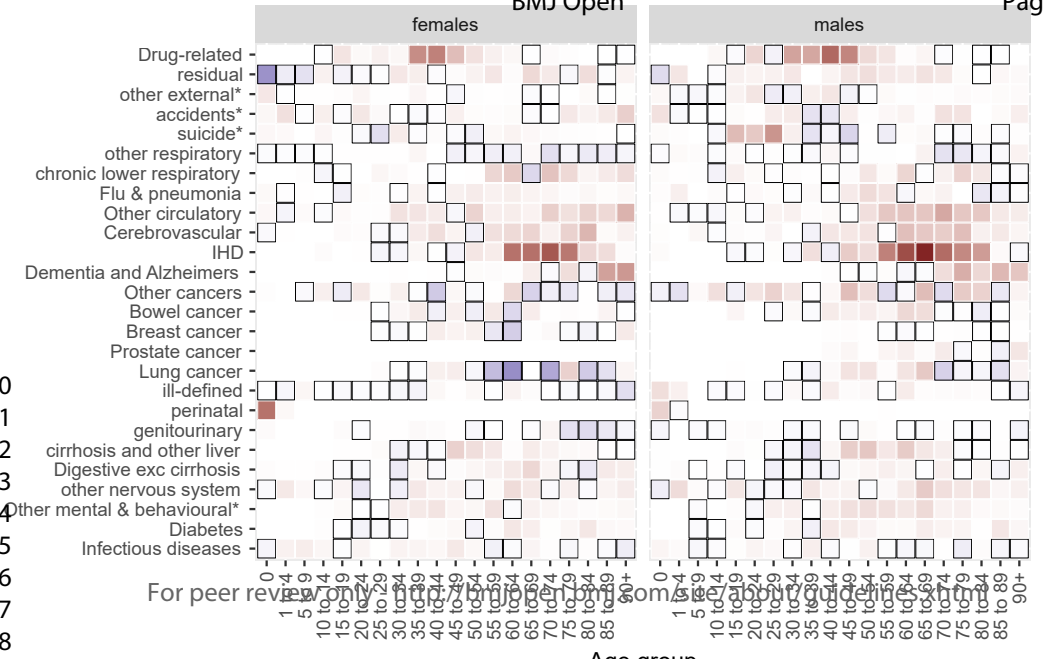

Males
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Other cancers
Other nervous system
Other mental & behavioural*
Residual
Cirrhosis and other liver
Chronic lower respiratory
Suicide*
Diabetes
Accidents*
Bowel cancer
Flu & pneumonia
Ill-defined
Prostate cancer
Other external*
Perinatal
Lung cancer
Digestive exc. cirrhosis
Infectious diseases
Breast cancer
Genitourinary
Other respiratory


Females
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Chronic lower respiratory
Accidents*
Other mental & behavioural*
Perinatal
Cirrhosis and other liver
Other nervous system
Flu & pneumonia
Digestive exc. cirrhosis
Diabetes
Infectious diseases
Other external*
Bowel cancer
Suicide*
Prostate cancer
Residual
Breast cancer
Ill-defined
Genitourinary
Other cancers
Other respiratory
Lung cancer









Web table 1: Categorisation of Causes of Death

#	Detailed Category (26)	ICD-10	Grouped Category (8)
1	Infectious diseases	A00-B99	Other
2	Lung cancer	C33-C34	Cancers
3	Prostate cancer	C61	Cancers
4	Breast cancer	C50	Cancers
5	Bowel cancer	C18-C21	Cancers
6	Other cancers	All other C codes	Cancers
7	Diabetes	E10-E14	Other
8	Dementia and Alzheimer's	F00, F01, F03, G30	Dementia and Alzheimer's
9	Mental and behavioural disorders excluding dementia *	All other F codes	Other
10	Nervous system diseases excluding Alzheimer's	All other G codes	Other
11	Ischaemic heart disease	I20-I25	Circulatory
12	Cerebrovascular	I60-I69	Circulatory
13	Other circulatory	All other I codes	Circulatory
14	Influenza and pneumonia	J09-J18	Respiratory
15	Chronic lower respiratory diseases	J40-J47	Respiratory
16	Other respiratory	All other J codes	Respiratory
17	Digestive excluding cirrhosis	K00-K69 K77-K99	Other
18	Cirrhosis and other diseases of the liver	K70-K76	Other
19	Genitourinary	N00-N99	Other
20	Perinatal conditions	P00-P96	Other
21	Ill-defined	R00-R99	Other
22	Suicide and injury/poisoning of undetermined intent *	X60-X84, Y10-Y34, Y87.0, Y87.2	External
23	Accidents *	V01-X59, Y85-Y86	External
24	Other external *	All other X&Y codes	External

25	Residual	All D Residual E codes All H All L All O All M All Q	Residual
26	Drug-related	F11-F15, F19, Plus X40-X44, X60-X64, X85, Y10-Y14 where an illegal drug was present in the body.	Drug-related

* excluding deaths which are also classified as drug-related.

As the drug-related codes overlap with mental and behavioural causes (exc. dementia) and external causes (suicides, accidents and other external), where a death would appear in both categories, we included it in the drug-related category only, and therefore the other 4 categories exclude drug-related deaths. This was done for two reasons: firstly, the interest in the impact of recent drug-related death trends; and secondly, because of ICD coding changes in 2011[1] there is a discontinuity in the figures for external causes and mental and behavioural causes. This change caused deaths which would previously have been coded as mental and behavioural causes to be coded as external causes. As this change occurred at a key point in the time period we are analysing, it would give misleading results on the relative impact of these causes on life expectancy growth. The coding change did not affect the figures for drug-related deaths, so by selecting these as a separate category, the discontinuity is avoided.

[1] https://www.nrscotland.gov.uk/files/statistics/vital-events/changes-to-coding-of-causes-of-death-between-2010-2011.pdf.

BMJ Open

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036529.R2
Article Type:	Original research
Date Submitted by the Author:	02-Jul-2020
Complete List of Authors:	Ramsay, Julie; National Records of Scotland, Vital Events Statistics Minton, Jon; NHS Health Scotland, Public Health Observatory Fischbacher, Colin; NHS National Services Scotland, NHS Information Services Division Fenton, Lynda; NHS Health Scotland, Public Health Observatory; NHS Greater Glasgow and Clyde, Public Health Kaye-Bardgett, Maria; National Records of Scotland, Vital Events Statistics Wyper, Grant; NHS Health Scotland, Public Health Observatory Richardson, Elizabeth; NHS Health Scotland, Public Health Observatory McCartney, Gerry; NHS Health Scotland, Public Health Science Directorate
Primary Subject Heading:	Public health
Secondary Subject Heading:	Health policy
Keywords:	PUBLIC HEALTH, Dementia < NEUROLOGY, Substance misuse < PSYCHIATRY, Ischaemic heart disease < CARDIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Julie Ramsay[1] MSc,*, Jon Minton[2] PhD, Colin Fischbacher[3] FFPH, Lynda Fenton[2 4] MPH, Maria Kaye-Bardgett[1] PhD, Grant MA Wyper[2] MSc, Elizabeth Richardson[2] PhD, Gerry McCartney[2] MD.

* Corresponding author. Email: julie.ramsay@nrscotland.gov.uk . Telephone: 0131 314 4330

[1] National Records of Scotland, Ladywell House, Ladywell Road, Edinburgh, Scotland, EH12 7TF.

[2] Public Health Observatory, NHS Health Scotland, 5 Cadogan Street, Glasgow, Scotland, G2 6QE.

[3] Information Services Division, NHS National Services Scotland, Gyle Square, 1 South Gyle Crescent, Edinburgh, EH12 9EB.

[4] Public Health Department, NHS Greater Glasgow & Clyde, West House, Gartnavel Royal Hospital Campus, 1055 Great Western Road, Glasgow, G12 0XH.

Abstract

Objective
Annual gains in life expectancy in Scotland were slower in recent years than in the previous two decades. This analysis investigates how deaths in different age-groups and from different causes have contributed to annual average change in life expectancy across two time periods: 2000-02 to 2012-14 and 2012-14 to 2015-17.

Setting
Scotland.

Methods
Life expectancy at birth was calculated from death and population counts, disaggregated by five-year age-group and by underlying cause of death. Arriaga's method of life expectancy decomposition was applied to produce estimates of the contribution of different age-groups and underlying causes to changes in life expectancy at birth for the two periods.

Results
Annualised gains in life expectancy between 2012-14 and 2015-17 were markedly smaller than in the earlier period. Almost all age-groups saw worsening mortality trends, which deteriorated for most cause of death groups between 2012-14 and 2015-17. In particular, the previously observed substantial life expectancy gains due to reductions in mortality from circulatory causes, which most benefited those aged 55-84 years, more than halved. Mortality rates for those aged 30-54 years and 90+ years worsened, due in large part to increases in drug-related deaths, and dementia and Alzheimer's disease respectively.

Conclusion
Future research should seek to explain the changes in mortality trends for all age-groups and causes. More investigation is required to establish to what extent shortcomings in the social security system and public services may be contributing to the adverse trends and preventing mitigation of the impact of other contributing factors, such as influenza outbreaks.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. JR and MK-B are salaried by NRS and GM, LF, JM, GW, CF and ER are salaried by the NHS.

Keywords
Life expectancy, decomposition, Scotland, mortality.

Article summary

Strengths and limitations of this study

- This is the first paper to describe the contribution of specific age-groups and causes of death to recent changes in life expectancy in Scotland.
- It uses a high quality dataset of deaths in which very few death registrations are missing and where less than 10% of deaths are coded using ill-defined causes.
- The results are limited to describing trends rather than explaining causal social and biological processes.
- The analysis does not identify the mechanism through which a given cause of death exerts an effect on life expectancy
- The analysis of cause of death within age-group required broad groupings of causes of death, which is likely to conflate diverse causal mechanisms

Introduction

Life expectancy improvement rates in Scotland have been slower since 2012-14 than in previous decades, the inequalities gradient across the deprivation scale has steepened, and age-standardised mortality rates have increased for those living in the most deprived areas, leading to widening health inequalities.[1,2] This comes against a background of consistently lower life expectancy in Scotland compared with the rest of Western Europe since the 1980s, and consistently worse socioeconomic inequalities in mortality.[3]

A similar slow-down since around 2012 in the long term trend of life expectancy has been observed across many high income countries.[2,4,5] Amongst 20 high-income countries, only the USA had a slower improvement in life expectancy than the UK in the most recent six years compared with the previous six years.[6] Continued improvements have been seen in some of the countries with the highest life expectancies, and amongst people living in more affluent areas, both of which undermine suggestions that the recent trends are due to a 'natural ceiling' being reached.[2,5]

Other explanations for the recent trends have included: that the UK, along with much of the rest of Western Europe, has experienced exceptionally high winter mortality;[7–9] that an increase in 'deaths of despair' – those from alcohol, drugs, and suicides – have offset broader health improvements;[10] that funding for health and social care services has not kept up with demand;[11,12]; and, relatedly, that austerity policies have impacted on health through mechanisms such as reduced social security payments and underemployment.[13,14] Such explanations are likely neither mutually exclusive nor exhaustive, and some (such as additional winter deaths and slowing improvements in ischaemic heart disease mortality) may plausibly result from other causes, such as increased pressure on healthcare services and associated unmet need.[15]

Many of the above explanations differ about how mortality changes for specific age-groups, and causes, have contributed to the overall slow-down in life expectancy growth. This includes increases in several countries in mortality from dementia/Alzheimer's disease, drug-related deaths and suicide and marked slow-downs in the previous rapid improvements in cardiovascular mortality.[9,10]

We aimed to explore the reasons for these recent changes by describing the contribution of specific age-groups and causes of death to the slow-down in life expectancy growth in Scotland in two successive time periods (2000-02 to 2012-14 and 2012-14 to 2015-17).

Methods

We used repeat cross-sectional data to undertake comparative decomposition analyses of life expectancy over time. The data used includes all deaths which occurred in Scotland from 2000 to 2017 (inclusive) as held by National Records of Scotland.

Period life expectancy at birth was calculated from abridged life tables available from National Records of Scotland for males and females separately, using three-years combined data to allow robust breakdowns by cause of death and age-group.[16] For the age-group decomposition, death counts and population data in five year age-groups were used, separating <1 year from 1-4 year olds and using 90+ years as the oldest age category. For the cause of death decomposition, International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) categories were grouped into 26 categories. These groupings are exclusive and exhaustive, and were developed on the basis that: at least the five leading causes of death should be separate categories; proposed and plausible contributory causes to life expectancy changes should be independent categories; and

that the residual group should overall make a small contribution to life expectancy changes. The leading causes of death categorisation used by the Office for National Statistics (ONS) was employed as the basis to determine groupings where appropriate.[17] Due to the overlaps between drug-related deaths and other causes (mental and behavioural excluding dementia, suicides, accidents and other external), for the purposes of this analysis these four causes exclude drug-related deaths (Supplementary file 3).

We calculated the changes in life expectancy between three-year rolling periods for males and females for the whole time series from 1980 before focusing on two time periods from 2000 onwards. (The tenth revision of ICD was implemented in 2000 in Scotland and data prior to this period is not consistent across the cause of death categories examined.) Life expectancy growth between 2000-02 and 2012-14 and between 2012-14 and 2015-17 was decomposed into age and cause components using Arriaga's method with the aid of syntax developed by Auger et al.[18,19] The break between the two periods was selected on the basis of the previously identified change in mortality trend which showed that the best estimate of when mortality rates changed to a slower rate of improvement was the year to 2012 quarter 4 for men and the year to 2014 quarter 2 for women.[2] As life expectancy data is based on three-year rolling periods, 2012-2014 was chosen to most accurately reflect this breakpoint. Life expectancy change and decomposition results are presented as annualised change in life expectancy (in weeks) to account for the different length of the two time periods. For the analysis of cause of death within age-group, the age and cause of death categories were aggregated into five mutually exclusive age-groups, and eight mutually exclusive cause-of-death groupings (40 age-cause groupings). A more detailed disaggregation (20 age-groups and 26 cause-of-death groups) is presented in Supplementary files 1 and 2.

Patient and public involvement

This research was done without direct patient or public involvement

Results

Rate of improvement in life expectancy

Life expectancy in Scotland had increased steadily until around 2012, but improvements have since stalled and life expectancy has decreased in recent years. Although the rate of improvement has fluctuated over time, it has rarely been as low as in the last few years, and any slower periods have not been sustained (Figure 1).

Decomposition of life expectancy changes by age and sex

In the earlier period (2000-02 to 2012-14) the annualised increase in male life expectancy was 16.3 weeks/year. However, during the later period (2012-14 to 2015-17) male life expectancy fell by an average of 1.1 weeks/year. During the earlier period, all age-groups contributed to increases in life expectancy (Figure 2) though the greatest contribution (61% of the increase) came from the 55-79 year age-group. During the later period, males aged 40-54 years and 90+ years made substantial negative contributions to overall changes in life expectancy. Although still contributing positively to life expectancy growth in the later period, mortality improvement among 55-84 year old males declined markedly and contributed considerably to the slowing of life expectancy growth. There was a notable reduction in the rate of improvement for males aged 15-34 years, although the smaller number of deaths at these ages meant that this made a smaller contribution to the overall change in life expectancy. There were also small but noticeable declines in the rate of improvement for infants and children aged 1-4 years.

Patterns across age-groups were similar for females, although both the rates of improvement and the scale of change were smaller than for males (Figure 2). During the earlier period female life

expectancy grew by 10.0 weeks/year, with mortality improvements in all age-groups. The largest contributions to the increase (64%) came from the 60-84 year age-group. During the later period the annualised improvement in life expectancy declined to less than 0.1 weeks/year. For those aged 30-49 years and 85+ years, mortality rates worsened. Mortality improvements amongst those aged 60-84 years were very much reduced compared to the earlier period. There was also slowing in improvements for infants, children aged 1-4 years and 10-14 year olds.

Decomposition by detailed cause of death

For males, the single largest cause of the slow-down in life expectancy growth was slower improvements in ischaemic heart disease (IHD) mortality (Figure 3). In the earlier period reductions in IHD mortality added 5.8 weeks/year to male life expectancy; in the later period they added only 2.2 weeks per year. Drug-related deaths made the second biggest contribution for males, changing from a small negative impact (-0.4 weeks/year) in the earlier period to a much larger negative impact (-2.4 weeks/year) afterwards. Other circulatory diseases, cerebrovascular disease, dementia and Alzheimer's disease also made substantial contributions to the slow-down. Only two causes, 'other respiratory' and genitourinary, contributed more to male life expectancy growth after 2012-14 than before.

For females, the same broad causes had the largest impact on life expectancy growth, although again the scale of change was smaller than for males. The single largest cause of the slow-down in life expectancy growth was IHD mortality. As in males, drug-related deaths had the second biggest impact on life expectancy, changing from a small negative impact in the earlier period to a much larger negative impact in the later one. Improvements in mortality from other circulatory causes reversed in the later time period. For cerebrovascular disease there was a marked decline in the rate of improvement between the two time periods. Dementia and Alzheimer's disease mortality worsened from the earlier period. For some causes female mortality improved after 2012-14, making a positive contribution to life expectancy growth; these included lung cancer, other respiratory causes, other cancers, genitourinary, ill-defined causes and breast cancer.

Decomposition by age and broad causes of death

The contributions of different causes of death to life expectancy trends varied across age-groups but were generally similar between males and females. For those aged <35 years, improvements in mortality from external causes made the greatest single contribution to the positive trend in the earlier period (2000-02 to 2012-14). In the later period (2012-14 to 2015-17) this fell to 0.3 weeks/year for males and disappeared for females. Mortality rates for drug-related deaths and cancers increased slightly in the later time period for those aged <35 years (Figure 4).

For those aged 35-54 years, the overall negative contribution to life expectancy changes was due both to substantial reductions in the rate of improvement for some causes of death (including circulatory causes) and absolute increases in mortality for others (such as drug-related deaths, cancers and other causes; Figures 4 and 5).

Although the overall contribution to life expectancy of those aged 55-74 years remained positive in the later period, the dramatic decline in the positive contribution of this age-group is important in explaining overall trends (Figure 2). Much of this decline was explained by the much slower improvement in deaths from circulatory causes in the later compared with the earlier period.

Improvements in cancer mortality slowed among males but increased markedly among females. For both males and females, deaths due to dementia, drugs and other causes all made negative contributions in the later time period to life expectancy growth (Figures 4 and 5).

The contributions of broad causes of death to trends in life expectancy amongst those aged 75-89 years was similar to that of those aged 55-74 years, but the negative contribution of dementia and Alzheimer's disease increased in the later period. Improvements in mortality from circulatory causes fell substantially. Positive trends in cancer mortality improved further for both males and females between the earlier and later periods (Figures 4 and 5).

Amongst the oldest age-group (90+ years), the small overall contribution to life expectancy growth changed from positive to negative between the earlier and later time periods (Figure 2). This was due to worsening mortality due to dementia as well as a slowing in the rate of improvement due to circulatory causes (Figures 4 and 5).

More detailed age-groups and causes of death are presented in supplementary files 1 and 2. These show that mortality in the first year of life from causes of death originating in the perinatal period has improved at a slower rate since 2012-14 for males and has worsened slightly for females (although given the relatively small numbers and the fact that this has not occurred for both sexes, this finding should be treated with caution). The detailed findings also indicate that the increasingly negative contribution of drug-related deaths to life expectancy trends is mainly concentrated among 35-44 year olds for females and 40-49 year olds for males. The slow-down of improvements in IHD mortality is mainly concentrated in 60-69 year old males and 65-74 year old females; the negative contribution of suicides is concentrated in 25-29 year old males, and the rising contribution of dementia and Alzheimer's disease is concentrated in the oldest age-groups.

Discussion

Main results

Life expectancy in Scotland steadily improved from the early 1980s until 2012-14, after which the rate of improvement slowed, followed by declines in life expectancy between 2014-16 and 2015-17. Between 2000-02 and 2012-14, annualised increases in male and female life expectancy were 16.3 and 10.0 weeks/year respectively, but this changed to a decline of 1.1 weeks/year for males and to a very small increase of less than 0.1 weeks/year for females between 2012-14 and 2015-17. In the earlier period most of the increases in life expectancy were due to falling mortality amongst those aged 55-84 years, although mortality rates declined for all age-groups. In the later period declines in mortality were slower for all age-groups, particularly those aged 55-84 years. Mortality increased for males aged 30-54 years, females aged 35-49 years and both males and females aged 90+ years.

Almost all causes of death demonstrated a change in trend in the recent period. Although mortality due to IHD and cerebrovascular disease continued to decline in the later period, life expectancy gains due to these conditions were less than half of those in the earlier period. This affected all age-groups, but was particularly important in explaining the slowing in improvement for those aged 55-74 years, and to a lesser extent those aged 35-54 years. Mortality from drug-related causes and from dementia and Alzheimer's disease, which were already making negative contributions to life expectancy in the earlier period, made larger negative contributions after 2012-14. The previous favourable trends in mortality from other circulatory causes reversed. The increase in drug-related deaths was particularly important in explaining increasing mortality amongst those aged 35-54 years, whilst increases in dementia and Alzheimer's disease mortality substantially explained trends among those aged 90+ years.

Strengths and limitations

The key strengths of this analysis are the use of a complete mortality dataset for the whole population which reduces the risk of bias from missing data or selection biases. Less than 10% of deaths in Scotland are coded using ill-defined causes. We also use standard decomposition analysis (Arriaga) methods that are thereby comparable to estimates produced for other populations. The analysis is limited to the use of cause of death codes which do not illuminate the overall social causation and mechanisms leading to mortality – this is the subject of other work. We also had to use broad grouping of death codes within age groups to improve the precision of our estimates which is likely to conflate diverse causal mechanisms.

How this compares with existing research

The stalling in life expectancy trends in Scotland is of a similar magnitude to the rest of the UK and USA, but greater than in some other parts of Europe.[2,4,5] Much of the initial research describing recent slowing in life expectancy gains has focused on the role of influenza and mortality amongst the oldest age-groups.[9,20] Although we report increases in deaths due to influenza and respiratory causes, and rising mortality amongst those aged 90+ years, these results show that the contribution they make to explaining the overall slowing in life expectancy growth in Scotland is small. This is consistent with other studies in England & Wales and the USA which report that slowing improvements for IHD and cerebrovascular disease and increases in mortality for other circulatory causes among 55-84 year olds and drug-related deaths for adults aged 35-49 years, all make substantial contributions to the overall trends.[21–25] The slightly slower rate of improvement in the most recent period for women compared to men indicates that the long-term closing of the sex gap seems to be continuing.

There is evidence that the increase in drug-related deaths in Scotland is due in part to a cohort effect amongst males who were young adults during the 1980s.[26] Some recent trends may therefore be attributable to historical exposures to political and social change at that time and before, whereby risk of mortality accumulates over time within that cohort.] [3,26]

The reasons for slowing improvements in cardiovascular disease mortality is not clear. Possible explanations might include slowing of progress in reducing exposure to tobacco, increases in the prevalence of obesity, changes in psychosocial risk factors related to economic insecurity or deterioration in access to, or the quality of, health and social care services.[27] This should be the focus of further specific work to understand the timing and reasons for the stalling.[28]

The increase in mortality from dementia and Alzheimer's disease has been attributed to a number of factors, including: people living longer and surviving other illnesses;[29] increased awareness of dementia, making it more likely to be diagnosed and recorded;[9,25] and NHS policies encouraging dementia diagnosis.[25] Changes in death certification practices have also been cited as one of the reasons for increase in deaths from dementia and Alzheimer's disease,[6] although it should be noted that these changes did not occur in Scotland until 2017 so will have had a limited impact on these results.

Implications

Several hypotheses have been proposed to explain recent life expectancy trends in Scotland and other high income countries.[15] Further research should include work to understand the mechanisms and processes underlying the changes at different life-course stages: the considerable rise in drug-related deaths among working-age adults; the substantial slow-down in improvements for IHD, cerebrovascular disease and other circulatory causes; and the rise in mortality from dementia and Alzheimer's disease amongst those aged 90+ years.

The recent change in life expectancy trends represents a very substantial mortality impact which needs to be reflected in the level of priority given to understanding this further. Mortality has worsened (through slowing improvements or mortality increases) across many age-groups and causes, so it is unlikely that any single factor provides sufficient explanation. The extent to which there is a common underlying cause or exposure affecting each of these age-groups should be prioritised for further investigation.

Figure 1 – Life Expectancy and annual change in life expectancy, 1980-82 to 2015-17, by sex, Scotland

Figure 2 – Decomposition of changes in life expectancy between 2002-02 to 2012-14, and from 2012-14 to 2015-17, by sex, Scotland

Figure 3 – Decomposition of the contribution of specific causes of death to changes in life expectancy between 2000-02 and 2012-14 and between 2012-14 and 2015-17, by sex, Scotland

*Excluding causes that are included under drug-related deaths.

Figure 4 - Decomposition of changes in life expectancy by grouped age and cause of death, 2000-02 to 2012-14 and 2012-14 to 2015-17, by sex, Scotland

Figure 5 - Decomposition of change in life expectancy growth pre and post 2012-14 by grouped age and cause of death, by sex, Scotland

Note: values in cells indicate the difference in contribution to life expectancy change between the two periods, in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Contributorship statement

LF and GM conceived the idea for this study. JR, MK-B and JM undertook the analyses. GM and JR drafted the manuscript. CF, GW and ER along will all other authors made substantial contributions to interpretation of results and editing the manuscript, and all approved the final draft.

Data availability statement

Life expectancy data and mortality breakdowns by cause of death and age are available on the National Records of Scotland website (www.nrscotland.gov.uk). Breakdowns by detailed cause of death are available on request from Julie.ramsay@nrscotland.gov.uk

Funding statement

No specific funding was received for this work. All authors are salaried employees of National Records of Scotland or the NHS.

Declaration of Interests

The authors declare that they have no competing interests. No funding was received for this work.

Ethics

No new data were collected in this study and there was no public or patient involvement. We used mortality data made available to us by National Records of Scotland and adhered to our standard procedures to protect against disclosure.

References

1 Fenton L, Wyper GM, McCartney G, *et al.* Socioeconomic inequality in recent adverse all-cause mortality trends in Scotland. *J Epidemiol Community Health* 2019;**73**:971–4. doi:10.1136/jech-2019-212300

2 Fenton L, Minton J, Ramsay J, *et al.* Recent adverse mortality trends in Scotland: comparison with other high-income countries. *BMJ Open* 2019;**9**:e029936. doi:10.1136/bmjopen-2019-029936

3 Walsh D, McCartney G, Collins C, *et al.* History, politics and vulnerability: explaining excess mortality in Scotland and Glasgow. Glasgow: 2106.

4 Ho JY, Hendi AS. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ* 2018;:k2562. doi:10.1136/bmj.k2562

5 Raleigh V. Stalling life expectancy in the UK | The King's Fund. 2018.https://www.kingsfund.org.uk/publications/stalling-life-expectancy-uk (accessed 20 Feb 2019).

6 Office for National Statistics. Changing trends in mortality: an international comparison: 2011 to 2016. 2018. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/changingtrendsinmortalityaninternationalcomparison/2000to2016

7 Molbak K, Espenhain L, Nielsen J, *et al.* Excess mortality among the elderly in European countries, December 2014 to February 2015. *Euro Surveill* 2015;**20**.http://www.ncbi.nlm.nih.gov/pubmed/25811643

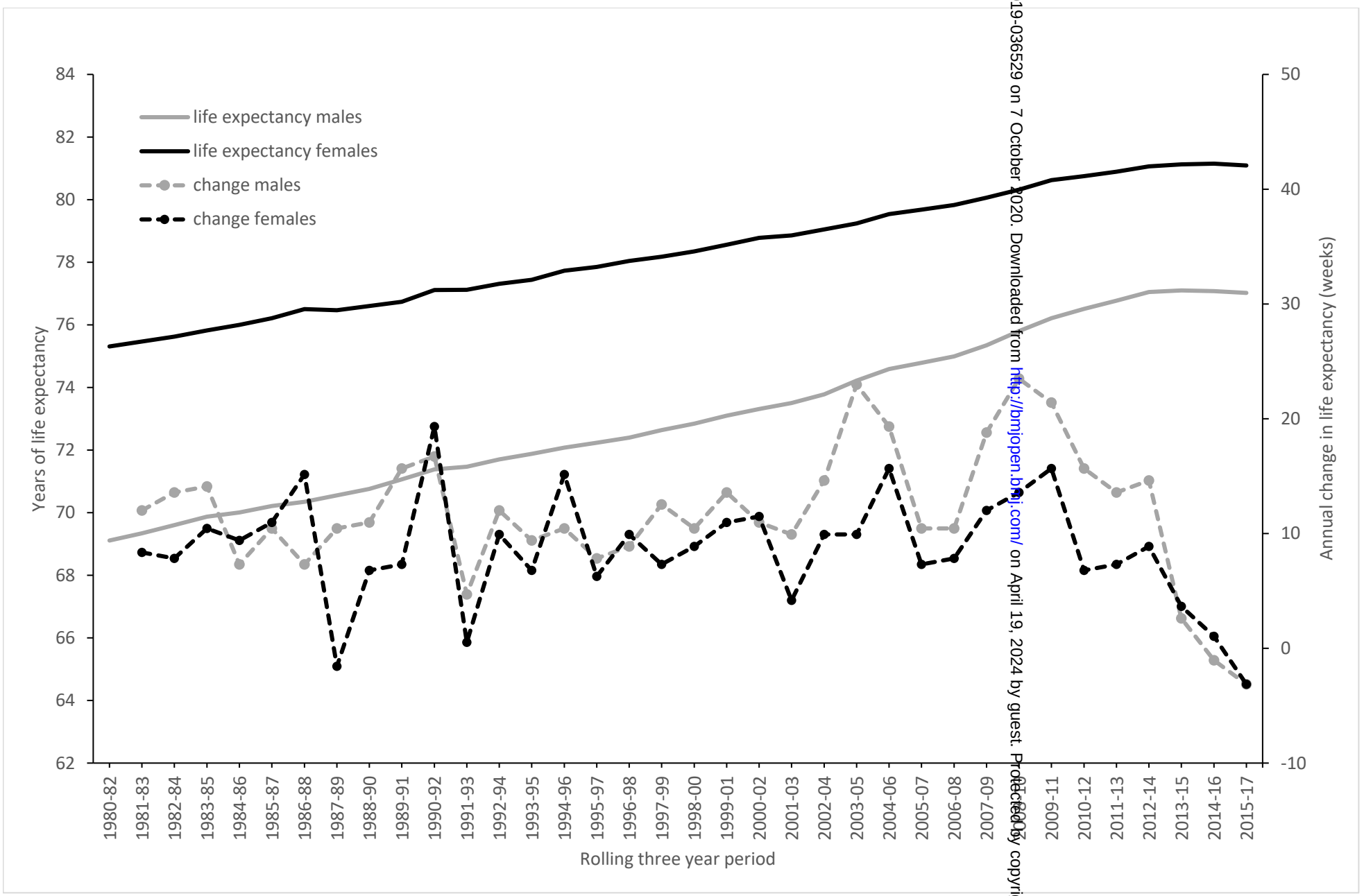
8 Vestergaard LS, Nielsen J, Krause TG, *et al.* Excess all-cause and influenza-attributable mortality in Europe, December 2016 to February 2017. *Euro Surveill* 2017;**22**. doi:https://doi.org/10.2807/1560-7917.ES.2017.22.14.30506

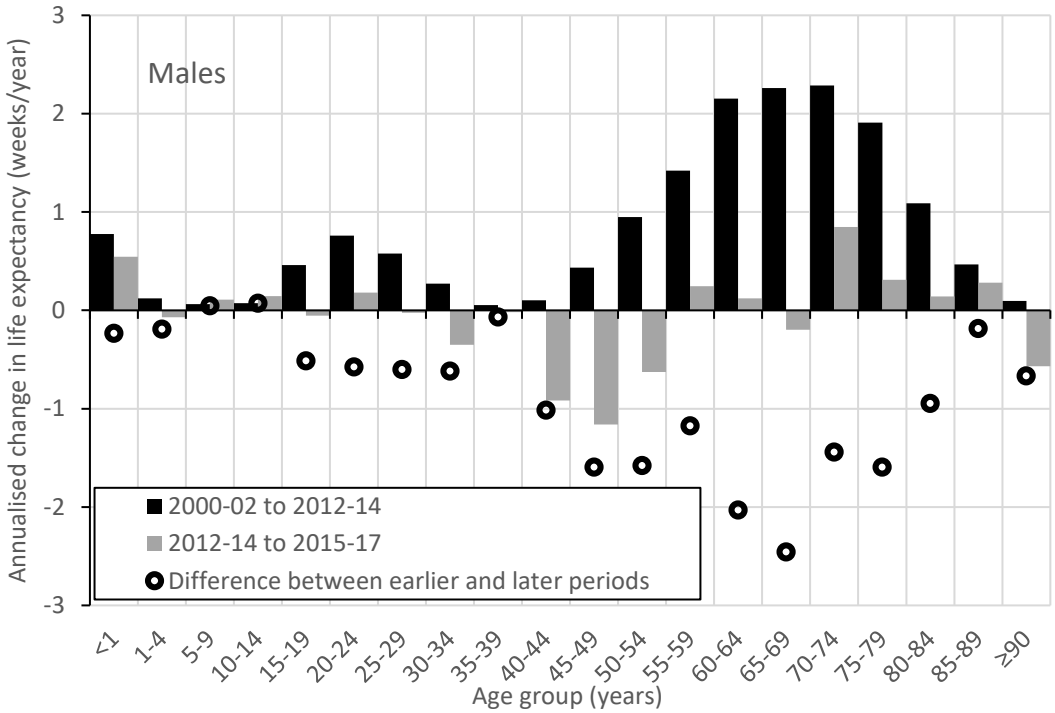
9 PHE. A review of recent trends in mortality in England. London: : Public Health England 2018.

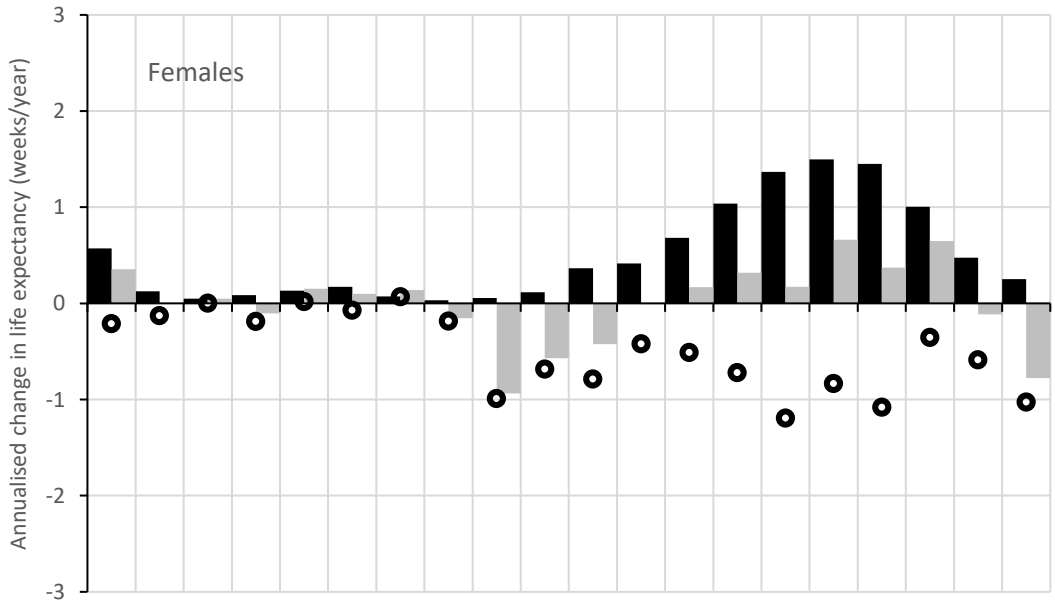
10 Steel N, Ford JA, Newton JN, *et al.* Changes in health in the countries of the UK and 150 English Local Authority areas 1990–2016: a systematic analysis for the Global Burden of

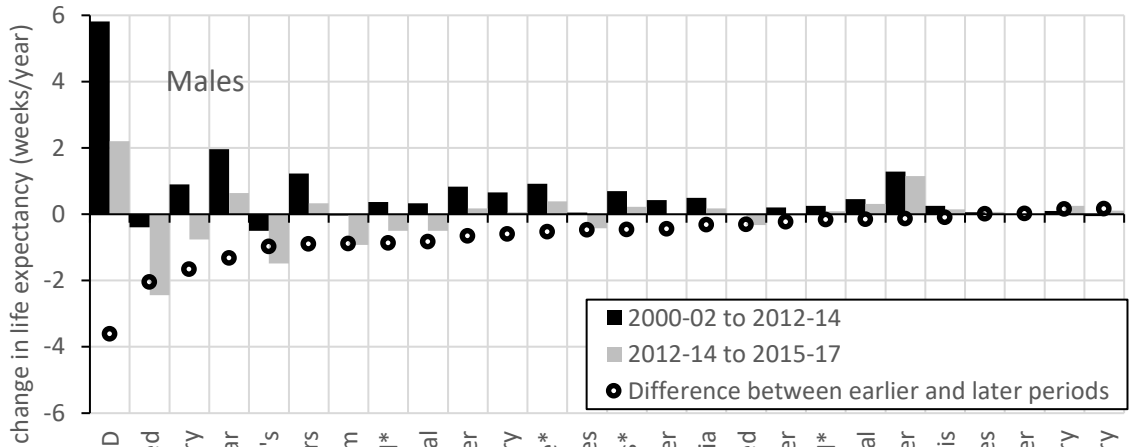
Disease Study 2016. *Lancet* 2018;**392**:1647–61. doi:10.1016/S0140-6736(18)32207-4
11 Watkins J, Wulaningsih W, Da Zhou C, *et al.* Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017;**7**:e017722. doi:10.1136/bmjopen-2017-017722
12 Currie J, Guzman Castillo M, Adekanmbi V, *et al.* Evaluating effects of recent changes in NHS resource allocation policy on inequalities in amenable mortality in England, 2007–2014: time-series analysis. *J Epidemiol Community Health* 2019;**73**:162–7. doi:10.1136/jech-2018-211141
13 Hiam L, Dorling D, McKee M. Rise in mortality—when will the government take note? *BMJ* 2018;:k2747. doi:10.1136/bmj.k2747
14 Taulbut M, Agbato D, McCartney NHS Health Scotland G. Working and hurting? Monitoring the health and health inequalities impacts of the economic downturn and changes to the social security system. 2018. http://www.healthscotland.scot/media/2147/working-and-hurting-sep-2018-english.pdf (accessed 25 Sep 2018).
15 Fenton L. Mortality trends workshop 13th November 2018 – short report and presentations. ScotPHO. 2018.https://www.scotpho.org.uk/publications/reports-and-papers/mortality-trends-workshop-13th-november-2018-short-report-and-presentations/
16 National Records of Scotland. Life Tables for Scotland 2015-2017. Natl. Rec. Scotl. 2018.https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/life-expectancy/life-expectancy-at-scotland-level/scottish-national-life-tables/2015-2017 (accessed 1 Oct 2018).
17 Office for National Statistics. Leading causes of death in England and Wales (revised 2016) - Office for National Statistics. 2016.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/methodologies/userguidetomortalitystatistics/leadingcausesofdeathinenglandandwalesrevised2016 (accessed 23 Oct 2018).
18 Arriaga EE. Measuring and Explaining the Change in Life Expectancies. *Demography* 1984;**21**:83. doi:10.2307/2061029
19 Auger N, Feuillet Msc P, Martel Msc S, *et al.* Mortality inequality in populations with equal life expectancy: Arriaga's decomposition method in SAS, Stata, and Excel. *Ann Epidemiol* 2014;**24**:575-580.e1. doi:10.1016/j.annepidem.2014.05.006
20 Pebody RG, Green HK, Warburton F, *et al.* Significant spike in excess mortality in England in winter 2014/15 - influenza the likely culprit. *Epidemiol Infect* 2018;**146**:1106–13. doi:10.1017/S0950268818001152
21 Acciai F, Firebaugh G. Why did life expectancy decline in the United States in 2015? A gender-specific analysis. *Soc Sci Med* 2017;**190**:174–80. doi:10.1016/j.socscimed.2017.08.004
22 Bennett JE, Pearson-Stuttard J, Kontis V, *et al.* Contributions of diseases and injuries to widening life expectancy inequalities in England from 2001 to 2016: a population-based analysis of vital registration data. *Lancet Public Heal* 2018;**3**:e586–97. doi:10.1016/S2468-2667(18)30214-7
23 Duffy M, Robinson A, Laverty C. Health Inequalities - Life Expectancy Decomposition 2017. 2012. http://www.health-ni.gov.uk/topics/dhssps-statistics-and-research/health-inequalities-statisticswww.nisra.gov.uk (accessed 25 Sep 2018).
24 Remund A, Camarda CG, Riffe T. A Cause-of-Death Decomposition of Young Adult Excess Mortality. *Demography* 2018;**55**:957–78. doi:10.1007/s13524-018-0680-9
25 Public Health England. Recent trends in mortality in England: review and data packs - GOV.UK. 2018.
26 Parkinson J, Minton J, Lewsey J, *et al.* Drug-related deaths in Scotland 1979-2013: Evidence of a vulnerable cohort of young men living in deprived areas. *BMC Public Health* 2018;**18**. doi:10.1186/s12889-018-5267-2
27 Sidney S, Quesenberry CP, Jaffe MG, *et al.* Recent trends in cardiovascular mortality in the United States and public health goals. *JAMA Cardiol* 2016;**1**:594–9.

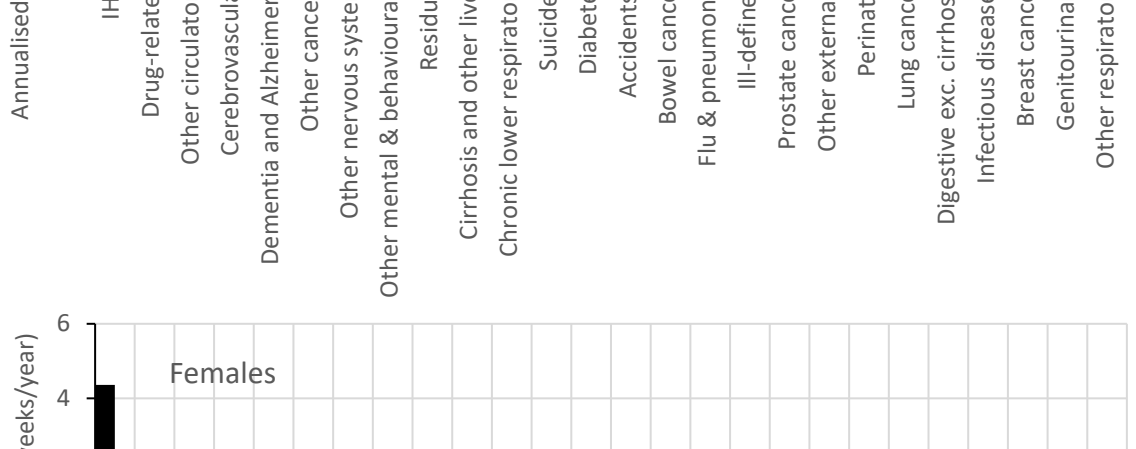
doi:10.1001/jamacardio.2016.1326
28 OECD/The King's Fund. Is Cardiovascular Disease Slowing Improvements in Life Expectancy?: OECD and The King's Fund Workshop Proceedings. OECD Publishing 2020. doi:10.1787/47a04a11-en
29 ONS. Changing trends in mortality: a cross-UK comparison, 1981 to 2016. Analysis of age-specific and age-standardised mortality rates for the UK, England, Wales, Scotland and Northern Ireland from 1981 to 2016. London: : Office for National Statistics 2018.

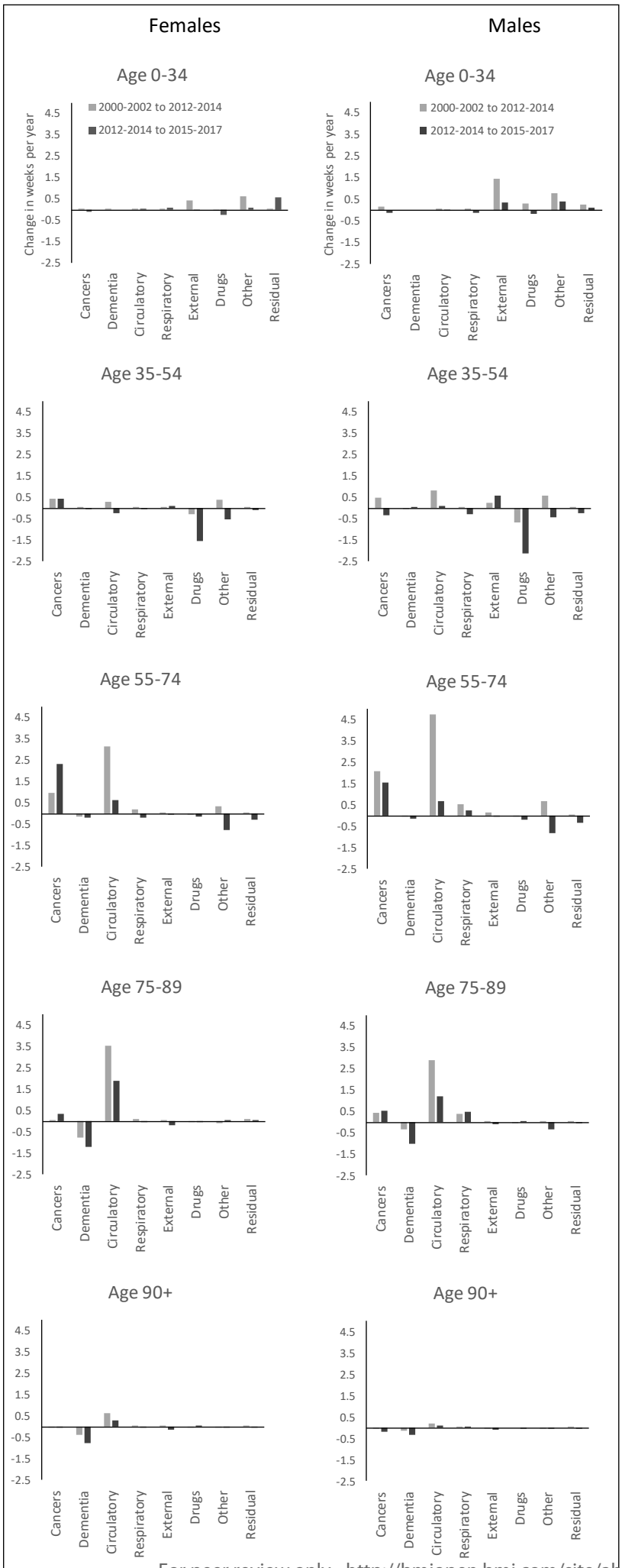


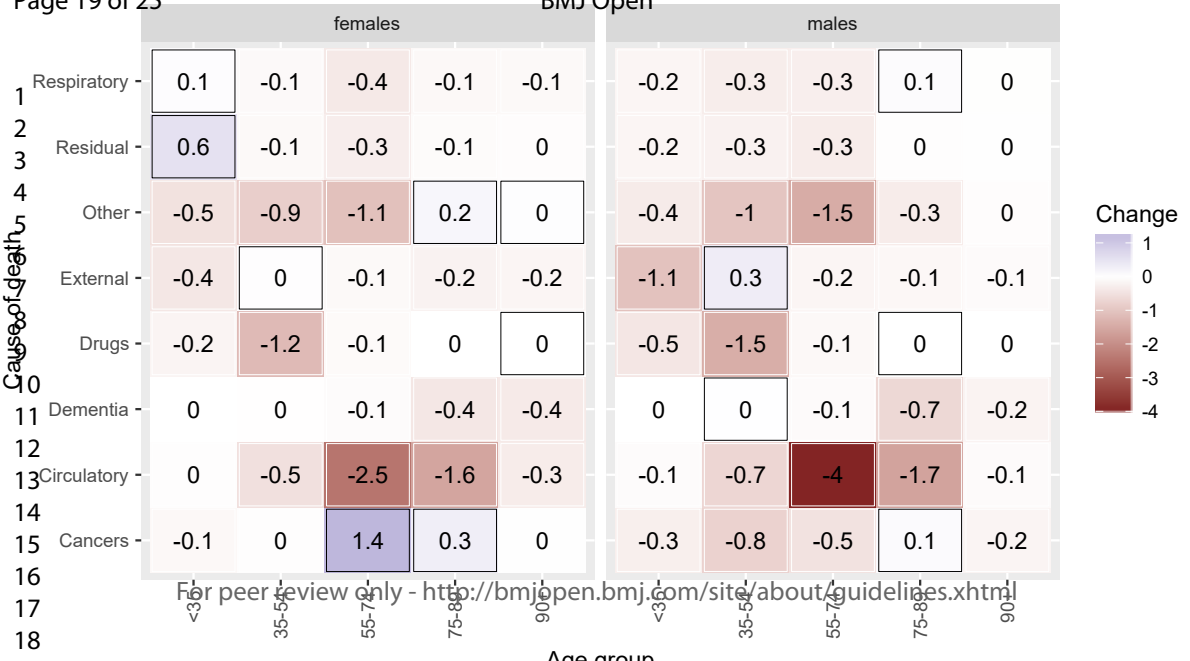

Males
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

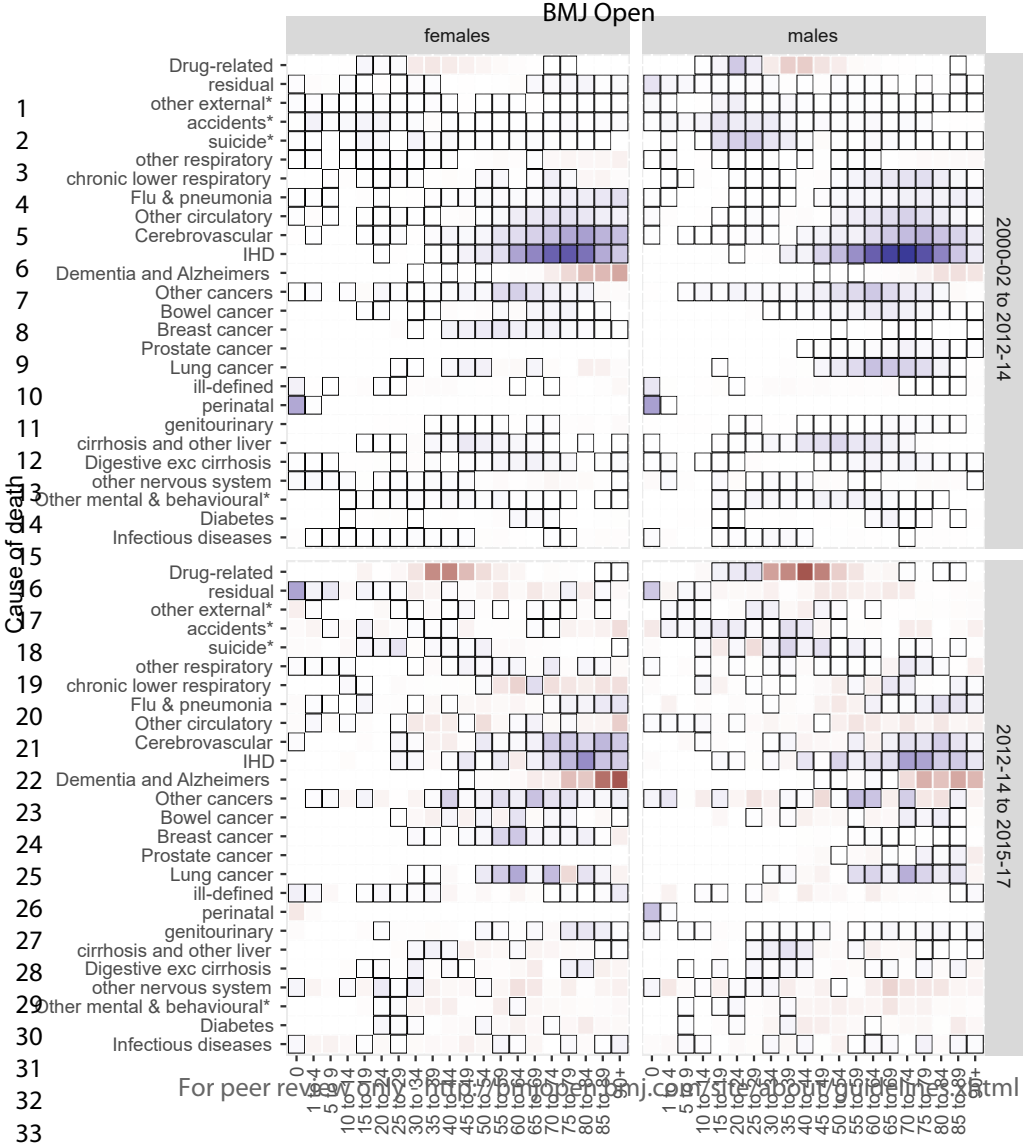

Females
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)

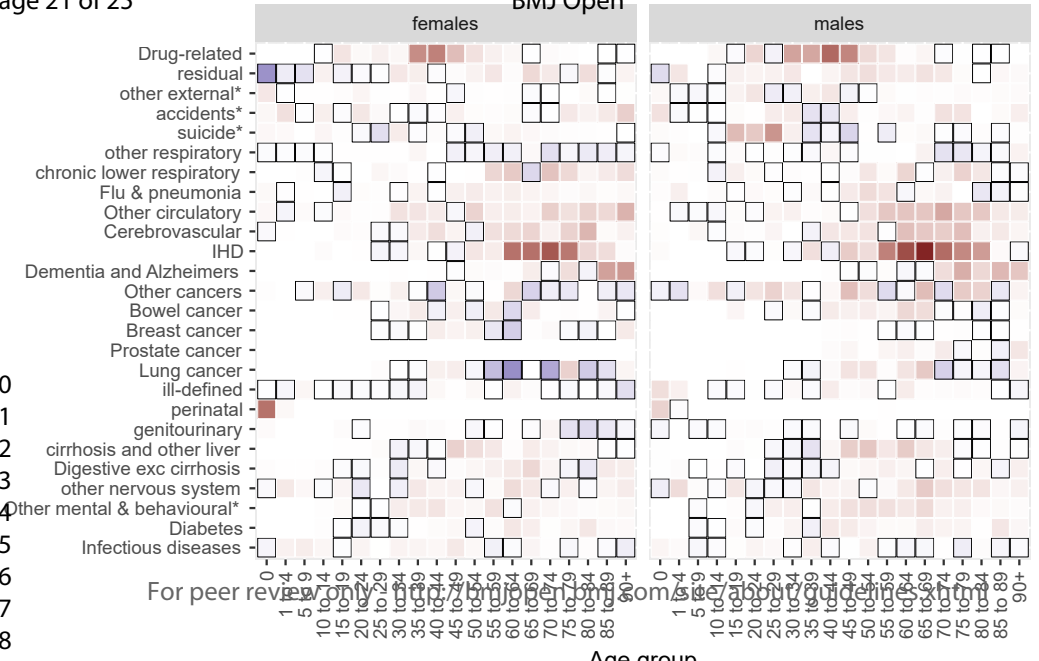

Males
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Other cancers
Other nervous system
Other mental & behavioural*
Residual
Cirrhosis and other liver
Chronic lower respiratory
Suicide*
Diabetes
Accidents*
Bowel cancer
Flu & pneumonia
Ill-defined
Prostate cancer
Other external*
Perinatal
Lung cancer
Digestive exc. cirrhosis
Infectious diseases
Breast cancer
Genitourinary
Other respiratory


Females
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Chronic lower respiratory
Accidents*
Other mental & behavioural*
Perinatal
Cirrhosis and other liver
Other nervous system
Flu & pneumonia
Digestive exc. cirrhosis
Diabetes
Infectious diseases
Other external*
Bowel cancer
Suicide*
Prostate cancer
Residual
Breast cancer
Ill-defined
Genitourinary
Other cancers
Other respiratory
Lung cancer


Females
Males
Age 0-34
Age 35-54
Age 55-74
Age 75-89
Age 90+
2000-2002 to 2012-2014
2012-2014 to 2015-2017
Change in weeks per year
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
Cancers
Dementia
Circulatory
Respiratory
External
Drugs
Other
Residual







Web table 1: Categorisation of Causes of Death

#	Detailed Category (26)	ICD-10	Grouped Category (8)
1	Infectious diseases	A00-B99	Other
2	Lung cancer	C33-C34	Cancers
3	Prostate cancer	C61	Cancers
4	Breast cancer	C50	Cancers
5	Bowel cancer	C18-C21	Cancers
6	Other cancers	All other C codes	Cancers
7	Diabetes	E10-E14	Other
8	Dementia and Alzheimer's	F00, F01, F03, G30	Dementia and Alzheimer's
9	Mental and behavioural disorders excluding dementia *	All other F codes	Other
10	Nervous system diseases excluding Alzheimer's	All other G codes	Other
11	Ischaemic heart disease	I20-I25	Circulatory
12	Cerebrovascular	I60-I69	Circulatory
13	Other circulatory	All other I codes	Circulatory
14	Influenza and pneumonia	J09-J18	Respiratory
15	Chronic lower respiratory diseases	J40-J47	Respiratory
16	Other respiratory	All other J codes	Respiratory
17	Digestive excluding cirrhosis	K00-K69 K77-K99	Other
18	Cirrhosis and other diseases of the liver	K70-K76	Other
19	Genitourinary	N00-N99	Other
20	Perinatal conditions	P00-P96	Other
21	Ill-defined	R00-R99	Other
22	Suicide and injury/poisoning of undetermined intent *	X60-X84, Y10-Y34, Y87.0, Y87.2	External
23	Accidents *	V01-X59, Y85-Y86	External
24	Other external *	All other X&Y codes	External

25	Residual	All D Residual E codes All H All L All O All M All Q	Residual
26	Drug-related	F11-F15, F19, Plus X40-X44, X60-X64, X85, Y10-Y14 where an illegal drug was present in the body.	Drug-related

* excluding deaths which are also classified as drug-related.

As the drug-related codes overlap with mental and behavioural causes (exc. dementia) and external causes (suicides, accidents and other external), where a death would appear in both categories, we included it in the drug-related category only, and therefore the other 4 categories exclude drug-related deaths. This was done for two reasons: firstly, the interest in the impact of recent drug-related death trends; and secondly, because of ICD coding changes in 2011[1] there is a discontinuity in the figures for external causes and mental and behavioural causes. This change caused deaths which would previously have been coded as mental and behavioural causes to be coded as external causes. As this change occurred at a key point in the time period we are analysing, it would give misleading results on the relative impact of these causes on life expectancy growth. The coding change did not affect the figures for drug-related deaths, so by selecting these as a separate category, the discontinuity is avoided.

[1] https://www.nrscotland.gov.uk/files/statistics/vital-events/changes-to-coding-of-causes-of-death-between-2010-2011.pdf.

STROBE Statement

	Item No	Recommendation	Location with manuscript
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title includes 'Comparative decomposition analysis'
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Contained within the methods and results section of the abstract.
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Contained within the introduction.
Objectives	3	State specific objectives, including any prespecified hypotheses	The objective of the study is stated in the last sentence of the introduction.
Methods			
Study design	4	Present key elements of study design early in the paper	The first sentence of the methods describes this.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	This is described in detail in the third paragraph of the methods.
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	This is included in the second sentence of the methods.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	This is not applicable for our manuscript.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	This is detailed in the second paragraph of the methods.
Bias	9	Describe any efforts to address potential sources of bias	Our study is descriptive but the limitations of the data are described in the discussion section.
Study size	10	Explain how the study size was arrived at	Not applicable to our study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	This is detailed in the second paragraph of the methods.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	This is detailed in the third paragraph of the methods.
		(*b*) Describe any methods used to examine subgroups and interactions	This is detailed in the third paragraph of the methods.
		(*c*) Explain how missing data were addressed	Not applicable to our study variables as we used death records.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable as we used routine administrative data.

		(*e*) Describe any sensitivity analyses	Not applicable to our study.
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable to our study.
		(b) Give reasons for non-participation at each stage	Not applicable to our study.
		(c) Consider use of a flow diagram	Not applicable to our study.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Not applicable to our study.
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable to our study.
Outcome data	15*	Report numbers of outcome events or summary measures	This is provided as a summary measure in Figure 1.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	All of our results are unadjusted.
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable to our study.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable to our study.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable to our study.
Discussion			
Key results	18	Summarise key results with reference to study objectives	This is summarised in the first two paragraphs of the discussion.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	These are summarised in the strengths and weaknesses section in the discussion.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	This is summarised in the implications section of the discussion.
Generalisability	21	Discuss the generalisability (external validity) of the study results	This is summarised in the implications section of the discussion.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	This is provided at the end of the manuscript.

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036529.R3
Article Type:	Original research
Date Submitted by the Author:	18-Aug-2020
Complete List of Authors:	Ramsay, Julie; National Records of Scotland, Vital Events Statistics Minton, Jon; NHS Health Scotland, Public Health Observatory Fischbacher, Colin; NHS National Services Scotland, NHS Information Services Division Fenton, Lynda; NHS Health Scotland, Public Health Observatory; NHS Greater Glasgow and Clyde, Public Health Kaye-Bardgett, Maria; National Records of Scotland, Vital Events Statistics Wyper, Grant; NHS Health Scotland, Public Health Observatory Richardson, Elizabeth; NHS Health Scotland, Public Health Observatory McCartney, Gerry; NHS Health Scotland, Public Health Science Directorate
Primary Subject Heading:	Public health
Secondary Subject Heading:	Health policy
Keywords:	PUBLIC HEALTH, Dementia < NEUROLOGY, Substance misuse < PSYCHIATRY, Ischaemic heart disease < CARDIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

How have changes in death by cause and age-group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000-02 to 2015-17.

Julie Ramsay[1] MSc,*, Jon Minton[2] PhD, Colin Fischbacher[3] FFPH, Lynda Fenton[2 4] MPH, Maria Kaye-Bardgett[1] PhD, Grant MA Wyper[2] MSc, Elizabeth Richardson[2] PhD, Gerry McCartney[2] MD.

* Corresponding author. Email: julie.ramsay@nrscotland.gov.uk . Telephone: 0131 314 4330

[1] National Records of Scotland, Ladywell House, Ladywell Road, Edinburgh, Scotland, EH12 7TF.

[2] Public Health Observatory, NHS Health Scotland, 5 Cadogan Street, Glasgow, Scotland, G2 6QE.

[3] Information Services Division, NHS National Services Scotland, Gyle Square, 1 South Gyle Crescent, Edinburgh, EH12 9EB.

[4] Public Health Department, NHS Greater Glasgow & Clyde, West House, Gartnavel Royal Hospital Campus, 1055 Great Western Road, Glasgow, G12 0XH.

Abstract

Objective
Annual gains in life expectancy in Scotland were slower in recent years than in the previous two decades. This analysis investigates how deaths in different age-groups and from different causes have contributed to annual average change in life expectancy across two time periods: 2000-02 to 2012-14 and 2012-14 to 2015-17.

Setting
Scotland.

Methods
Life expectancy at birth was calculated from death and population counts, disaggregated by five-year age-group and by underlying cause of death. Arriaga's method of life expectancy decomposition was applied to produce estimates of the contribution of different age-groups and underlying causes to changes in life expectancy at birth for the two periods.

Results
Annualised gains in life expectancy between 2012-14 and 2015-17 were markedly smaller than in the earlier period. Almost all age-groups saw worsening mortality trends, which deteriorated for most cause of death groups between 2012-14 and 2015-17. In particular, the previously observed substantial life expectancy gains due to reductions in mortality from circulatory causes, which most benefited those aged 55-84 years, more than halved. Mortality rates for those aged 30-54 years and 90+ years worsened, due in large part to increases in drug-related deaths, and dementia and Alzheimer's disease respectively.

Conclusion
Future research should seek to explain the changes in mortality trends for all age-groups and causes. More investigation is required to establish to what extent shortcomings in the social security system and public services may be contributing to the adverse trends and preventing mitigation of the impact of other contributing factors, such as influenza outbreaks.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. JR and MK-B are salaried by NRS and GM, LF, JM, GW, CF and ER are salaried by the NHS.

Keywords
Life expectancy, decomposition, Scotland, mortality.

Article summary

Strengths and limitations of this study

- This is the first paper to describe the contribution of specific age-groups and causes of death to recent changes in life expectancy in Scotland.
- It uses a high quality dataset of deaths in which very few death registrations are missing and where less than 10% of deaths are coded using ill-defined causes.
- The results are limited to describing trends rather than explaining causal social and biological processes.
- The analysis does not identify the mechanism through which a given cause of death exerts an effect on life expectancy
- The analysis of cause of death within age-group required broad groupings of causes of death, which is likely to conflate diverse causal mechanisms

Introduction

Life expectancy improvement rates in Scotland have been slower since 2012-14 than in previous decades, the inequalities gradient across the deprivation scale has steepened, and age-standardised mortality rates have increased for those living in the most deprived areas, leading to widening health inequalities.[1,2] This comes against a background of consistently lower life expectancy in Scotland compared with the rest of Western Europe since the 1980s, and consistently worse socioeconomic inequalities in mortality.[3]

A similar slow-down since around 2012 in the long term trend of life expectancy has been observed across many high income countries.[2,4,5] Amongst 20 high-income countries, only the USA had a slower improvement in life expectancy than the UK in the most recent six years compared with the previous six years.[6] Continued improvements have been seen in some of the countries with the highest life expectancies, and amongst people living in more affluent areas, both of which undermine suggestions that the recent trends are due to a 'natural ceiling' being reached.[2,5]

Other explanations for the recent trends have included: that the UK, along with much of the rest of Western Europe, has experienced exceptionally high winter mortality;[7–9] that an increase in 'deaths of despair' – those from alcohol, drugs, and suicides – have offset broader health improvements;[10] that funding for health and social care services has not kept up with demand;[11,12]; and, relatedly, that austerity policies have impacted on health through mechanisms such as reduced social security payments and underemployment.[13,14] Such explanations are likely neither mutually exclusive nor exhaustive, and some (such as additional winter deaths and slowing improvements in ischaemic heart disease mortality) may plausibly result from other causes, such as increased pressure on healthcare services and associated unmet need.[15]

Many of the above explanations differ about how mortality changes for specific age-groups, and causes, have contributed to the overall slow-down in life expectancy growth. This includes increases in several countries in mortality from dementia/Alzheimer's disease, drug-related deaths and suicide and marked slow-downs in the previous rapid improvements in cardiovascular mortality.[9,10]

We aimed to explore the reasons for these recent changes by describing the contribution of specific age-groups and causes of death to the slow-down in life expectancy growth in Scotland in two successive time periods (2000-02 to 2012-14 and 2012-14 to 2015-17).

Methods

We used repeat cross-sectional data to undertake comparative decomposition analyses of life expectancy over time. The data used includes all deaths which occurred in Scotland from 2000 to 2017 (inclusive) as held by National Records of Scotland.

Period life expectancy at birth was calculated from abridged life tables available from National Records of Scotland for males and females separately, using three-years combined data to allow robust breakdowns by cause of death and age-group.[16] For the age-group decomposition, death counts and population data in five year age-groups were used, separating <1 year from 1-4 year olds and using 90+ years as the oldest age category. For the cause of death decomposition, International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) categories were grouped into 26 categories. These groupings are exclusive and exhaustive, and were developed on the basis that: at least the five leading causes of death should be separate categories; proposed and plausible contributory causes to life expectancy changes should be independent categories; and

that the residual group should overall make a small contribution to life expectancy changes. The leading causes of death categorisation used by the Office for National Statistics (ONS) was employed as the basis to determine groupings where appropriate.[17] Due to the overlaps between drug-related deaths and other causes (mental and behavioural excluding dementia, suicides, accidents and other external), for the purposes of this analysis these four causes exclude drug-related deaths (Supplementary file 1).

We calculated the changes in life expectancy between three-year rolling periods for males and females for the whole time series from 1980 before focusing on two time periods from 2000 onwards. (The tenth revision of ICD was implemented in 2000 in Scotland and data prior to this period is not consistent across the cause of death categories examined.) Life expectancy growth between 2000-02 and 2012-14 and between 2012-14 and 2015-17 was decomposed into age and cause components using Arriaga's method with the aid of syntax developed by Auger et al.[18,19] The break between the two periods was selected on the basis of the previously identified change in mortality trend which showed that the best estimate of when mortality rates changed to a slower rate of improvement was the year to 2012 quarter 4 for men and the year to 2014 quarter 2 for women.[2] As life expectancy data is based on three-year rolling periods, 2012-2014 was chosen to most accurately reflect this breakpoint. Life expectancy change and decomposition results are presented as annualised change in life expectancy (in weeks) to account for the different length of the two time periods. For the analysis of cause of death within age-group, the age and cause of death categories were aggregated into five mutually exclusive age-groups, and eight mutually exclusive cause-of-death groupings (40 age-cause groupings). A more detailed disaggregation (20 age-groups and 26 cause-of-death groups) is presented in Supplementary files 2 and 3.

Patient and public involvement

This research was done without direct patient or public involvement

Results

Rate of improvement in life expectancy

Life expectancy in Scotland had increased steadily until around 2012, but improvements have since stalled and life expectancy has decreased in recent years. Although the rate of improvement has fluctuated over time, it has rarely been as low as in the last few years, and any slower periods have not been sustained (Figure 1).

Decomposition of life expectancy changes by age and sex

In the earlier period (2000-02 to 2012-14) the annualised increase in male life expectancy was 16.3 weeks/year. However, during the later period (2012-14 to 2015-17) male life expectancy fell by an average of 1.1 weeks/year. During the earlier period, all age-groups contributed to increases in life expectancy (Figure 2) though the greatest contribution (61% of the increase) came from the 55-79 year age-group. During the later period, males aged 40-54 years and 90+ years made substantial negative contributions to overall changes in life expectancy. Although still contributing positively to life expectancy growth in the later period, mortality improvement among 55-84 year old males declined markedly and contributed considerably to the slowing of life expectancy growth. There was a notable reduction in the rate of improvement for males aged 15-34 years, although the smaller number of deaths at these ages meant that this made a smaller contribution to the overall change in life expectancy. There were also small but noticeable declines in the rate of improvement for infants and children aged 1-4 years.

Patterns across age-groups were similar for females, although both the rates of improvement and the scale of change were smaller than for males (Figure 2). During the earlier period female life

expectancy grew by 10.0 weeks/year, with mortality improvements in all age-groups. The largest contributions to the increase (64%) came from the 60-84 year age-group. During the later period the annualised improvement in life expectancy declined to less than 0.1 weeks/year. For those aged 30-49 years and 85+ years, mortality rates worsened. Mortality improvements amongst those aged 60-84 years were very much reduced compared to the earlier period. There was also slowing in improvements for infants, children aged 1-4 years and 10-14 year olds.

Decomposition by detailed cause of death

For males, the single largest cause of the slow-down in life expectancy growth was slower improvements in ischaemic heart disease (IHD) mortality (Figure 3). In the earlier period reductions in IHD mortality added 5.8 weeks/year to male life expectancy; in the later period they added only 2.2 weeks per year. Drug-related deaths made the second biggest contribution for males, changing from a small negative impact (-0.4 weeks/year) in the earlier period to a much larger negative impact (-2.4 weeks/year) afterwards. Other circulatory diseases, cerebrovascular disease, dementia and Alzheimer's disease also made substantial contributions to the slow-down. Only two causes, 'other respiratory' and genitourinary, contributed more to male life expectancy growth after 2012-14 than before.

For females, the same broad causes had the largest impact on life expectancy growth, although again the scale of change was smaller than for males. The single largest cause of the slow-down in life expectancy growth was IHD mortality. As in males, drug-related deaths had the second biggest impact on life expectancy, changing from a small negative impact in the earlier period to a much larger negative impact in the later one. Improvements in mortality from other circulatory causes reversed in the later time period. For cerebrovascular disease there was a marked decline in the rate of improvement between the two time periods. Dementia and Alzheimer's disease mortality worsened from the earlier period. For some causes female mortality improved after 2012-14, making a positive contribution to life expectancy growth; these included lung cancer, other respiratory causes, other cancers, genitourinary, ill-defined causes and breast cancer.

Decomposition by age and broad causes of death

The contributions of different causes of death to life expectancy trends varied across age-groups but were generally similar between males and females. For those aged <35 years, improvements in mortality from external causes made the greatest single contribution to the positive trend in the earlier period (2000-02 to 2012-14). In the later period (2012-14 to 2015-17) this fell to 0.3 weeks/year for males and disappeared for females. Mortality rates for drug-related deaths and cancers increased slightly in the later time period for those aged <35 years (Figure 4).

For those aged 35-54 years, the overall negative contribution to life expectancy changes was due both to substantial reductions in the rate of improvement for some causes of death (including circulatory causes) and absolute increases in mortality for others (such as drug-related deaths, cancers and other causes; Figures 4 and 5).

Although the overall contribution to life expectancy of those aged 55-74 years remained positive in the later period, the dramatic decline in the positive contribution of this age-group is important in explaining overall trends (Figure 2). Much of this decline was explained by the much slower improvement in deaths from circulatory causes in the later compared with the earlier period.

Improvements in cancer mortality slowed among males but increased markedly among females. For both males and females, deaths due to dementia, drugs and other causes all made negative contributions in the later time period to life expectancy growth (Figures 4 and 5).

The contributions of broad causes of death to trends in life expectancy amongst those aged 75-89 years was similar to that of those aged 55-74 years, but the negative contribution of dementia and Alzheimer's disease increased in the later period. Improvements in mortality from circulatory causes fell substantially. Positive trends in cancer mortality improved further for both males and females between the earlier and later periods (Figures 4 and 5).

Amongst the oldest age-group (90+ years), the small overall contribution to life expectancy growth changed from positive to negative between the earlier and later time periods (Figure 2). This was due to worsening mortality due to dementia as well as a slowing in the rate of improvement due to circulatory causes (Figures 4 and 5).

More detailed age-groups and causes of death are presented in supplementary files 2 and 3. These show that mortality in the first year of life from causes of death originating in the perinatal period has improved at a slower rate since 2012-14 for males and has worsened slightly for females (although given the relatively small numbers and the fact that this has not occurred for both sexes, this finding should be treated with caution). The detailed findings also indicate that the increasingly negative contribution of drug-related deaths to life expectancy trends is mainly concentrated among 35-44 year olds for females and 40-49 year olds for males. The slow-down of improvements in IHD mortality is mainly concentrated in 60-69 year old males and 65-74 year old females; the negative contribution of suicides is concentrated in 25-29 year old males, and the rising contribution of dementia and Alzheimer's disease is concentrated in the oldest age-groups.

Discussion

Main results

Life expectancy in Scotland steadily improved from the early 1980s until 2012-14, after which the rate of improvement slowed, followed by declines in life expectancy between 2014-16 and 2015-17. Between 2000-02 and 2012-14, annualised increases in male and female life expectancy were 16.3 and 10.0 weeks/year respectively, but this changed to a decline of 1.1 weeks/year for males and to a very small increase of less than 0.1 weeks/year for females between 2012-14 and 2015-17. In the earlier period most of the increases in life expectancy were due to falling mortality amongst those aged 55-84 years, although mortality rates declined for all age-groups. In the later period declines in mortality were slower for all age-groups, particularly those aged 55-84 years. Mortality increased for males aged 30-54 years, females aged 35-49 years and both males and females aged 90+ years.

Almost all causes of death demonstrated a change in trend in the recent period. Although mortality due to IHD and cerebrovascular disease continued to decline in the later period, life expectancy gains due to these conditions were less than half of those in the earlier period. This affected all age-groups, but was particularly important in explaining the slowing in improvement for those aged 55-74 years, and to a lesser extent those aged 35-54 years. Mortality from drug-related causes and from dementia and Alzheimer's disease, which were already making negative contributions to life expectancy in the earlier period, made larger negative contributions after 2012-14. The previous favourable trends in mortality from other circulatory causes reversed. The increase in drug-related deaths was particularly important in explaining increasing mortality amongst those aged 35-54 years, whilst increases in dementia and Alzheimer's disease mortality substantially explained trends among those aged 90+ years.

Strengths and limitations

The key strengths of this analysis are the use of a complete mortality dataset for the whole population which reduces the risk of bias from missing data or selection biases. Less than 10% of deaths in Scotland are coded using ill-defined causes. We also use standard decomposition analysis (Arriaga) methods that are thereby comparable to estimates produced for other populations. The analysis is limited to the use of cause of death codes which do not illuminate the overall social causation and mechanisms leading to mortality – this is the subject of other work. We also had to use broad grouping of death codes within age groups to improve the precision of our estimates which is likely to conflate diverse causal mechanisms.

How this compares with existing research

The stalling in life expectancy trends in Scotland is of a similar magnitude to the rest of the UK and USA, but greater than in some other parts of Europe.[2,4,5] Much of the initial research describing recent slowing in life expectancy gains has focused on the role of influenza and mortality amongst the oldest age-groups.[9,20] Although we report increases in deaths due to influenza and respiratory causes, and rising mortality amongst those aged 90+ years, these results show that the contribution they make to explaining the overall slowing in life expectancy growth in Scotland is small. This is consistent with other studies in England & Wales and the USA which report that slowing improvements for IHD and cerebrovascular disease and increases in mortality for other circulatory causes among 55-84 year olds and drug-related deaths for adults aged 35-49 years, all make substantial contributions to the overall trends.[21–25] The slightly slower rate of improvement in the most recent period for women compared to men indicates that the long-term closing of the sex gap seems to be continuing.

There is evidence that the increase in drug-related deaths in Scotland is due in part to a cohort effect amongst males who were young adults during the 1980s.[26] Some recent trends may therefore be attributable to historical exposures to political and social change at that time and before, whereby risk of mortality accumulates over time within that cohort.] [3,26]

The reasons for slowing improvements in cardiovascular disease mortality is not clear. Possible explanations might include slowing of progress in reducing exposure to tobacco, increases in the prevalence of obesity, changes in psychosocial risk factors related to economic insecurity or deterioration in access to, or the quality of, health and social care services.[27] This should be the focus of further specific work to understand the timing and reasons for the stalling.[28]

The increase in mortality from dementia and Alzheimer's disease has been attributed to a number of factors, including: people living longer and surviving other illnesses;[29] increased awareness of dementia, making it more likely to be diagnosed and recorded;[9,25] and NHS policies encouraging dementia diagnosis.[25] Changes in death certification practices have also been cited as one of the reasons for increase in deaths from dementia and Alzheimer's disease,[6] although it should be noted that these changes did not occur in Scotland until 2017 so will have had a limited impact on these results.

Implications

Several hypotheses have been proposed to explain recent life expectancy trends in Scotland and other high income countries.[15] Further research should include work to understand the mechanisms and processes underlying the changes at different life-course stages: the considerable rise in drug-related deaths among working-age adults; the substantial slow-down in improvements for IHD, cerebrovascular disease and other circulatory causes; and the rise in mortality from dementia and Alzheimer's disease amongst those aged 90+ years.

The recent change in life expectancy trends represents a very substantial mortality impact which needs to be reflected in the level of priority given to understanding this further. Mortality has worsened (through slowing improvements or mortality increases) across many age-groups and causes, so it is unlikely that any single factor provides sufficient explanation. The extent to which there is a common underlying cause or exposure affecting each of these age-groups should be prioritised for further investigation.

Figure 1 – Life Expectancy and annual change in life expectancy, 1980-82 to 2015-17, by sex, Scotland

Figure 2 – Decomposition of changes in life expectancy between 2002-02 to 2012-14, and from 2012-14 to 2015-17, by sex, Scotland

Figure 3 – Decomposition of the contribution of specific causes of death to changes in life expectancy between 2000-02 and 2012-14 and between 2012-14 and 2015-17, by sex, Scotland

*Excluding causes that are included under drug-related deaths.

Figure 4 - Decomposition of changes in life expectancy by grouped age and cause of death, 2000-02 to 2012-14 and 2012-14 to 2015-17, by sex, Scotland

Figure 5 - Decomposition of change in life expectancy growth pre and post 2012-14 by grouped age and cause of death, by sex, Scotland

Note: values in cells indicate the difference in contribution to life expectancy change between the two periods, in weeks per year. Positive contributions are shaded blue and outlined with boxes. Negative contributions are shaded red and have no box outline

Contributorship statement

LF and GM conceived the idea for this study. JR, MK-B and JM undertook the analyses. GM and JR drafted the manuscript. CF, GW and ER along will all other authors made substantial contributions to interpretation of results and editing the manuscript, and all approved the final draft.

Data availability statement

Life expectancy data and mortality breakdowns by cause of death and age are available on the National Records of Scotland website (www.nrscotland.gov.uk). Breakdowns by detailed cause of death are available on request from Julie.ramsay@nrscotland.gov.uk

Funding statement

No specific funding was received for this work. All authors are salaried employees of National Records of Scotland or the NHS.

Declaration of Interests

The authors declare that they have no competing interests. No funding was received for this work.

Ethics

No new data were collected in this study and there was no public or patient involvement. We used mortality data made available to us by National Records of Scotland and adhered to our standard procedures to protect against disclosure.

References

1 Fenton L, Wyper GM, McCartney G, *et al.* Socioeconomic inequality in recent adverse all-cause mortality trends in Scotland. *J Epidemiol Community Health* 2019;**73**:971–4. doi:10.1136/jech-2019-212300

2 Fenton L, Minton J, Ramsay J, *et al.* Recent adverse mortality trends in Scotland: comparison with other high-income countries. *BMJ Open* 2019;**9**:e029936. doi:10.1136/bmjopen-2019-029936

3 Walsh D, McCartney G, Collins C, *et al.* History, politics and vulnerability: explaining excess mortality in Scotland and Glasgow. Glasgow: 2106.

4 Ho JY, Hendi AS. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ* 2018;:k2562. doi:10.1136/bmj.k2562

5 Raleigh V. Stalling life expectancy in the UK | The King's Fund. 2018.https://www.kingsfund.org.uk/publications/stalling-life-expectancy-uk (accessed 20 Feb 2019).

6 Office for National Statistics. Changing trends in mortality: an international comparison: 2011 to 2016. 2018. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/changingtrendsinmortalityaninternationalcomparison/2000to2016

7 Molbak K, Espenhain L, Nielsen J, *et al.* Excess mortality among the elderly in European countries, December 2014 to February 2015. *Euro Surveill* 2015;**20**.http://www.ncbi.nlm.nih.gov/pubmed/25811643

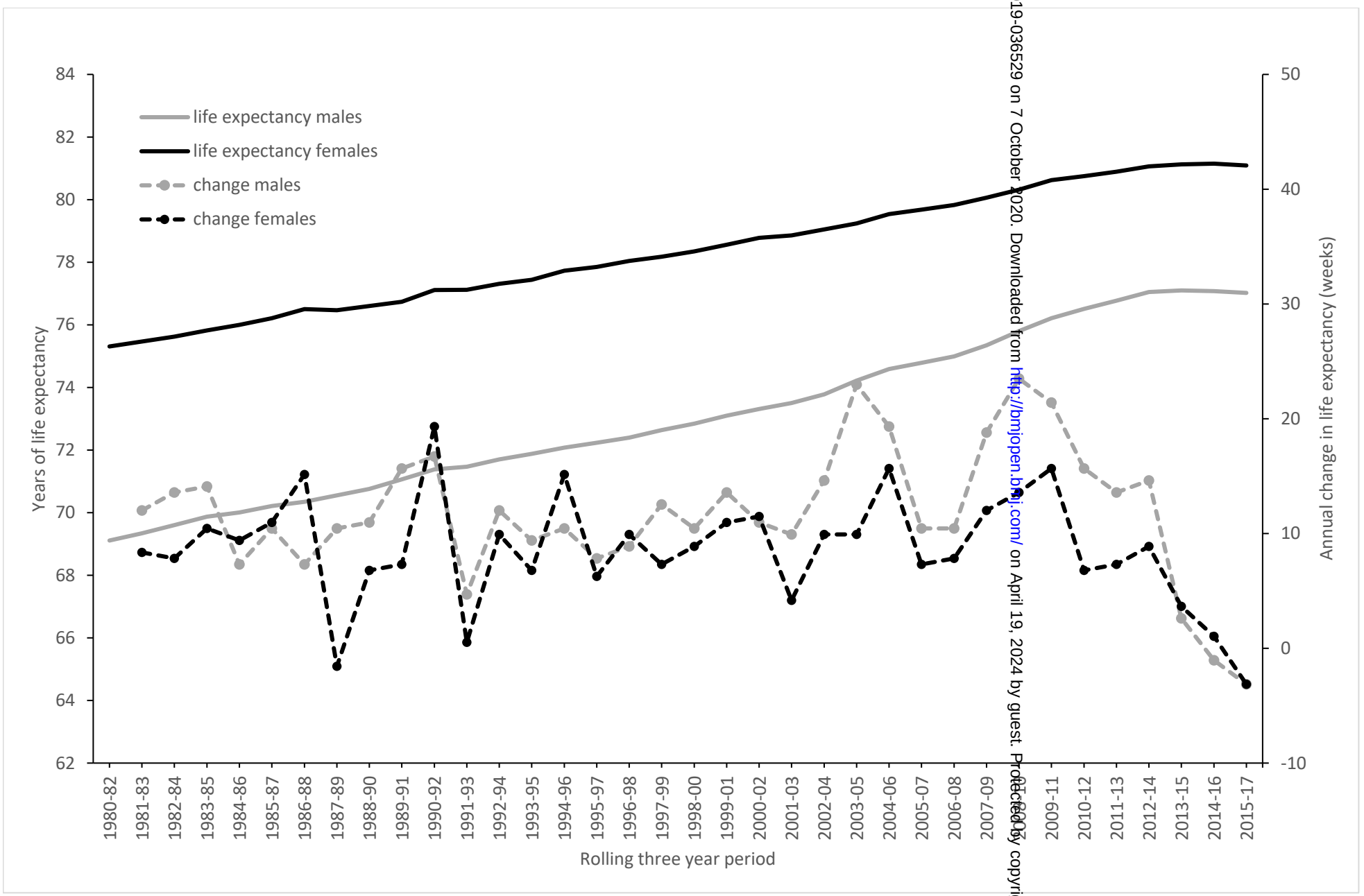
8 Vestergaard LS, Nielsen J, Krause TG, *et al.* Excess all-cause and influenza-attributable mortality in Europe, December 2016 to February 2017. *Euro Surveill* 2017;**22**. doi:https://doi.org/10.2807/1560-7917.ES.2017.22.14.30506

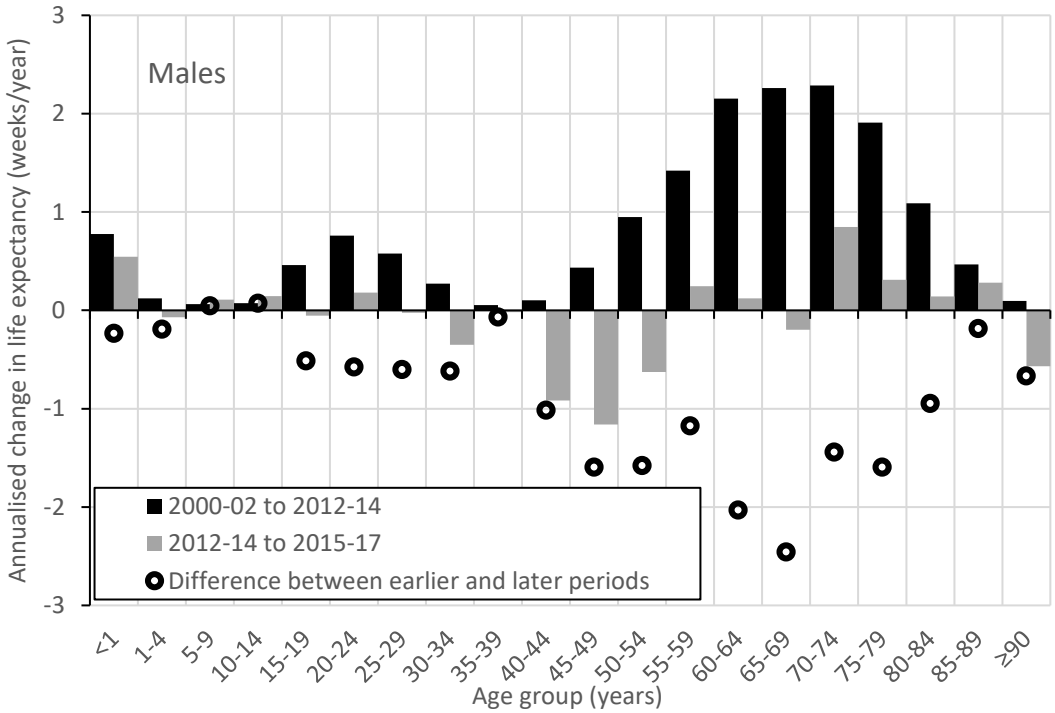
9 PHE. A review of recent trends in mortality in England. London: : Public Health England 2018.

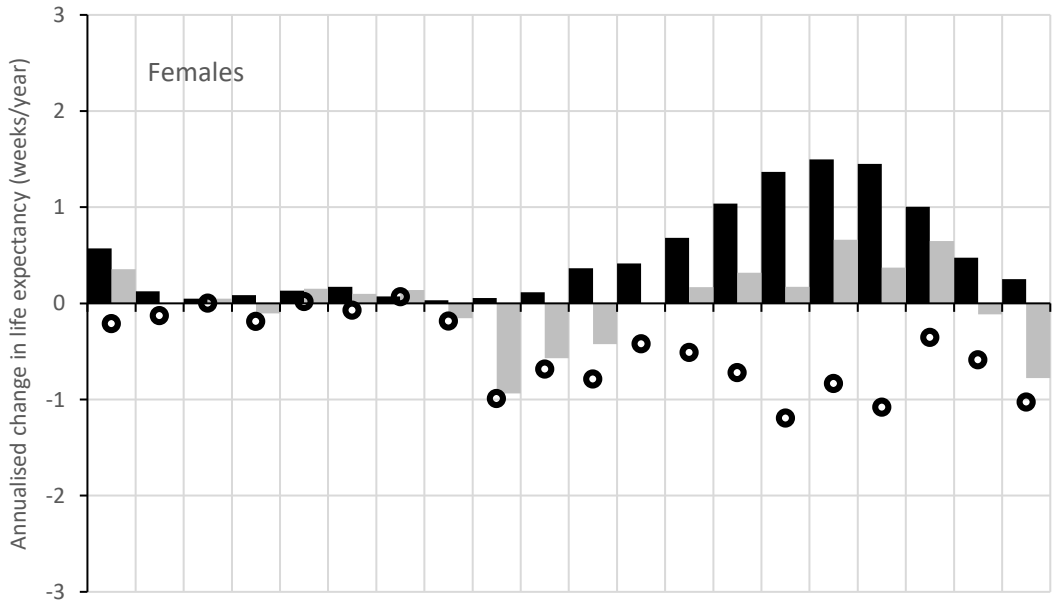
10 Steel N, Ford JA, Newton JN, *et al.* Changes in health in the countries of the UK and 150 English Local Authority areas 1990–2016: a systematic analysis for the Global Burden of

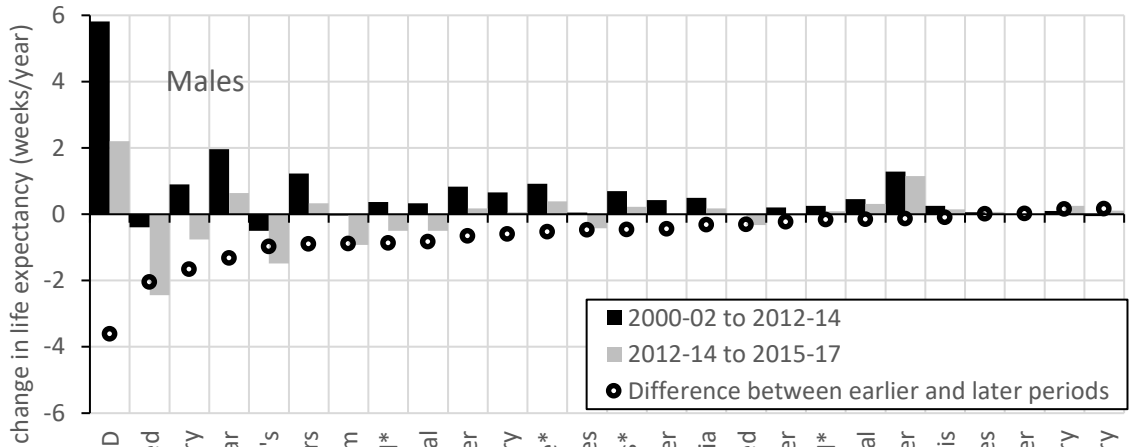
Disease Study 2016. *Lancet* 2018;**392**:1647–61. doi:10.1016/S0140-6736(18)32207-4
11 Watkins J, Wulaningsih W, Da Zhou C, *et al.* Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017;**7**:e017722. doi:10.1136/bmjopen-2017-017722
12 Currie J, Guzman Castillo M, Adekanmbi V, *et al.* Evaluating effects of recent changes in NHS resource allocation policy on inequalities in amenable mortality in England, 2007–2014: time-series analysis. *J Epidemiol Community Health* 2019;**73**:162–7. doi:10.1136/jech-2018-211141
13 Hiam L, Dorling D, McKee M. Rise in mortality—when will the government take note? *BMJ* 2018;:k2747. doi:10.1136/bmj.k2747
14 Taulbut M, Agbato D, McCartney NHS Health Scotland G. Working and hurting? Monitoring the health and health inequalities impacts of the economic downturn and changes to the social security system. 2018. http://www.healthscotland.scot/media/2147/working-and-hurting-sep-2018-english.pdf (accessed 25 Sep 2018).
15 Fenton L. Mortality trends workshop 13th November 2018 – short report and presentations. ScotPHO. 2018.https://www.scotpho.org.uk/publications/reports-and-papers/mortality-trends-workshop-13th-november-2018-short-report-and-presentations/
16 National Records of Scotland. Life Tables for Scotland 2015-2017. Natl. Rec. Scotl. 2018.https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/life-expectancy/life-expectancy-at-scotland-level/scottish-national-life-tables/2015-2017 (accessed 1 Oct 2018).
17 Office for National Statistics. Leading causes of death in England and Wales (revised 2016) - Office for National Statistics. 2016.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/methodologies/userguidetomortalitystatistics/leadingcausesofdeathinenglandandwalesrevised2016 (accessed 23 Oct 2018).
18 Arriaga EE. Measuring and Explaining the Change in Life Expectancies. *Demography* 1984;**21**:83. doi:10.2307/2061029
19 Auger N, Feuillet Msc P, Martel Msc S, *et al.* Mortality inequality in populations with equal life expectancy: Arriaga's decomposition method in SAS, Stata, and Excel. *Ann Epidemiol* 2014;**24**:575-580.e1. doi:10.1016/j.annepidem.2014.05.006
20 Pebody RG, Green HK, Warburton F, *et al.* Significant spike in excess mortality in England in winter 2014/15 - influenza the likely culprit. *Epidemiol Infect* 2018;**146**:1106–13. doi:10.1017/S0950268818001152
21 Acciai F, Firebaugh G. Why did life expectancy decline in the United States in 2015? A gender-specific analysis. *Soc Sci Med* 2017;**190**:174–80. doi:10.1016/j.socscimed.2017.08.004
22 Bennett JE, Pearson-Stuttard J, Kontis V, *et al.* Contributions of diseases and injuries to widening life expectancy inequalities in England from 2001 to 2016: a population-based analysis of vital registration data. *Lancet Public Heal* 2018;**3**:e586–97. doi:10.1016/S2468-2667(18)30214-7
23 Duffy M, Robinson A, Laverty C. Health Inequalities - Life Expectancy Decomposition 2017. 2012. http://www.health-ni.gov.uk/topics/dhssps-statistics-and-research/health-inequalities-statisticswww.nisra.gov.uk (accessed 25 Sep 2018).
24 Remund A, Camarda CG, Riffe T. A Cause-of-Death Decomposition of Young Adult Excess Mortality. *Demography* 2018;**55**:957–78. doi:10.1007/s13524-018-0680-9
25 Public Health England. Recent trends in mortality in England: review and data packs - GOV.UK. 2018.
26 Parkinson J, Minton J, Lewsey J, *et al.* Drug-related deaths in Scotland 1979-2013: Evidence of a vulnerable cohort of young men living in deprived areas. *BMC Public Health* 2018;**18**. doi:10.1186/s12889-018-5267-2
27 Sidney S, Quesenberry CP, Jaffe MG, *et al.* Recent trends in cardiovascular mortality in the United States and public health goals. *JAMA Cardiol* 2016;**1**:594–9.

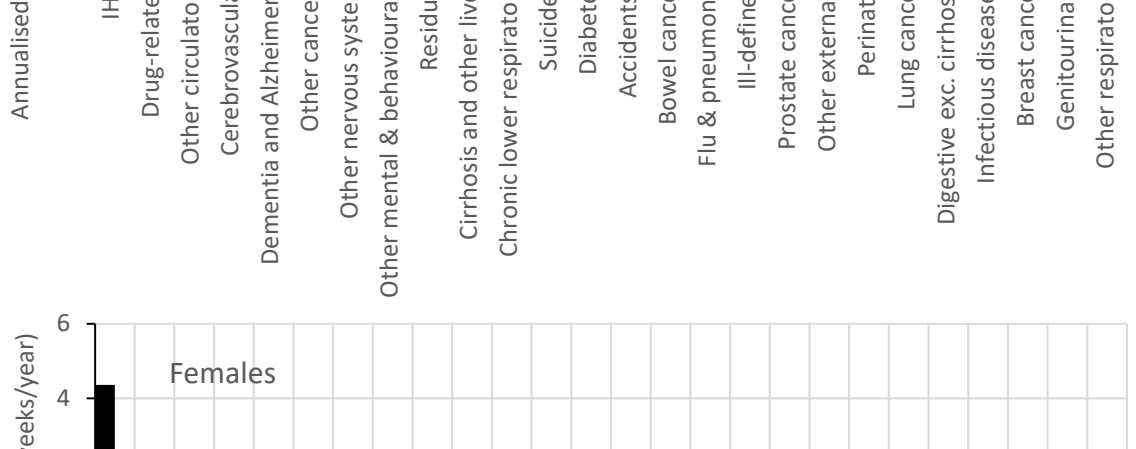
doi:10.1001/jamacardio.2016.1326
28 OECD/The King's Fund. Is Cardiovascular Disease Slowing Improvements in Life Expectancy?: OECD and The King's Fund Workshop Proceedings. OECD Publishing 2020. doi:10.1787/47a04a11-en
29 ONS. Changing trends in mortality: a cross-UK comparison, 1981 to 2016. Analysis of age-specific and age-standardised mortality rates for the UK, England, Wales, Scotland and Northern Ireland from 1981 to 2016. London: : Office for National Statistics 2018.

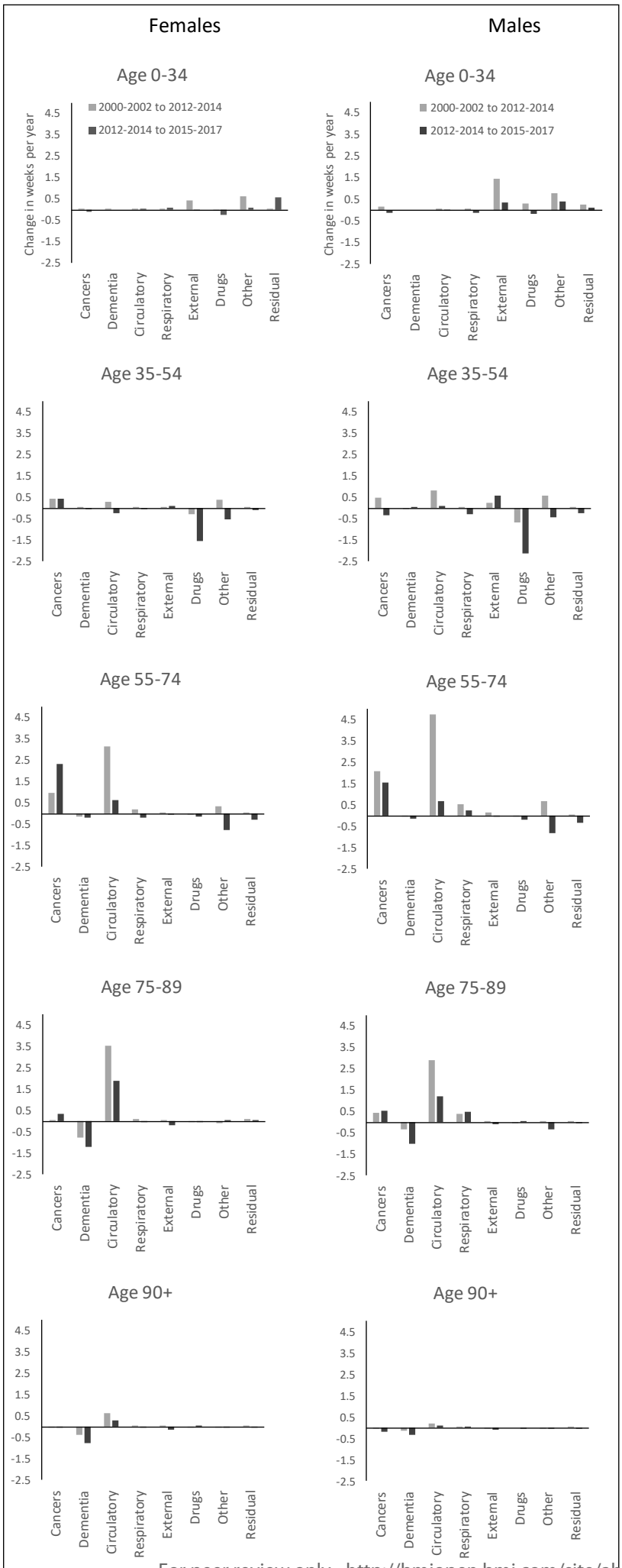


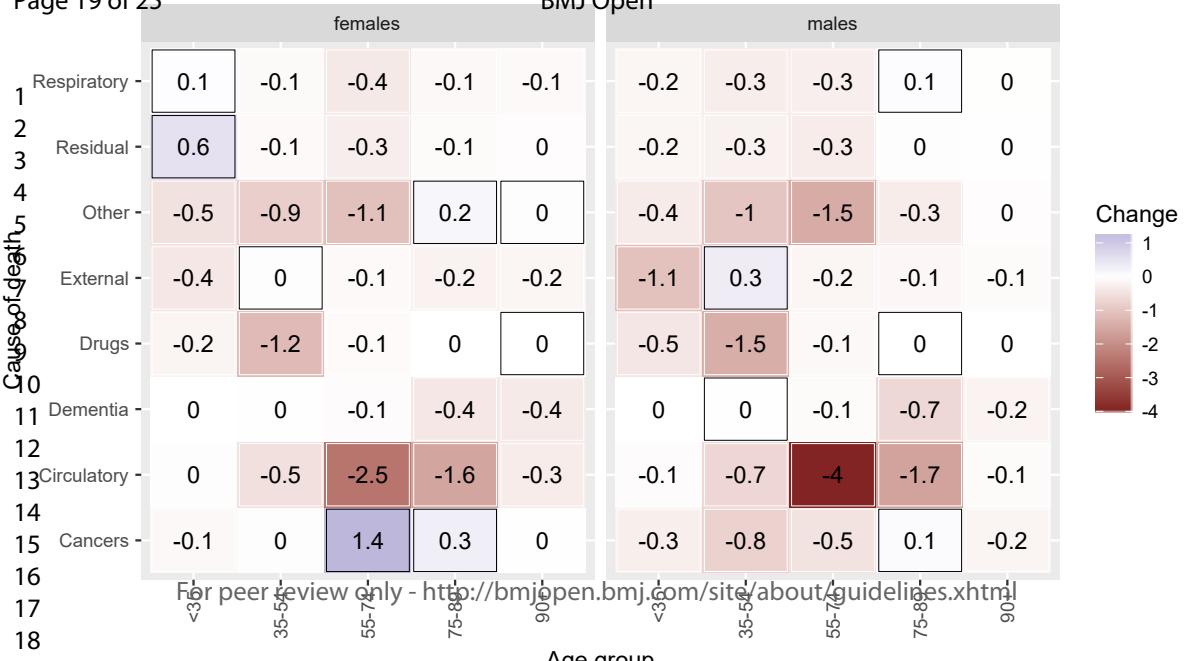

Males
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)


Females
Annualised change in life expectancy (weeks/year)
3
2
1
0
-1
-2
-3
<1
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
≥90
Age group (years)


Males
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
2000-02 to 2012-14
2012-14 to 2015-17
Difference between earlier and later periods
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Other cancers
Other nervous system
Other mental & behavioural*
Residual
Cirrhosis and other liver
Chronic lower respiratory
Suicide*
Diabetes
Accidents*
Bowel cancer
Flu & pneumonia
Ill-defined
Prostate cancer
Other external*
Perinatal
Lung cancer
Digestive exc. cirrhosis
Infectious diseases
Breast cancer
Genitourinary
Other respiratory


Females
Annualised change in life expectancy (weeks/year)
6
4
2
0
-2
-4
-6
IHD
Drug-related
Other circulatory
Cerebrovascular
Dementia and Alzheimer's
Chronic lower respiratory
Accidents*
Other mental & behavioural*
Perinatal
Cirrhosis and other liver
Other nervous system
Flu & pneumonia
Digestive exc. cirrhosis
Diabetes
Infectious diseases
Other external*
Bowel cancer
Suicide*
Prostate cancer
Residual
Breast cancer
Ill-defined
Genitourinary
Other cancers
Other respiratory
Lung cancer


Females
Males
Age 0-34
Age 35-54
Age 55-74
Age 75-89
Age 90+
2000-2002 to 2012-2014
2012-2014 to 2015-2017
Change in weeks per year
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
Cancers
Dementia
Circulatory
Respiratory
External
Drugs
Other
Residual



Supplementary file 1: Categorisation of Causes of Death

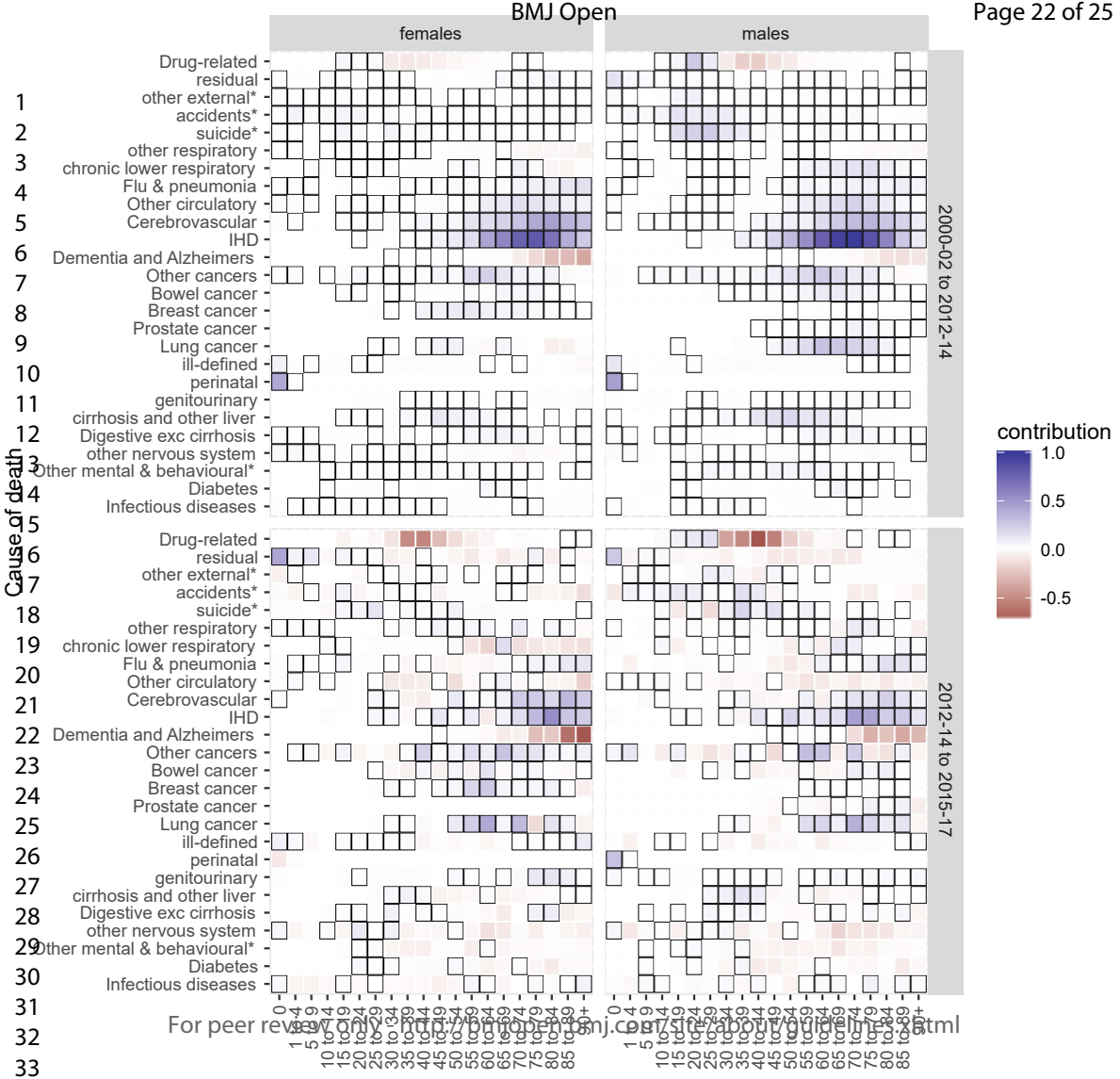
#	Detailed Category (26)	ICD-10	Grouped Category (8)
1	Infectious diseases	A00-B99	Other
2	Lung cancer	C33-C34	Cancers
3	Prostate cancer	C61	Cancers
4	Breast cancer	C50	Cancers
5	Bowel cancer	C18-C21	Cancers
6	Other cancers	All other C codes	Cancers
7	Diabetes	E10-E14	Other
8	Dementia and Alzheimer's	F01, F03, G30	Dementia and Alzheimer's
9	Mental and behavioural disorders excluding dementia *	All other F codes	Other
10	Nervous system diseases excluding Alzheimer's	All other G codes	Other
11	Ischaemic heart disease	I20-I25	Circulatory
12	Cerebrovascular	I60-I69	Circulatory
13	Other circulatory	All other I codes	Circulatory
14	Influenza and pneumonia	J09-J18	Respiratory
15	Chronic lower respiratory diseases	J40-J47	Respiratory
16	Other respiratory	All other J codes	Respiratory
17	Digestive excluding cirrhosis	K00-K69 K77-K99	Other
18	Cirrhosis and other diseases of the liver	K70-K76	Other
19	Genitourinary	N00-N99	Other
20	Perinatal conditions	P00-P96	Other
21	Ill-defined	R00-R99	Other
22	Suicide and injury/poisoning of undetermined intent *	X60-X84, Y10-Y34, Y87.0, Y87.2	External
23	Accidents *	V01-X59, Y85-Y86	External
24	Other external *	All other X&Y codes	External

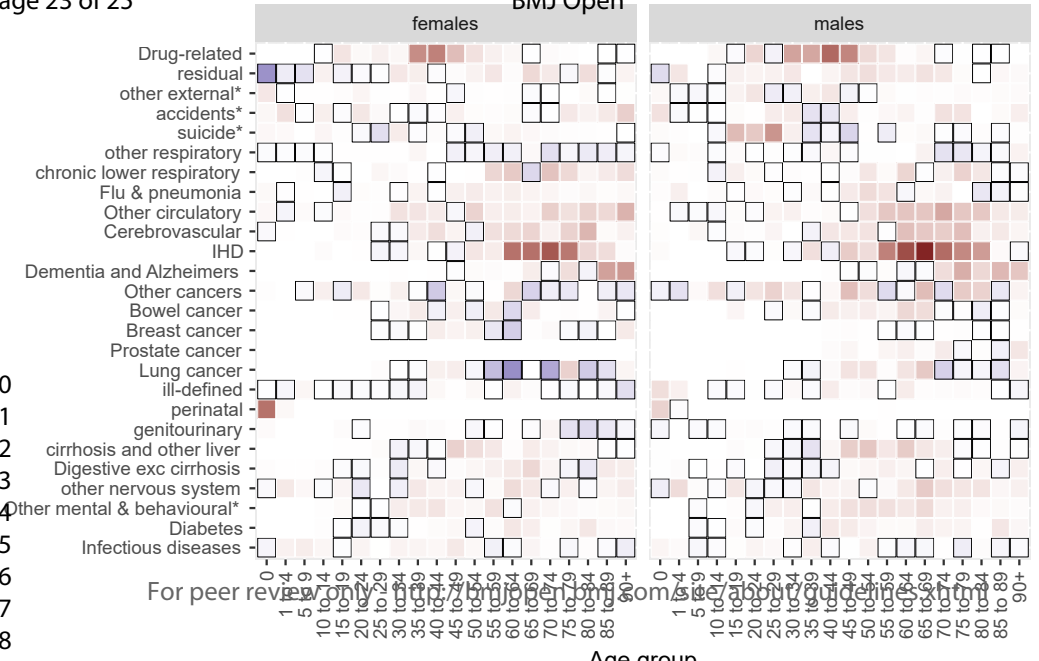
25	Residual	All D Residual E codes All H All L All O All M All Q	Residual
26	Drug-related	F11-F15, F19, Plus X40-X44, X60-X64, X85, Y10-Y14 where an illegal drug was present in the body.	Drug-related

* excluding deaths which are also classified as drug-related.

As the drug-related codes overlap with mental and behavioural causes (exc. dementia) and external causes (suicides, accidents and other external), where a death would appear in both categories, we included it in the drug-related category only, and therefore the other 4 categories exclude drug-related deaths. This was done for two reasons: firstly, the interest in the impact of recent drug-related death trends; and secondly, because of ICD coding changes in 2011[1] there is a discontinuity in the figures for external causes and mental and behavioural causes. This change caused deaths which would previously have been coded as mental and behavioural causes to be coded as external causes. As this change occurred at a key point in the time period we are analysing, it would give misleading results on the relative impact of these causes on life expectancy growth. The coding change did not affect the figures for drug-related deaths, so by selecting these as a separate category, the discontinuity is avoided.

[1] https://www.nrscotland.gov.uk/files/statistics/vital-events/changes-to-coding-of-causes-of-death-between-2010-2011.pdf.





STROBE Statement

	Item No	Recommendation	Location with manuscript
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title includes 'Comparative decomposition analysis'
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Contained within the methods and results section of the abstract.
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Contained within the introduction.
Objectives	3	State specific objectives, including any prespecified hypotheses	The objective of the study is stated in the last sentence of the introduction.
Methods			
Study design	4	Present key elements of study design early in the paper	The first sentence of the methods describes this.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	This is described in detail in the third paragraph of the methods.
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	This is included in the second sentence of the methods.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	This is not applicable for our manuscript.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	This is detailed in the second paragraph of the methods.
Bias	9	Describe any efforts to address potential sources of bias	Our study is descriptive but the limitations of the data are described in the discussion section.
Study size	10	Explain how the study size was arrived at	Not applicable to our study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	This is detailed in the second paragraph of the methods.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	This is detailed in the third paragraph of the methods.
		(*b*) Describe any methods used to examine subgroups and interactions	This is detailed in the third paragraph of the methods.
		(*c*) Explain how missing data were addressed	Not applicable to our study variables as we used death records.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable as we used routine administrative data.

		(*e*) Describe any sensitivity analyses	Not applicable to our study.
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable to our study.
		(b) Give reasons for non-participation at each stage	Not applicable to our study.
		(c) Consider use of a flow diagram	Not applicable to our study.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Not applicable to our study.
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable to our study.
Outcome data	15*	Report numbers of outcome events or summary measures	This is provided as a summary measure in Figure 1.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	All of our results are unadjusted.
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable to our study.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable to our study.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable to our study.
Discussion			
Key results	18	Summarise key results with reference to study objectives	This is summarised in the first two paragraphs of the discussion.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	These are summarised in the strengths and weaknesses section in the discussion.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	This is summarised in the implications section of the discussion.
Generalisability	21	Discuss the generalisability (external validity) of the study results	This is summarised in the implications section of the discussion.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	This is provided at the end of the manuscript.

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.