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Mortality trends in the UK: average stalling of improvement masks worsening rates within countries and cities - a population based trend analysis.

David Walsh[1], Gerry McCartney[2], Jon Minton[3], Jane Parkinson[3], Deborah Shipton[4], Bruce Whyte[1]

1. Public Health Programme Manager, Glasgow Centre for Population Health, Olympia Building, 2-16 Orr Street, Bridgeton Cross, Glasgow G40 2QH, Scotland. Tel: 0141 330 2793

2. Consultant in Public Health and Head of the Public Health Observatory team, NHS Health Scotland, Glasgow, Scotland

3. Public Health Intelligence Adviser, NHS Health Scotland, Glasgow, Scotland

4. Public Health Intelligence Principal, NHS Health Scotland, Glasgow, Scotland

Correspondence to: david.walsh.2@glasgow.ac.uk

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Abstract

Background

Previously improving life expectancy and all-cause mortality in the UK has stalled since the early 2010s. National analyses have demonstrated changes in mortality rates for most age groups and causes of death, and with deprived populations most affected. The aims here were to establish whether similar changes have occurred across different parts of the UK (countries, cities), and to examine cause-specific trends in more detail.

Methods

Mortality and population data for UK countries and selected cities were obtained from national statistical agencies. European age-standardised mortality rates were calculated by cause of death, country, city, year (1981-2017), age group, sex, and - for all countries and Scottish cities - deprivation quintiles. Changes in rates between five-year periods, and summary measures of inequality (RII, SII), were also calculated.

Results

Changes in mortality from around 2011/13 were observed throughout the UK. For example, female rates decreased by c. 4-6% during the 1980s and 1990s, c. 7-9% during the 2000s, but by <1% between 2011/13 and 2015/17. This later period saw increased mortality among the most deprived populations. This was observed in all countries and cities analysed, and for most causes of death; absolute and relative inequalities therefore increased. Although similar trends were seen across all parts of the UK, particular issues apply in Scotland e.g. higher and increasing drug-related mortality.

Conclusions

The study presents further evidence of changing mortality in the UK. The timing, geography and socio-economic gradients associated with the changes appear to support suggestions

that they result at least in part from UK Government 'austerity' measures which have disproportionately affected the poorest. It is therefore imperative that policies are introduced to reverse previous cuts to social security and social services, and thereby protect the most vulnerable in society.

(288 Words)

ARTICLE SUMMARY

Strengths and limitations of this study

- We examine recent changes in mortality in the UK in the context of much longer-term trends: almost 40 years in most cases.
- Given the importance of urban health to national outcomes, we include the largest cities in Scotland, England (London excepted) and Northern Ireland.
- We analyse data for 10 major causes of death (not just all-causes combined), and by country-specific and (for Scotland) city-specific deprivation levels.
- Limitations include the fact that interpretation of trends at city level can be problematic, given the fluctuation in rates.

INTRODUCTION

The recent slow-down in improvement in life expectancy and mortality rates in the UK has been highlighted by researchers[1,2] and media[3,4] alike. Similar changing trends have been observed in many other high-income countries, although the slow-down has been particularly marked in the UK and the USA[5]. Other high-income countries with higher life expectancy have seen continued improvements[2,5].

Data from Scotland and England (92% of the UK population) have shown that these changing mortality patterns have been observed for almost all age groups and for most causes of death[6,7]. Worryingly, *increasing* mortality rates among the most socio-economically deprived populations have also been observed; as a result, inequalities in all-cause mortality have widened considerably since around 2012[7-9]. An emerging body of UK[1,10-13] and international[14,15] work suggests the recent stalling is likely to be associated with the implementation from 2010 of UK Government 'austerity' measures – cuts to public services and social security – which have particularly affected the most vulnerable populations.

The principal aim of this project was to establish whether similar changing mortality trends (in terms of rates of improvement, causes of death, and socio-economic inequalities) have occurred ubiquitously across the UK. This included examining cause-specific trends in more detail, and focussing on selected individual cities, given the importance of urban health to national outcomes[16].

METHODS

Mortality & population data

Numbers of deaths by year of registration, age, sex, underlying cause, city and country for Scotland, England & Wales and Northern Ireland were obtained from, respectively, the National Records of Scotland (NRS), the Office for National Statistics (ONS), and the

Northern Ireland Statistics and Research Agency (NISRA). Data were available for the following years: 1974-2017 (Scotland); 1981-2017 (England & Wales); and 1997-2017 (Northern Ireland).

Data were obtained for all-cause deaths, and for the following 10 major individual causes: respiratory disease; ischaemic heart disease (IHD); cerebrovascular disease; all malignant neoplasms; lung cancer (malignant neoplasm of trachea, bronchus and lung); intentional self-harm (including events of undetermined intent); external causes; motor vehicle traffic accidents (MVTAs); alcohol-related causes; and drug-related poisonings. Causes were defined by groups of ICD8, ICD9 and ICD10 codes: these are listed in the online appendix (Web Table 1). As stated in Web Table 1, the definition of external causes overlaps with other causes of death i.e. MVTAs, intentional self-harm, drug-related poisonings. ICD9 codes were used for the years 1979-1999 in Scotland, and for 1981-2000 in England & Wales and Northern Ireland; ICD10 codes were used for all later years. ICD8 codes were used for 1974-1978 (Scotland only) but the data for those years are not presented here.

Matching population data by year, five-year age group, sex, city and country were obtained from the same national statistical agencies.

Geography

Scotland, England & Wales (combined) and Northern Ireland were the countries used in the main analyses. For analysis by deprivation quintiles (discussed further below), England alone, rather than England & Wales, was used. With the exception of London, the largest cities in each country were selected: Glasgow, Edinburgh, Dundee and Aberdeen in Scotland; Liverpool, Manchester, Birmingham, Leeds, Sheffield and Bristol in England; and Belfast in Northern Ireland. London was excluded as its size and ethnic diversity makes meaningful comparisons with other cities problematic[17]. Scottish and English cities were defined by

current local authority boundaries. Belfast was defined by its 1992 local government district (LGD) boundary.

Deprivation analyses employed the separate Scottish, English and Northern Irish area-based indices of deprivation: the Scottish Index of Multiple Deprivation (SIMD)[18], the (English) Index of Multiple Deprivation (IMD)[19], and the Northern Ireland Multiple Deprivation Measure (NIMDM)[20] respectively. In all three cases data were available for the period 2001-2017. The SIMD has been updated multiple times: thus, the 2004 version was used for analyses covering the years 2001-04, SIMD 2006 was used for 2005-07, SIMD 2009 for 2008-10, SIMD 2012 for 2011-13 and SIMD 2016 for 2014-17. Similarly, the (English) IMD 2004 was used for the years 2001-05, IMD 2007 for 2006-08, IMD 2010 for 2009-13, IMD 2015 for 2014-16 and IMD 2019 for 2017. For Northern Ireland, NIMDM 2010 was used for all years of analyses.

Statistical analyses

European age-standardised mortality rates (EASRs) per 100,000 population were calculated using the 2013 European Standard Population[21]. Analyses were undertaken by sex, age (all ages, 0-64 years, 15-44 years, 45-64 years, 65+ years), year, cause of death, city, country and deprivation quintile (see below). Three-year rolling average rates were derived; to quantify the rate of improvement over time, the percentage changes in rates between three-year averages at five-year intervals (i.e. between 1981/83 and 1985/88, 1986/88 and 1990/92… up to 2011/13 and 2015/17) were calculated.

For the deprivation analyses, mortality rates by quintile were calculated on the basis of both *national* quintiles (based on levels of deprivation within individual countries) and – for Scottish cities only – *city-specific* quintiles (based on levels of deprivation *within each individual city*). In all analyses Quintile 1 represented the *most deprived* fifth of the country's/city's small areas, and Quintile 5 the *least deprived* fifth. The aim was to compared

quintile rates *within the same location* (country or city), not between different locations. Note that as the English IMD does not include Wales, for comparison all-cause mortality rates by year and sex for England alone (rather than England & Wales combined) were also calculated. Analyses by deprivation were undertaken for all-cause deaths for all geographies, and for cause-specific mortality for all Scottish areas.

The Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) were calculated, based on the above deprivation quintiles[22].

Patient and Public Involvement

Patients were not involved in this study

RESULTS

Figure 1 presents trends in all-cause standardised mortality rates for all ages by country and city for (a) males and (b) females. At the national level, a change in the male death trend appears visible from around 2011/13 for both Scotland and England, with no or little improvement observed in the periods after that; there is greater fluctuation in rates in Northern Ireland. A change in rates appears more apparent, occurring slightly earlier, for deaths among females including those in Northern Ireland. At the city level, greater fluctuation in rates is clearly evident, as would be expected given the smaller population sizes and associated numbers of deaths: nonetheless the majority of cities appear to have experienced a flattening, or worsening, of mortality rates in the last 3-4 time points shown.

[Figure 1 about here]

To quantify the changes shown above, Figure 2 shows the percentage change in rates between five-year periods for Scotland, England & Wales and Northern Ireland. For women, mortality rates were decreasing by approximately 4-6% during the 1980s and 1990s, with a faster improvement of approximately 7-9% during the 2000s, and a much slower decrease of

<1% between 2011/13 and 2015/17. Amongst men, mortality rates were decreasing slightly faster during the 1980s and early 1990s (by 4-7%), with a faster improvement of approximately 8-12% during the late 1990s and 2000s, and again a much slower decrease between 2011-13 and 2015/7 of 1-3%. Similar data for the cities are shown in the online appendix (Web Figure 1): these show a very similar overall pattern to the country-level analyses, albeit with greater fluctuation in the percentage change figures in some cities such as Dundee. However, it is also notable that – despite that fluctuation – in the most recent five-year period mortality rates actually worsened among both males and females in Dundee and Aberdeen, and among females in Manchester, while there was virtually no improvement among males in Liverpool and females in Birmingham (-0.3% for both).

[Figure 2 about here]

Analyses of trends and changes in rates for ages 0-64 years (rather than all ages) are presented in Web Figure 2 for the countries of interest. While the results are broadly similar to those seen for all ages, the data suggest there has been a slight increase (rather than slow-down) in mortality rates for Scotland in the most recent period. Across the cities, a more notable change was observed in Dundee for males in this age group: a 26% increase in mortality between 2011/13 and 2015/17 (Web Figure 3). Notwithstanding the greater fluctuation in changes in rates in this age group at city level, it is also of note that there was an increase in female mortality rates in the last period in each English city.

Trends in all-cause rates for 45-64 years were similar to those described above for 0-64 years, and rates for 65+ years were broadly similar to those observed for all ages. For the 15-44 age group, rates were notably higher in Scotland than England & Wales, and the mortality gap had become wider in the most recent period. These data are all shown in Web Figure 4.

Figure 3 again shows trends in male all-cause mortality rates for all ages but additionally presents the rates for the least and most deprived deprivation quintiles within Scotland,

England, Northern Ireland and an illustrative selection of three Scottish cities. Increased mortality rates are observed in the most recent period for the most deprived fifth of the population in each country/city shown (albeit that there is again more fluctuation in rates at the city level). Similar trends were observed for female mortality rates, as shown in Web Figure 5. Summary measures of inequalities (SIIs, RIIs) confirm widening absolute and relative inequalities across deprivation quintiles since 2011/13 in all countries and cities analysed (Web Tables 2a and 2b).

[Figure 3 about here]

Mortality trends by deprivation quintile are explored in more detail for Scotland in Figure 4, which presents trends for females for all ten causes of death analysed. A widening gap between the most and least deprived quintiles in the most recent years of analysis can be seen for the majority of causes, in particular respiratory disease, external causes, drug-related poisonings and alcohol-related causes. Different trends are observed for suicide (where the gap has narrowed) and MVTAs (where numbers of deaths are relatively small and there is considerable fluctuation in rates across quintiles of deprivation). Generally, the same patterns, in terms of a widening gap between the most and least deprived deprivation quintiles for the majority of causes of death, are observed for male deaths (Web Figure 6). The main difference between the male and female trends relates to cancer mortality, in particular lung cancer, with a widening deprivation gap observed for females but not males. The general pattern of widening inequalities for the majority of causes is confirmed by analysis of SIIs and RIIs (Web Table 3a and 3b).

[Figure 4 about here]

Aside from evidence of a slow-down in mortality improvement and widening deprivation gaps (already shown in Figures 1 and 3), the analyses of city level mortality trends highlight a number of other issues. Foremost among them is that Glasgow stands out in terms of having

the highest mortality rates of all the cities for all cause deaths and the majority of causes analysed (including strikingly different trends for alcohol related causes). Some exceptions do apply, however: for example, for all ages death rates from IHD are now marginally higher in Manchester for both males and females, while deaths from drug-related poisonings are now highest in Dundee. Some of these trends are shown for males in Figure 5, and for females in Web Figure 7.

[Figure 5 about here]

Finally Figure 5/Web Figure 7 also highlight notable similarities and differences in long-term mortality trends between Scotland and England. For example: a narrowing of the gap between the countries for IHD; much higher drug-related poisonings in Scotland compared to England - although rates are increasing in both countries; and notably higher rates of death from alcohol related causes in Scotland, with the most recent increase in rates much more pronounced in Scotland than in England.

DISCUSSION

Overall findings and implications

The study presents further evidence of a slow-down in mortality rate improvement over time within the UK. In some cases – deaths under 65 years in Scotland and all-age mortality in particular cities – rates have increased, rather than stalled, in recent years. These overall changes appear to be particularly driven by worsening mortality among the most socio-economically disadvantaged populations. Similar trends are observed across all countries and cities in the UK; however, particular issues apply in Scotland, for example in relation to drug-related mortality. The timing, geographical coverage and socio-economic gradients associated with the changes appear to further support suggestions that recent changes in mortality are at least partly a consequence of UK Government 'austerity' measures.

Strengths and weaknesses

The analyses were based on data covering the whole population, not samples. Mortality is a robust population health indicator and is not subject to the limitations and potential biases associated with self-reported measures[23,24]. We included the largest cities within Scotland and Northern Ireland and, with the exception of London, the six largest cities in England. We were able to examine recent changes in mortality in the context of much longer-term trends: almost 40 years in the case of Scotland and England & Wales. We analysed data for a broad set of causes of death, not just all-deaths combined.

The exclusion of London is arguably a weakness, although it was done to facilitate more meaningful comparisons across the other cities with more similar population sizes. Other limitations include the fact that time trend data for Northern Ireland were much more limited than for the rest of the UK. Interpretation of trends at city, rather than country level can also be problematic, given the fluctuation in rates that occur. Although the measures of area-based multiple deprivation that are employed within Scotland, England and Northern Ireland have many similarities, they are derived from different data sets and calculated at different spatial scales and are thus not directly comparable. We standardised mortality rates using 18 age groups (0-4 years to 85 years and above) while it is now recommended to standardise on the basis of 19 groups (0-4 years to 90 years and above)[25]: however, the impact of this is fairly minimal. Finally, the definition of drug-related poisonings is a broader, less sophisticated, definition than that employed in official UK publications of drug-related mortality in the UK. In 2017, for example, there were 1,037 such drug-related poisonings in Scotland, 11% higher than the 934 drug-related deaths recorded by the National Records of Scotland[26].

Relevance to other studies

Slower improvement in mortality and life expectancy in the UK in recent years has been shown by various authors and organisations[1,2,5-8]. Similar trends have been observed in a number of countries, although in a recent analysis of 20 high-income countries, only the USA had experienced a greater reduction in improvement than the UK[5]. As others have proposed, it appears increasingly likely that these changes are at least in part attributable to UK Government policy which since 2010 have brought about dramatic cuts to social security budgets and other public services, particularly affecting the most vulnerable[10-13]. There is international evidence of the associations between such government measures and increased mortality rates[14,15] , and the particular model of austerity adopted in the UK (based on spending cuts rather than a taxation approach) is known to be more regressive[13]. UK research has highlighted associations between different UK austerity measures and increased child poverty[27,28], expansion of foodbanks[29], increased homelessness[30], poorer mental health among affected populations[31] and, ultimately, increased numbers of deaths among the poorest at different ages[8]. Interactions between such policy-driven factors and other influences such as high winter mortality in particular years have also been suggested[6].

The widening socio-economic inequalities in mortality since around 2012 have been shown previously for Scotland[8,9] and England[7,32], but only at national level, and only for all-cause mortality and life expectancy. The increase in drug-related deaths within Scotland has been the focus of much media attention, resulting in two recent Westminster Parliamentary Committee enquiries[33,34], and the establishment of 'drugs death task force' by the Scottish Government in 2019[35]. The increase is known to be the result of a 'perfect storm' of factors: a previously-described vulnerable cohort of drugs users who are now encountering multiple morbidities as they age; increased affordability and accessibility of chosen drugs; and the aforementioned UK Government austerity measures which have impacted on both individual income and funding of drug-related and other relevant social services[33,34,36]. These

drug mortality trends are likely to have influenced the overall increasing death rates in Scotland (and in Dundee) among 0-64 year-olds.

Alcohol mortality trends have historically been impacted by changes in price and availability in combination with socioeconomic vulnerability[37,38], while the reasons for Glasgow's particularly high mortality rates (including from alcohol, drugs and other causes) have been described in detail previously, being attributable to higher socio-economic deprivation alongside an additional vulnerability created by a combination of multiple historical factors including worse living conditions and adverse policy-making at different levels of government[39].

The contrasting trends in lung cancer mortality between males (decreasing rates) and females (increasing rates) living in the most deprived quintile in Scotland are also best explained in terms of different cohorts, with females having started smoking later than males: this has been shown in a number of other analyses[40]. Finally, one of the other notable differences between male and female trends – the apparent earlier slow-down in mortality improvement for females – is worthy of further analysis. Data presented here for both countries and cities suggest a change in female mortality rates from around 2010/12 or 2011/13, potentially suggesting women's circumstances might be more sensitive to government austerity policies. However, more detailed analysis of Scottish data by Fenton et al instead suggested a change between 2013 and 2014[2].

Conclusions

These results add to the growing body of evidence of changing mortality rates within the UK in recent years and their likely political causes. It is imperative that a range of policies are introduced at UK Government level to reverse previous cuts to social security and social services, and to therefore protect the health of the most vulnerable in society.

(3011 words)

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DECLARATIONS

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Contributions: DW originally conceived the study. The research questions and analysis plan were agreed by all authors. DW undertook the analyses and drafted the manuscript. All authors provided substantial critical input to improve the manuscript and all authors approved the final draft.

Competing interests: None declared

Ethical approval: None required

Data sharing: No additional data available

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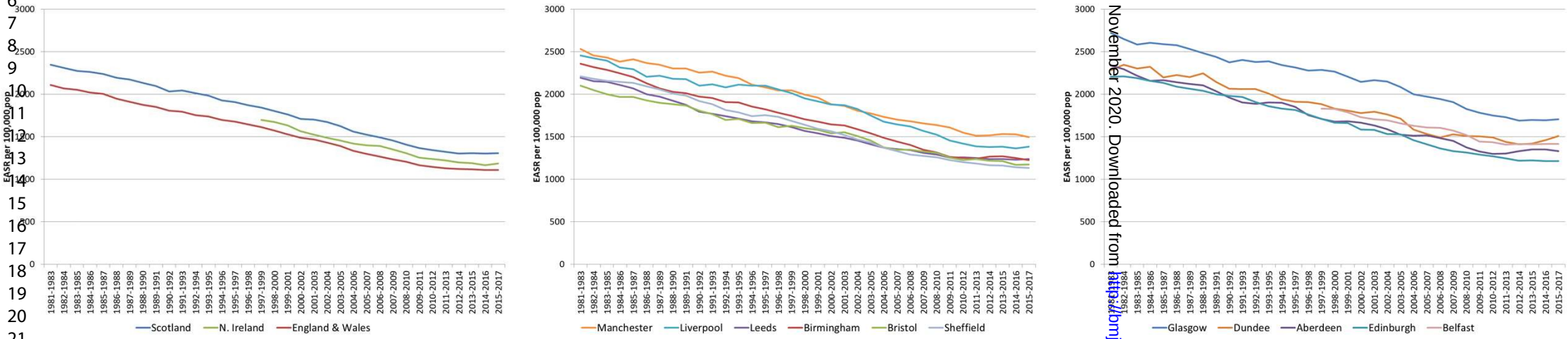
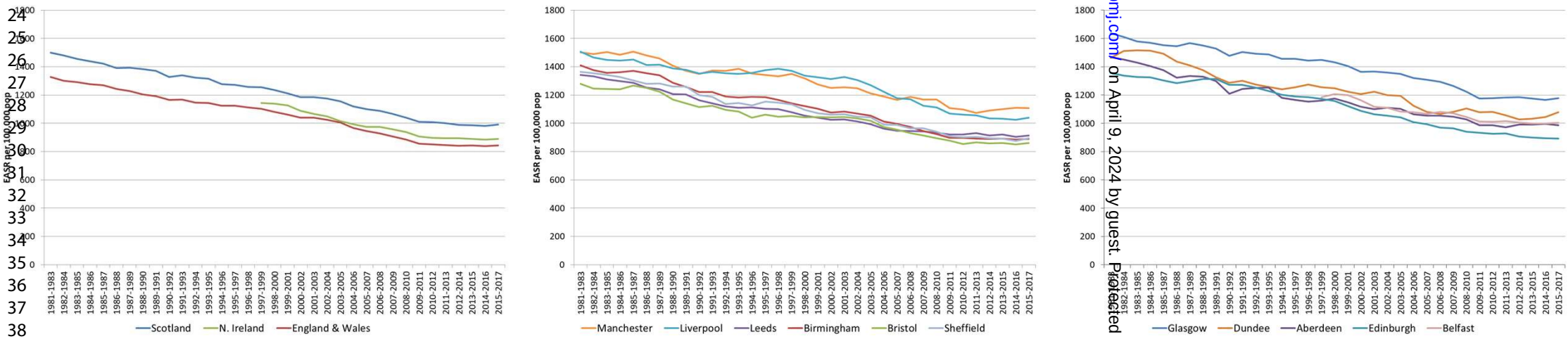
Figure 1. European age-standardised mortality rates (all ages, all causes) per 100,000 population, three-year rolling averages, by UK country and city, 1981-2017

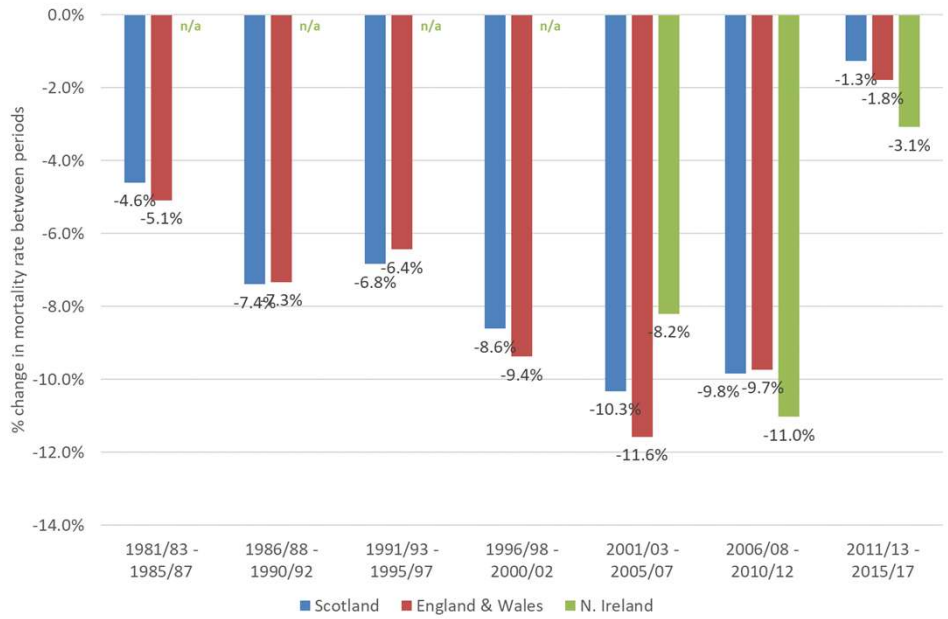
a) Males



b) Females



a) Males



b) Females

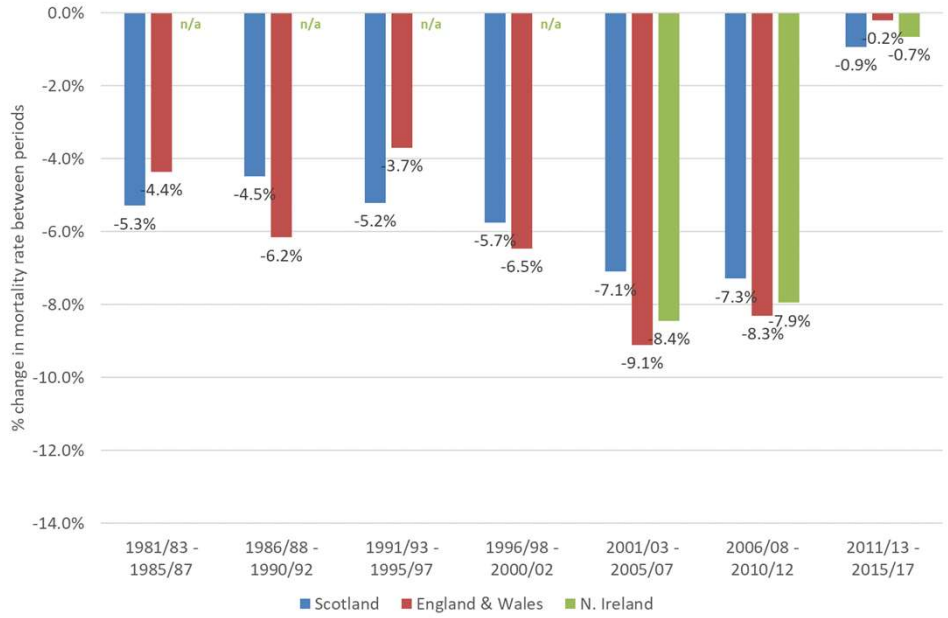


Figure 2. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods

Figure 3. European age-standardised mortality rates (males, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles

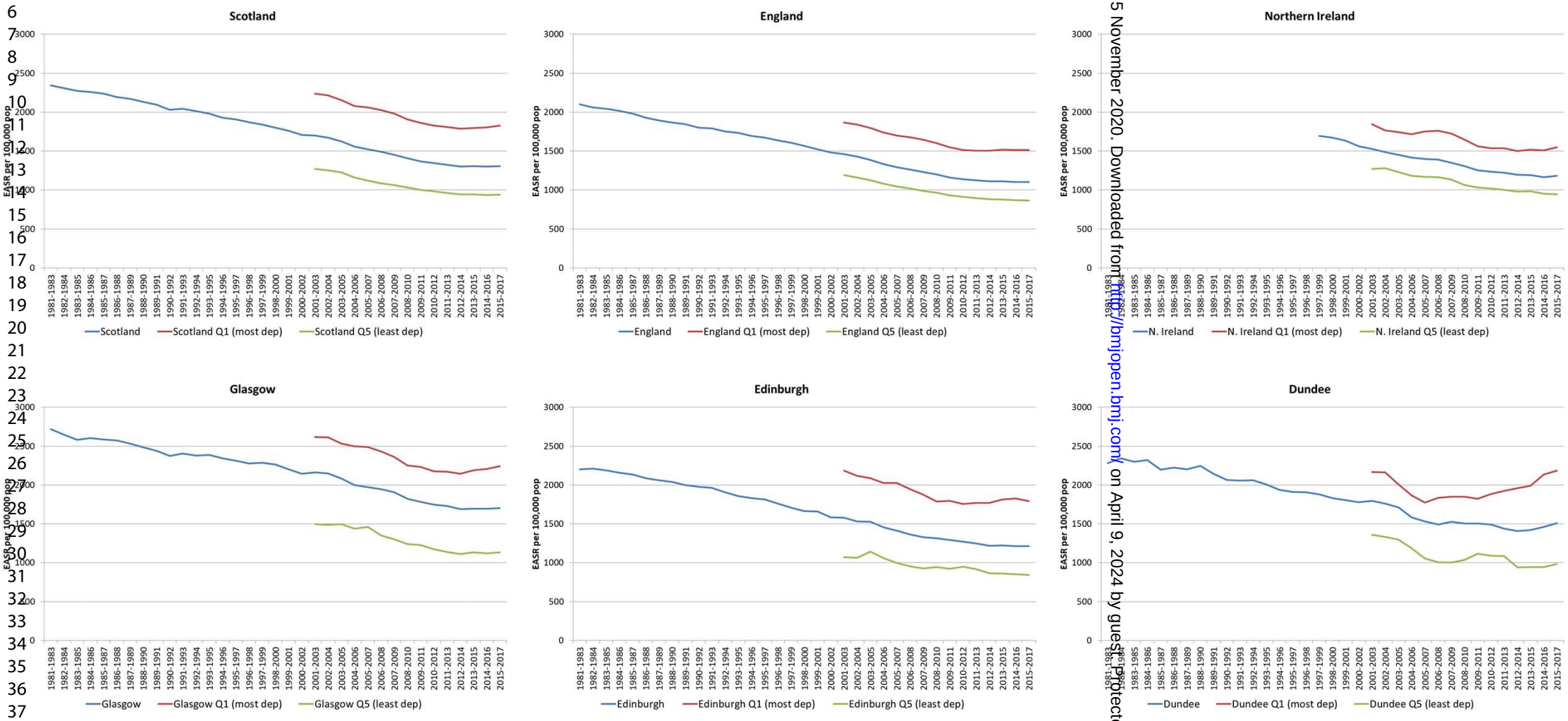
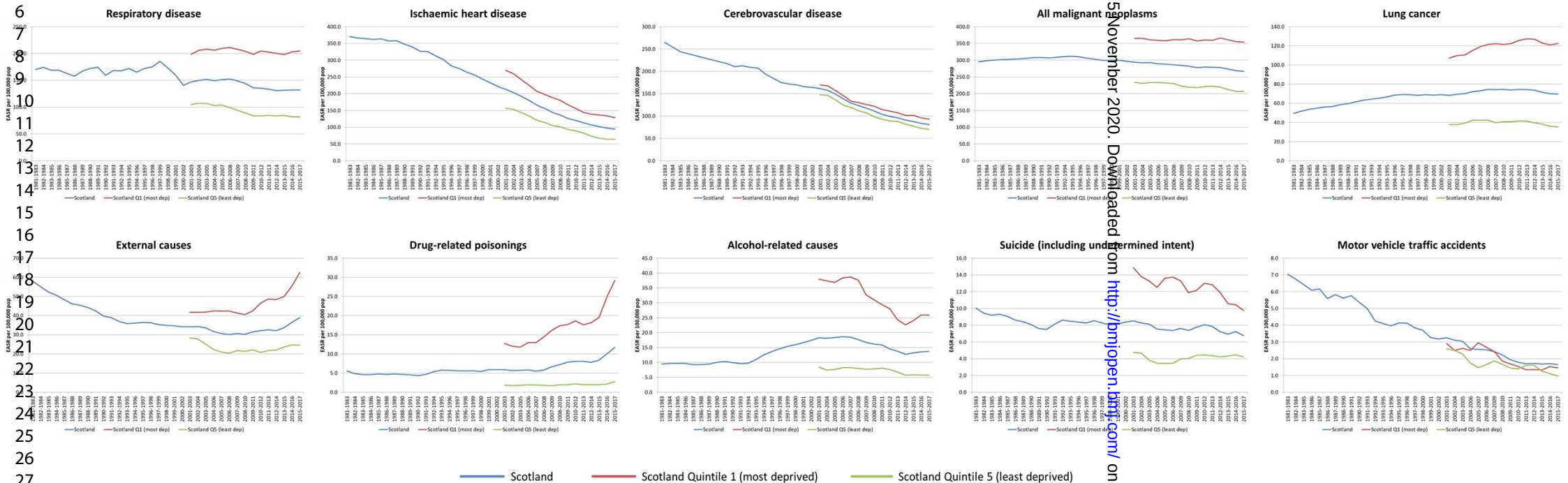
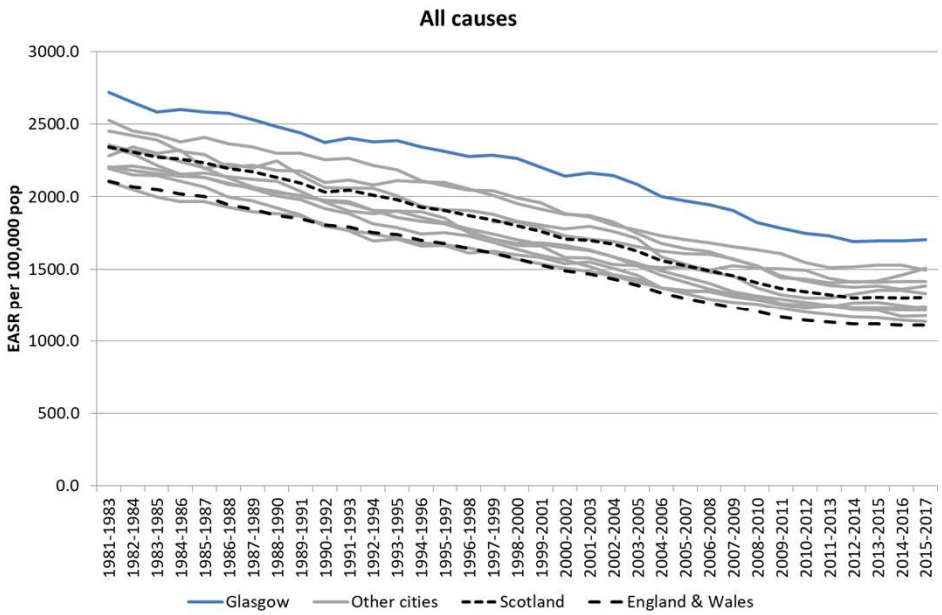
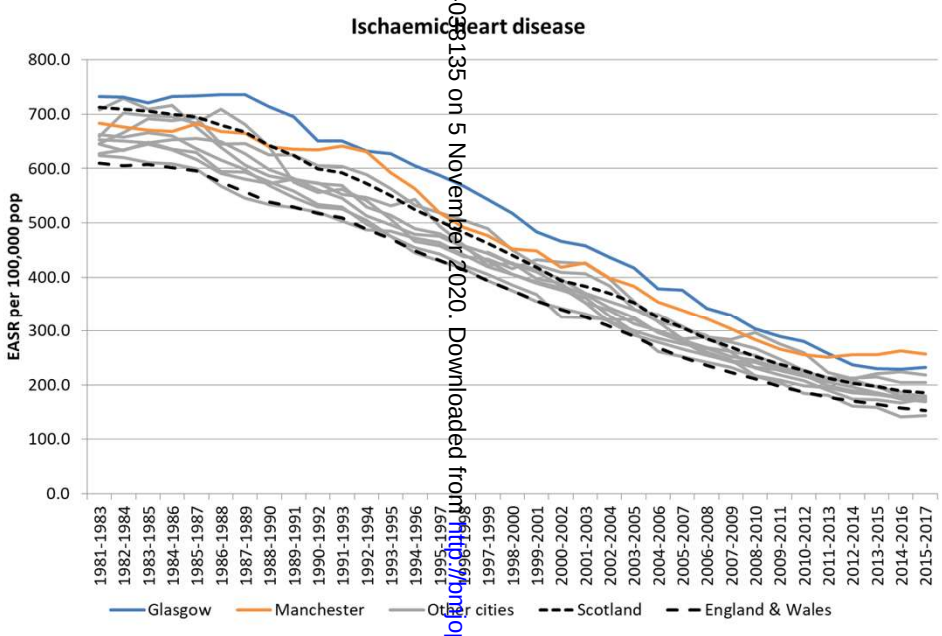
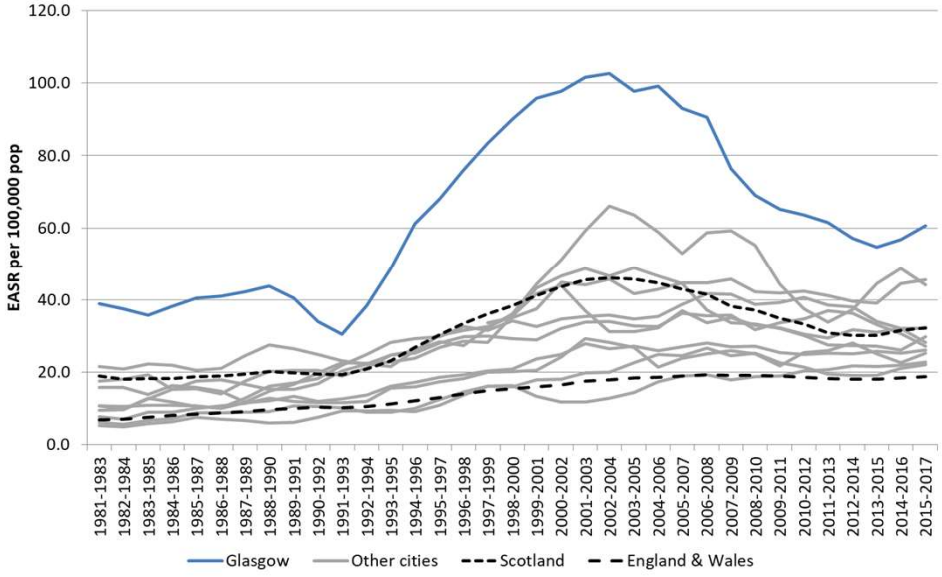


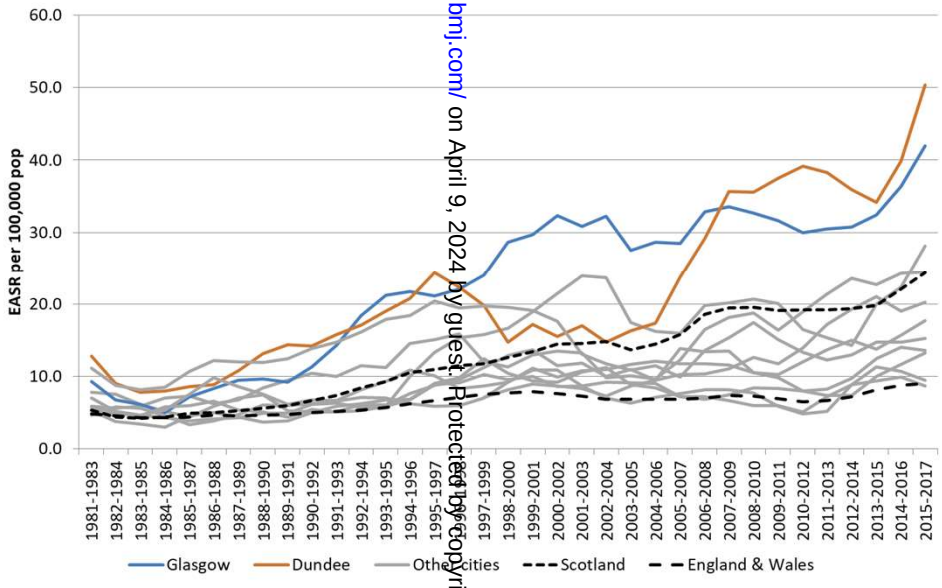
Fig. 4. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles











Web Table 1. Causes of death and associated ICD co

Cause	ICD8 code(s)	ICD9 code(s)	ICD10 codes
Respirat	46-51	46–51	J C-J 9
Ischaemic	41-41	41-41	I 2-I 2
Cerebrovas	43-43	43-43	I 6-I 6
All malign	14-20	14-20	C0-C9
Lung cance neoplasm of trachea/bronchus/lung)	16	16	C3-C3
Intenti-har (including eve undetermined intent)	E9-E95 E980-E989	E9-E95 E980-E989	X6-X84,-Y3 Y87.0, Y87.2
Externa	E8-E9	E8-E9	ICD1(-Y9
Motor veh accidents (MVTAs)	E8-E8	E8-E8	V0-V04, V- V14, V19-V79, V86-V
Alcohol ri	262, 291, 571.9, E860	291, 305.5, 571.0, 571.8, E860	F10, G312, K70, K73, K7 K7, K74, K746-K749, K860, X45, X65, Y1
Drug relat	304, -E85 E8540-E8554, E8550-E8559, E8560-E8569, E950, E962, E980	304, -305 E850-E858, E950.0-E950.5, E962, E980.0-E980.5	F1-F16, F X40-X44, X60-X64, Y10-Y14

Note that there are overlaps between an external causes, intentional self-harm and drug-re

[i] ICD9 and ICD10 codes as used in previous analyses e.g. mortality in a European context 1950-2010: an analysis o

[ii] These are the groups of codes agreed by National Recor (ONS) in 2007. They have since been updated, but the req change in codes.

[iii] These are the set of codes previously deemed most comp Bendel N., Jones R., Hanlon P. It's not 'just deprivatio outcomes? Public Health 2010; 124: 487-495.

Web Table 2a. Slope Index of Inequality (SII) and by deprivation quintile - males

	Scotland		England		Northern Ireland			
	SII	RII	SII	RII	SII	RII		
2001-2003	1168.8	0.69	823.3	0.56	620.7	0.41		
2002-2004	1166.5	0.70	821.8	0.58	536.0	0.36		
2003-2005	1118.8	0.69	811.7	0.59	562.0	0.39		
2004-2006	1102.6	0.71	796.5	0.60	593.3	0.42		
2005-2007	1133.7	0.74	792.7	0.61	639.2	0.46		
2006-2008	1129.6	0.76	797.3	0.63	653.7	0.47		
2007-2009	1106.7	0.76	795.0	0.65	629.1	0.47		
2008-2010	1044.7	0.74	776.0	0.65	615.4	0.47		
2009-2011	1030.8	0.75	755.6	0.65	569.9	0.45		
2010-2012	1018.7	0.76	738.8	0.65	586.9	0.48		
2011-2013	1019.2	0.77	743.0	0.66	615.6	0.50		
2012-2014	1012.4	0.78	745.6	0.67	609.3	0.51		
2013-2015	1022.8	0.78	766.9	0.69	606.7	0.51		
2014-2016	1050.7	0.81	778.2	0.71	616.5	0.53		
2015-2017	1078.2	0.83	784.6	0.71	656.0	0.55		

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	1373.7	0.64	1365.7	0.87	1023.4	0.57		
2002-2004	1383.3	0.64	1292.4	0.84	993.9	0.56		
2003-2005	1270.9	0.61	1198.3	0.79	877.8	0.51		
2004-2006	1294.3	0.65	1229.5	0.84	778.1	0.49		
2005-2007	1279.0	0.65	1314.4	0.93	943.0	0.62		
2006-2008	1299.4	0.67	1265.2	0.93	1041.7	0.70		
2007-2009	1239.5	0.65	1193.2	0.90	1044.4	0.68		
2008-2010	1138.2	0.62	1068.5	0.81	912.2	0.61		
2009-2011	1187.1	0.67	1127.3	0.87	848.4	0.56		
2010-2012	1238.5	0.71	1045.7	0.82	986.1	0.66		
2011-2013	1300.2	0.75	1081.5	0.87	1061.9	0.74		
2012-2014	1266.5	0.75	1120.2	0.92	1235.2	0.88		
2013-2015	1248.0	0.74	1187.1	0.97	1249.0	0.88		
2014-2016	1278.6	0.76	1211.4	1.00	1422.1	0.97		
2015-2017	1329.8	0.78	1178.6	0.97	1443.5	0.96		

Web Table 2b. Slope Index of Inequality (SII) and by deprivation quintile - females

	Scotland		England		Northern Ireland			
	SII	RII	SII	RII	SII	RII		
2001-2003	568.3	0.48	453.0	0.44	226.3	0.21		
2002-2004	580.2	0.49	465.9	0.46	247.1	0.24		
2003-2005	581.9	0.50	473.7	0.47	289.7	0.29		
2004-2006	587.7	0.53	461.6	0.48	337.1	0.34		
2005-2007	585.8	0.53	455.5	0.48	329.6	0.34		
2006-2008	603.7	0.56	457.8	0.50	333.4	0.34		
2007-2009	616.0	0.58	461.2	0.51	341.8	0.36		
2008-2010	617.8	0.59	459.3	0.52	339.4	0.36		
2009-2011	599.1	0.59	453.9	0.53	329.2	0.36		
2010-2012	607.3	0.60	454.5	0.54	323.0	0.36		
2011-2013	607.4	0.61	469.5	0.56	331.6	0.37		
2012-2014	628.6	0.63	478.3	0.57	342.5	0.38		
2013-2015	643.4	0.65	502.3	0.60	368.3	0.41		
2014-2016	662.5	0.67	512.9	0.61	374.3	0.42		
2015-2017	685.7	0.69	528.6	0.63	367.6	0.41		

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	562.8	0.41	579.4	0.54	445.9	0.36		
2002-2004	676.4	0.50	606.3	0.57	534.1	0.45		
2003-2005	620.7	0.46	575.0	0.55	570.7	0.48		
2004-2006	683.0	0.52	538.4	0.53	612.9	0.54		
2005-2007	656.8	0.50	515.7	0.52	605.7	0.56		
2006-2008	678.3	0.52	589.1	0.61	585.4	0.55		
2007-2009	694.3	0.55	639.7	0.66	556.6	0.51		
2008-2010	709.5	0.58	676.2	0.72	493.5	0.45		
2009-2011	757.4	0.64	676.8	0.73	536.6	0.50		
2010-2012	781.4	0.66	698.6	0.75	643.8	0.60		
2011-2013	795.7	0.67	692.6	0.75	624.7	0.59		
2012-2014	744.4	0.63	665.3	0.73	605.3	0.59		
2013-2015	740.9	0.63	704.1	0.78	498.5	0.48		
2014-2016	794.7	0.68	726.0	0.81	684.7	0.66		
2015-2017	887.7	0.75	767.0	0.86	783.1	0.73		

Web Table 3a. Slope Index of Inequality (SII) and I
deprivation quintile: 10 major causes of death, Sc

	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer		
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII	
2001-2003	197.1	0.90	283.8	0.74	62.7	0.37	269.				
2002-2004	202.0	0.93	267.4	0.72	60.1	0.36	269.				
2003-2005	197.2	0.91	256.1	0.73	61.6	0.39	262.				
2004-2006	183.9	0.90	225.0	0.69	52.2	0.36	276.				
2005-2007	185.4	0.90	233.0	0.76	50.0	0.37	289.				
2006-2008	189.1	0.93	215.6	0.76	53.0	0.41	280.				
2007-2009	196.8	0.98	211.3	0.78	55.2	0.45	268.				
2008-2010	189.4	0.99	190.2	0.75	50.9	0.44	254.				
2009-2011	185.0	1.01	182.7	0.77	45.7	0.43	268.				
2010-2012	177.8	1.00	187.1	0.83	39.9	0.40	270.				
2011-2013	184.0	1.05	180.3	0.85	41.3	0.43	269.				
2012-2014	174.4	1.02	182.7	0.90	34.7	0.38	262.				
2013-2015	179.8	1.05	174.6	0.89	39.0	0.44	253.				
2014-2016	178.9	1.06	169.4	0.90	42.0	0.49	255.				
2015-2017	185.3	1.12	165.6	0.89	45.1	0.54	254.				

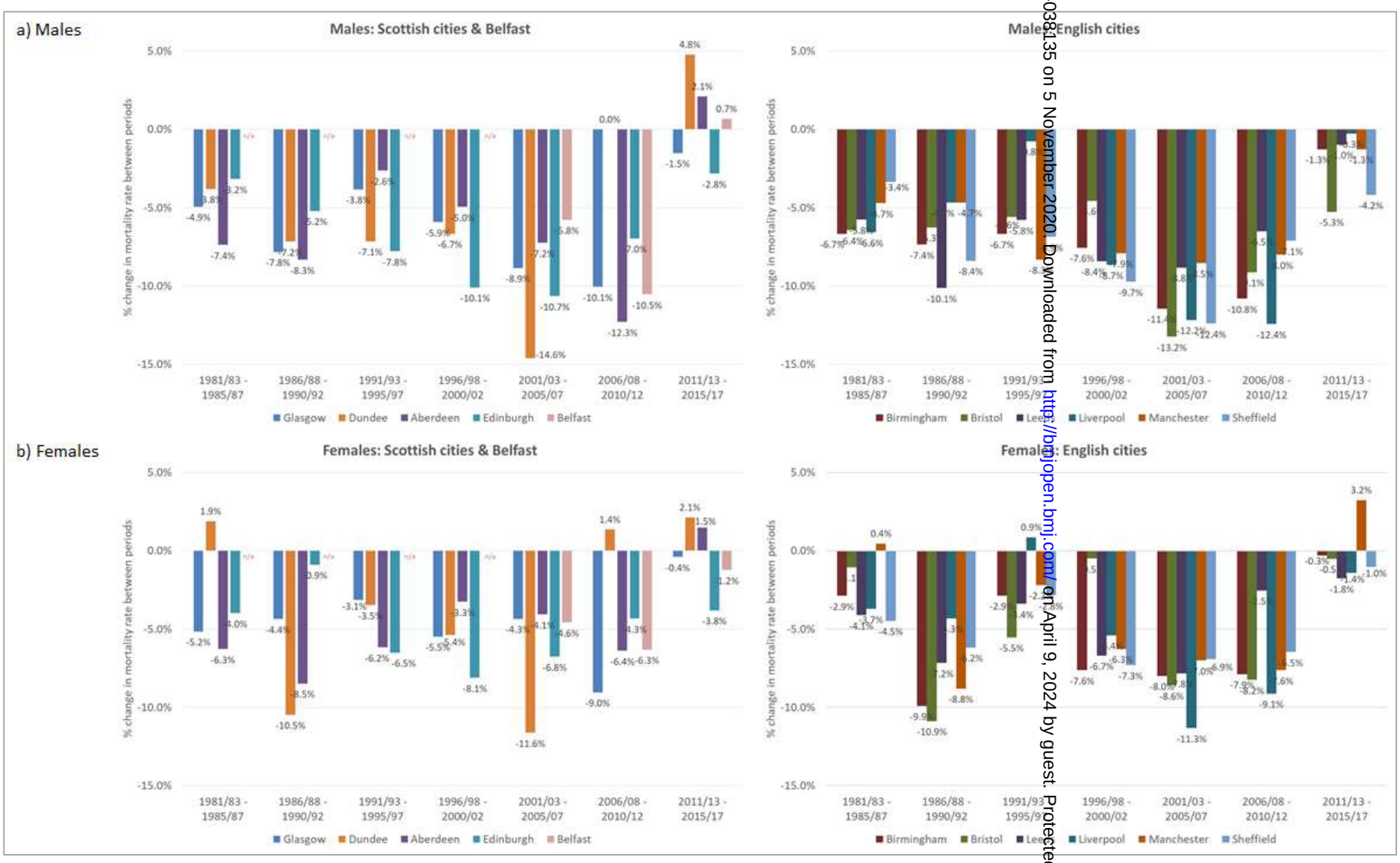
	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents		
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII	
2001-2003	77.6	1.16	37.5	2.58	106.5	2.33	35.7				
2002-2004	79.3	1.17	36.6	2.47	110.8	2.40	34.3				
2003-2005	72.7	1.10	32.1	2.36	106.3	2.33	29.4				
2004-2006	72.9	1.11	36.0	2.49	106.9	2.40	30.1				
2005-2007	69.7	1.11	39.4	2.50	102.7	2.40	29.8				
2006-2008	69.4	1.11	47.0	2.53	102.0	2.46	31.8				
2007-2009	67.1	1.11	48.3	2.49	91.5	2.40	31.9				
2008-2010	64.8	1.11	48.4	2.48	87.3	2.35	31.6				
2009-2011	72.9	1.17	46.3	2.43	76.5	2.20	32.8				
2010-2012	80.0	1.21	47.1	2.46	72.6	2.18	31.3				
2011-2013	89.7	1.28	47.5	2.47	65.0	2.11	30.4				
2012-2014	89.8	1.32	49.7	2.56	66.4	2.20	25.9				
2013-2015	89.5	1.33	51.4	2.59	64.3	2.13	22.9				
2014-2016	101.0	1.43	58.7	2.66	67.4	2.14	22.7				
2015-2017	112.4	1.50	65.9	2.71	67.0	2.08	23.5				

Web Table 3b. Slope Index of Inequality (SII) and I
deprivation quintile: 10 major causes of death, Sc

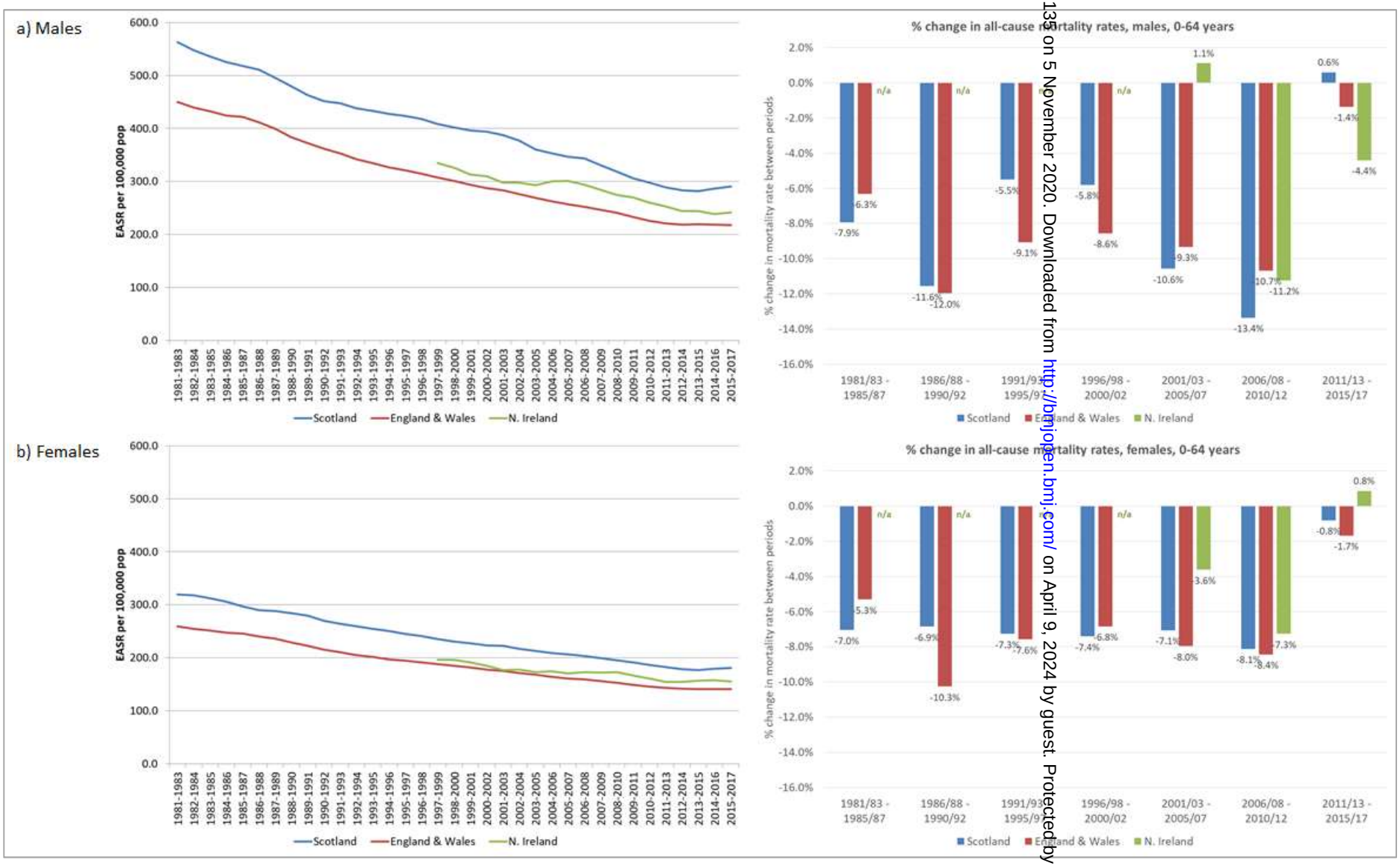
	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer		
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII	
2001-2003	110.5	0.75			135.7	0.64	24.3	0.15			154.
2002-2004	116.7	0.78			125.1	0.61	24.8	0.16			160.
2003-2005	121.1	0.80			119.8	0.62	22.6	0.15			157.
2004-2006	124.3	0.83			111.9	0.62	19.5	0.14			155.
2005-2007	127.1	0.84			109.4	0.66	10.2	0.08			155.
2006-2008	133.5	0.88			103.8	0.67	17.6	0.14			158.
2007-2009	136.3	0.92			102.6	0.71	18.5	0.16			169.
2008-2010	137.8	0.96			96.2	0.71	24.5	0.22			174.3
2009-2011	137.4	1.01			87.4	0.69	22.2	0.21			175.6
2010-2012	147.2	1.09			80.9	0.67	22.7	0.23			173.9
2011-2013	146.3	1.10			76.1	0.67	20.3	0.21			174.7
2012-2014	143.6	1.10			83.9	0.79	19.5	0.21			183.7
2013-2015	139.5	1.06			84.9	0.83	23.9	0.27			186.3
2014-2016	146.9	1.12			87.4	0.90	24.0	0.29			184.8
2015-2017	150.8	1.14			80.7	0.86	25.5	0.32			180.6

	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents		
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII	
2001-2003	17.0	0.50			13.2	2.26	35.9	1.96			12.5
2002-2004	18.1	0.53			12.7	2.25	35.2	1.94			11.5
2003-2005	18.7	0.56			12.0	2.10	35.0	1.91			10.9
2004-2006	21.7	0.68			12.6	2.17	35.4	1.90			10.1
2005-2007	23.5	0.76			12.6	2.28	35.6	1.93			11.6
2006-2008	25.2	0.84			14.6	2.50	34.5	1.95			12.1
2007-2009	22.7	0.74			16.8	2.55	30.6	1.84			11.3
2008-2010	21.1	0.70			17.9	2.49	29.0	1.80			9.6 1
2009-2011	23.4	0.74			18.7	2.39	26.5	1.66			9.7 1
2010-2012	29.6	0.92			19.5	2.41	25.7	1.77			10.5
2011-2013	32.9	1.01			19.0	2.35	23.1	1.68			10.0
2012-2014	31.8	0.99			19.3	2.47	21.8	1.70			9.2 1
2013-2015	32.7	0.97			21.1	2.52	23.0	1.74			7.8 1
2014-2016	37.6	1.03			27.1	2.71	24.2	1.78			7.5 1
2015-2017	46.1	1.18			31.3	2.69	24.3	1.77			6.6 0

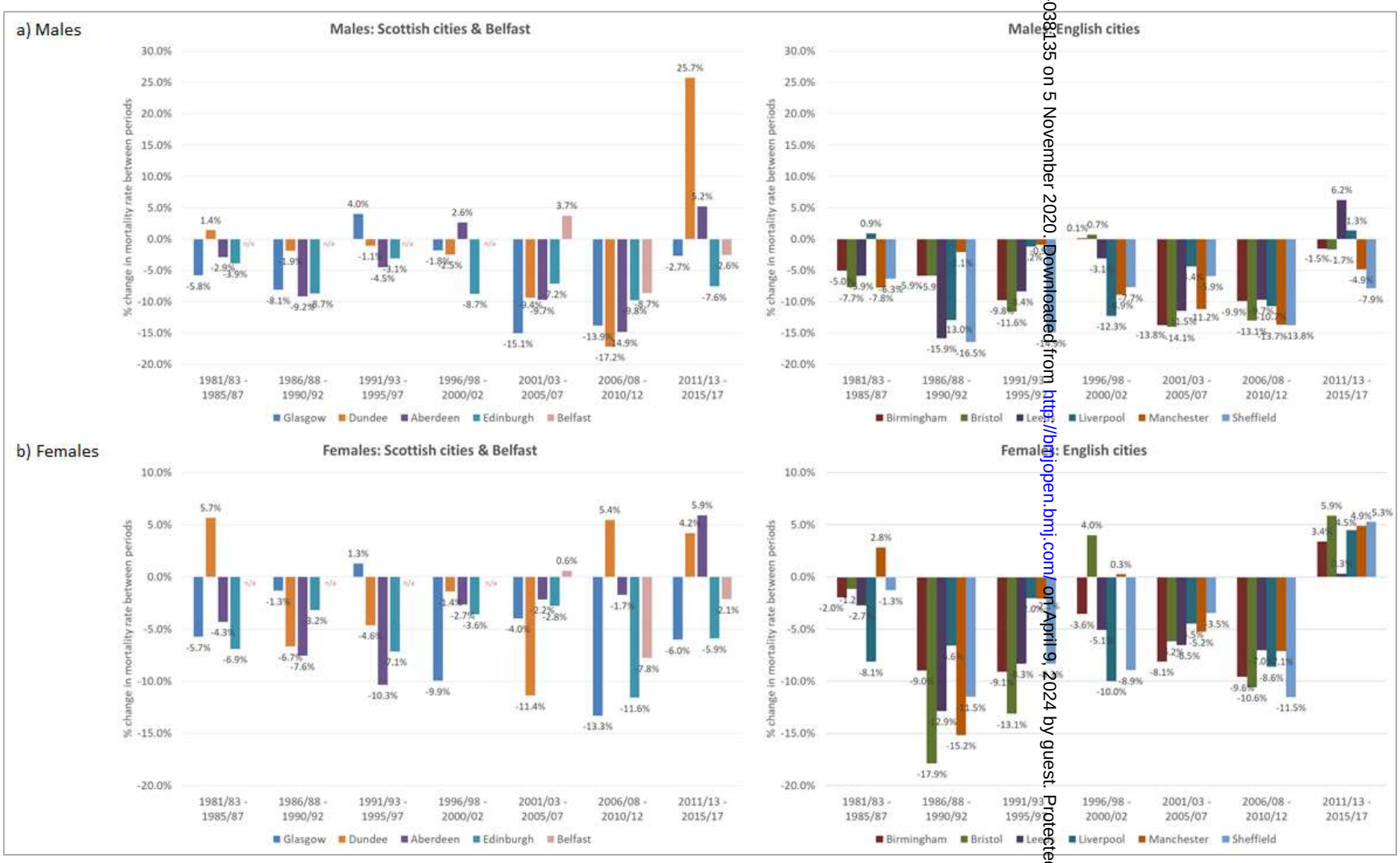
Web Figure 1. All cause deaths, all ages: percentage change in standar



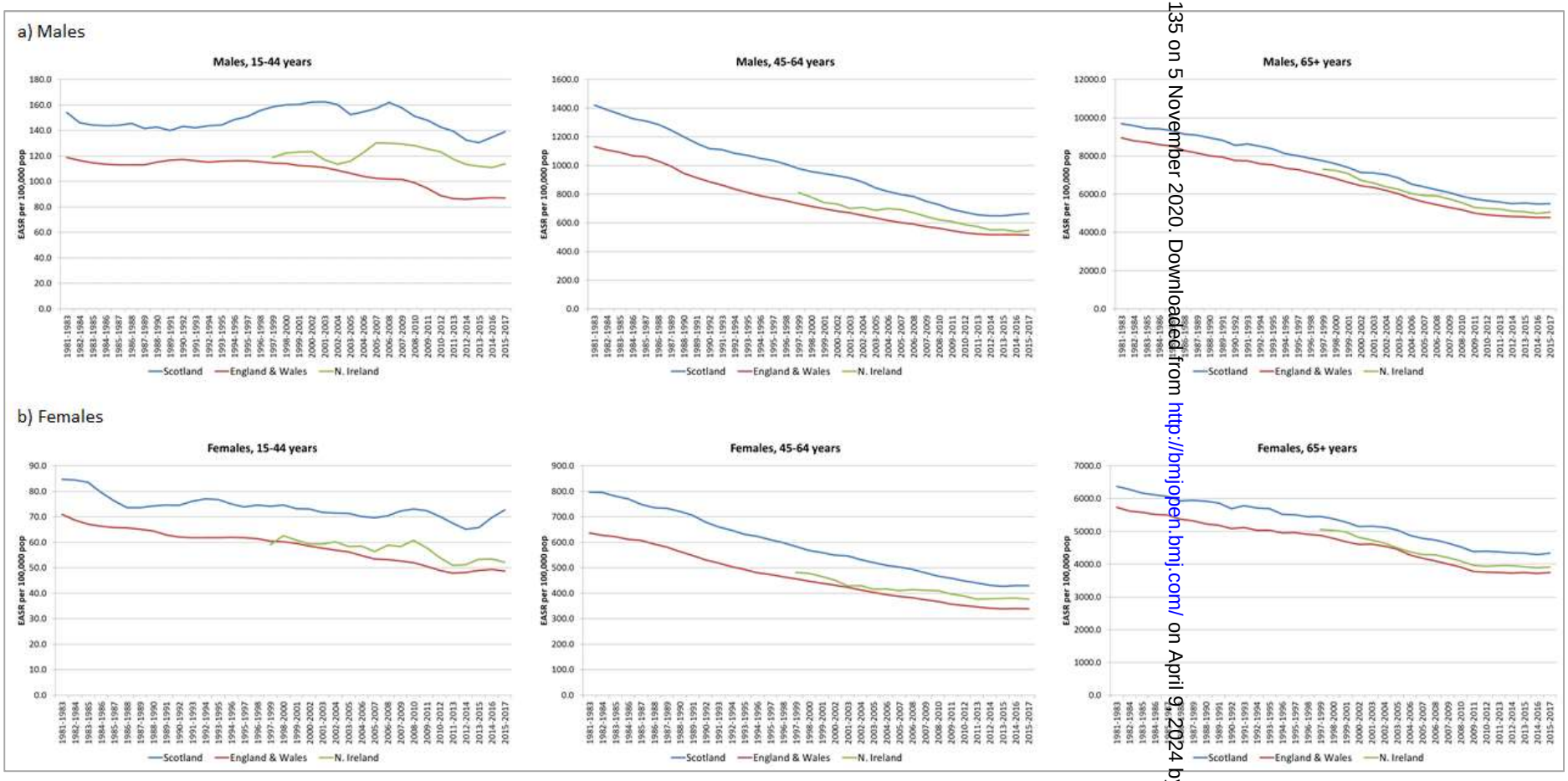
Web Figure 2. European age-standardised mortality rates (0-64 years, a
2017; and percentage change in standardised mortality rates between fi



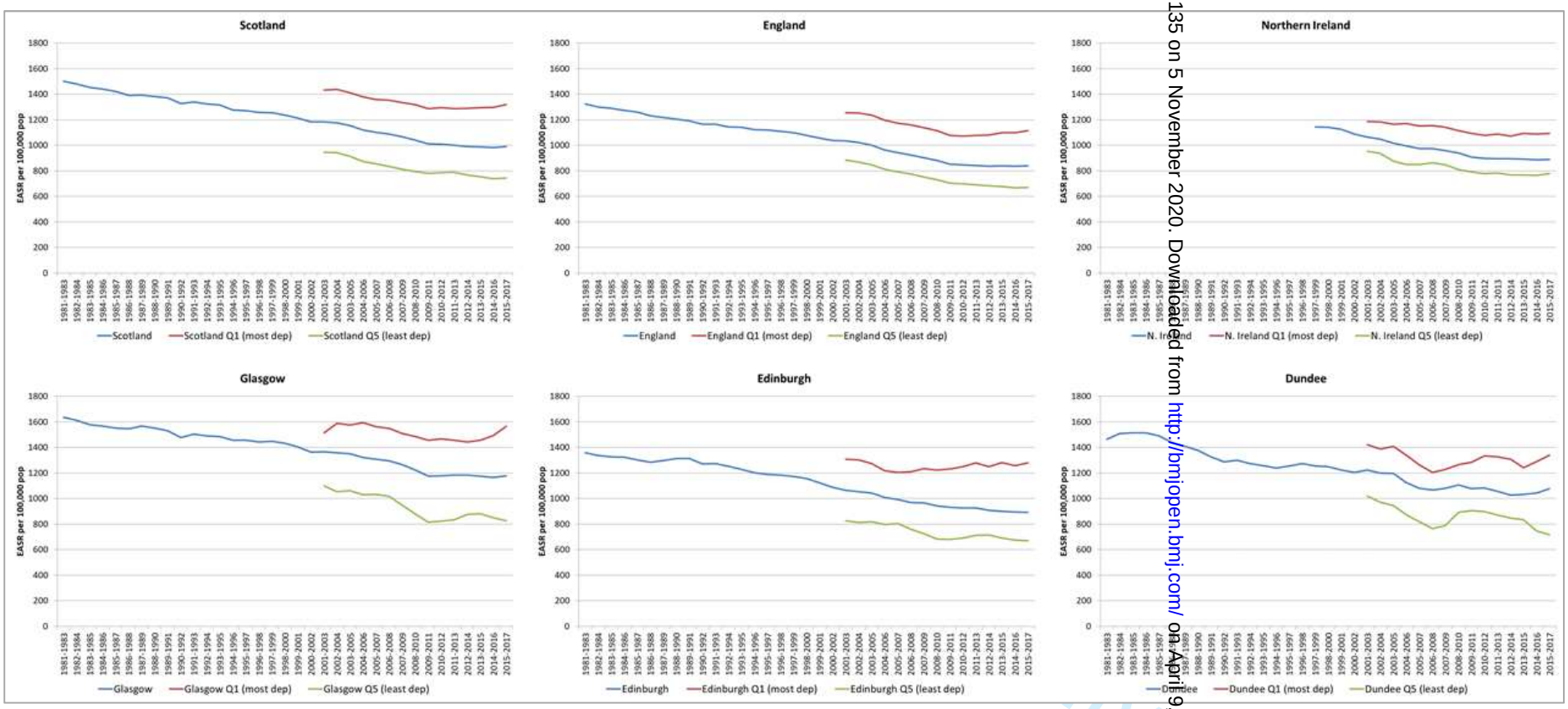
Web Figure 3. All cause deaths, 0-64 years: percentage change in stand



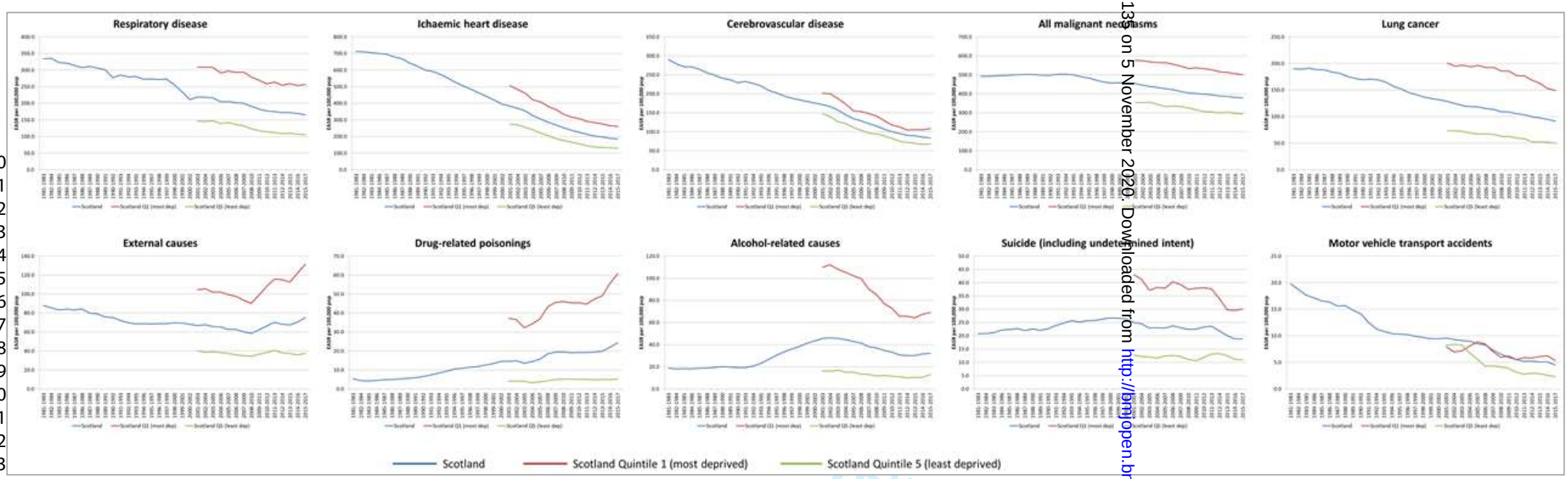
Web Figure 4. European age-standardised mortality rates (all causes) per country, 1981-2017 (note different axis scales on each chart)



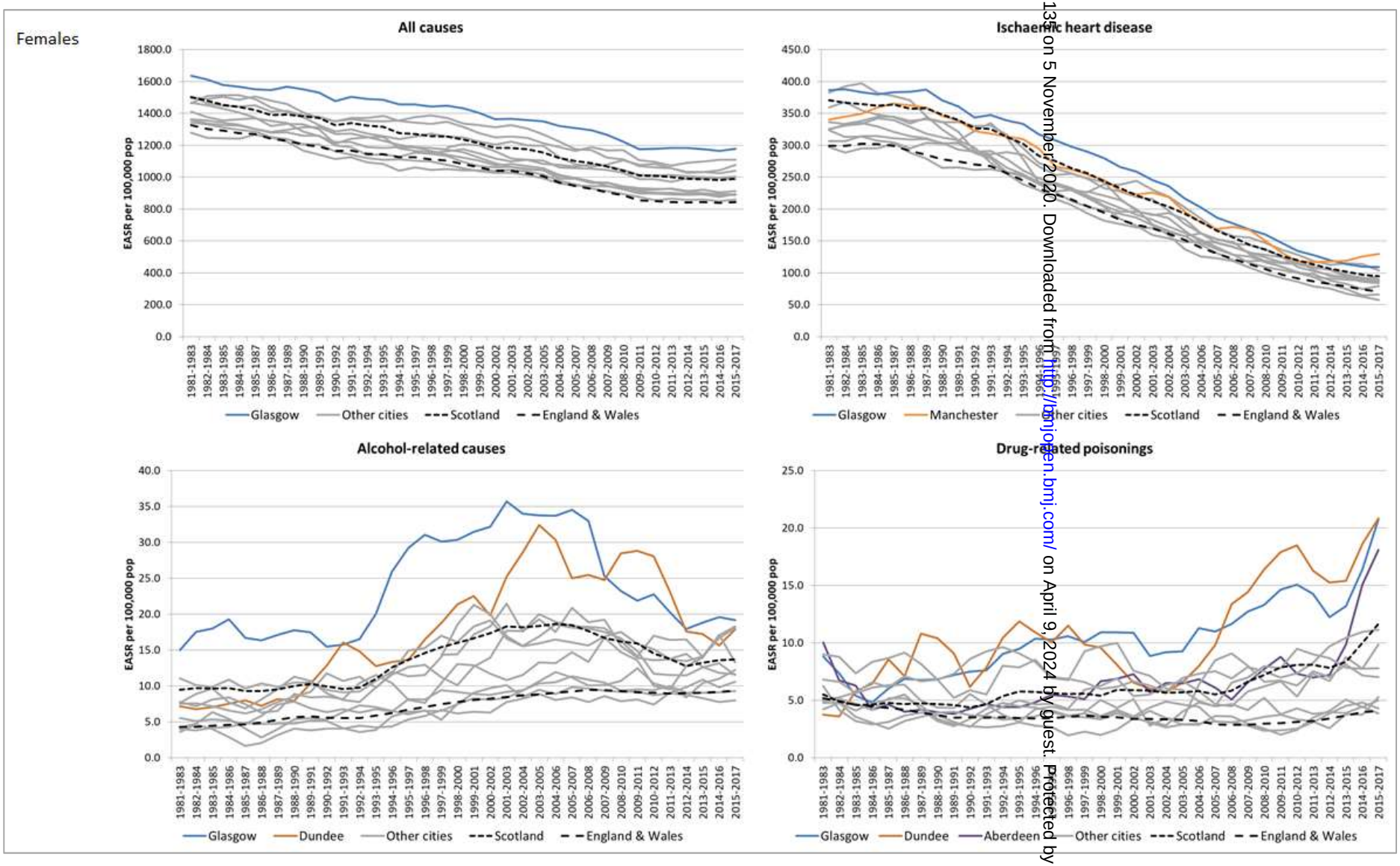
Web Figure 5. European age-standardised mortality rates (females, all country, city and country/city-specific deprivation quintiles



Web Figure 6. European age-standardised mortality rates (males, all ag
Scotland and most and least deprived deprivation quintiles



Web Figure 7. European age-standardised mortality rates (females, all ischaemic heart disease, alcohol-related causes and drug-related poiso



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
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	4-5
Bias	9	Describe any efforts to address potential sources of bias	4-6; 11
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	n/a (total population)
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	n/a
		(b) Indicate number of participants with missing data for each variable of interest	n/a (total population)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	Figs 1-5
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	Figs 1-5
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10; 11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-13
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	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

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Changing mortality trends in UK countries and cities: a population based trend analysis.

David Walsh[1], Gerry McCartney[2], Jon Minton[3], Jane Parkinson[3], Deborah Shipton[4], Bruce Whyte[1]

1. Public Health Programme Manager, Glasgow Centre for Population Health, Olympia Building, 2-16 Orr Street, Bridgeton Cross, Glasgow G40 2QH, Scotland. Tel: 0141 330 2793

2. Consultant in Public Health and Head of the Public Health Observatory team, Public Health Scotland, Glasgow, Scotland

3. Public Health Intelligence Adviser, Public Health Scotland, Glasgow, Scotland

4. Public Health Intelligence Principal, Public Health Scotland, Glasgow, Scotland

Correspondence to: david.walsh.2@glasgow.ac.uk

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Abstract

Background

Previously improving life expectancy and all-cause mortality in the UK has stalled since the early 2010s. National analyses have demonstrated changes in mortality rates for most age groups and causes of death, and with deprived populations most affected. The aims here were to establish whether similar changes have occurred across different parts of the UK (countries, cities), and to examine cause-specific trends in more detail.

Methods

Mortality and population data for UK countries and selected cities were obtained from national statistical agencies. European age-standardised mortality rates were calculated by cause of death, country, city, year (1981-2017), age group, sex, and - for all countries and Scottish cities - deprivation quintiles. Changes in rates between five-year periods, and summary measures of both relative (Relative Index of Inequality (RII)) and absolute (Slope Index of Inequality (SII)) inequality, were also calculated.

Results

Changes in mortality from around 2011/13 were observed throughout the UK for all adult age groups. For example, all-age female rates decreased by c. 4-6% during the 1980s and 1990s, c. 7-9% during the 2000s, but by <1% between 2011/13 and 2015/17. Equivalent figures for men were 4-7%, 8-12% and 1-3% respectively. This later period saw increased mortality among the most deprived populations, something observed in all countries and cities analysed, and for most causes of death: absolute and relative inequalities therefore increased. Although similar trends were seen across all parts of the UK, particular issues apply in Scotland e.g. higher and increasing drug-related mortality (with the highest rates observed in Dundee and Glasgow).

Conclusions

The study presents further evidence of changing mortality in the UK. The timing, geography and socio-economic gradients associated with the changes appear to support suggestions that they may result, at least in part, from UK Government 'austerity' measures which have disproportionately affected the poorest.

(299 Words)

ARTICLE SUMMARY

Strengths and limitations of this study

- We examine recent changes in mortality in the UK in the context of much longer-term trends: almost 40 years in most cases.
- Given the importance of urban health to national outcomes, we include the largest cities in Scotland, England (London excepted) and Northern Ireland.
- We analyse data for 10 major causes of death (not just all-causes combined), and by country-specific and (for Scotland) city-specific deprivation levels.
- Limitations include the fact that interpretation of trends at city level can be problematic, given the fluctuation in rates.

INTRODUCTION

The recent (pre-COVID-19 pandemic) slow-down in improvement in life expectancy and mortality rates in the UK has been highlighted by researchers[1,2] and media[3,4] alike. Similar changing trends have been observed in many other high-income countries, although the slow-down has been particularly marked in the UK and the USA[5]. Other high-income countries with higher life expectancy have seen continued improvements[2,5].

Data from Scotland and England (92% of the UK population) have shown that these changing mortality patterns have been observed for almost all age groups and for most causes of death[6,7]. Worryingly, *increasing* mortality rates among the most socio-economically deprived populations have also been observed; as a result, inequalities in all-cause mortality have widened considerably since around 2012[7-9]. An emerging body of UK[1,10-13] and international[14,15] work suggests the recent stalling is likely to be associated with the implementation from 2010 of UK Government 'austerity' measures – cuts to public services and social security – which have particularly affected the most vulnerable populations.

The principal aim of this project was to establish whether similar changing mortality trends (in terms of rates of improvement, causes of death, and socio-economic inequalities) have occurred ubiquitously across the UK. This included examining cause-specific trends in more detail, and focussing on selected individual cities, given the importance of urban health to national outcomes[16].

METHODS

Mortality & population data

Numbers of deaths by year of registration, age, sex, underlying cause, city and country for Scotland, England & Wales and Northern Ireland were obtained from, respectively, the National Records of Scotland (NRS), the Office for National Statistics (ONS), and the

Northern Ireland Statistics and Research Agency (NISRA). Data were available for the following years: 1974-2017 (Scotland); 1981-2017 (England & Wales); and 1997-2017 (Northern Ireland).

Data were obtained for all-cause deaths, and for the following 10 major individual causes: respiratory disease; ischaemic heart disease (IHD); cerebrovascular disease; all malignant neoplasms; lung cancer (malignant neoplasm of trachea, bronchus and lung); intentional self-harm (including events of undetermined intent); external causes; motor vehicle traffic accidents (MVTAs); alcohol-related causes; and drug-related poisonings. Causes were defined by groups of ICD8, ICD9 and ICD10 codes: these are listed in the online appendix (Web Table 1). As stated in Web Table 1, the definition of external causes overlaps with other causes of death i.e. MVTAs, intentional self-harm, drug-related poisonings. ICD9 codes were used for the years 1979-1999 in Scotland, and for 1981-2000 in England & Wales and Northern Ireland; ICD10 codes were used for all later years. ICD8 codes were used for 1974-1978 (Scotland only) but the data for those years are not presented here.

Matching population data by year, five-year age group, sex, city and country were obtained from the same national statistical agencies.

Geography

Scotland, England & Wales (combined) and Northern Ireland were the countries used in the main analyses. For analysis by deprivation quintiles (discussed further below), England alone, rather than England & Wales, was used. With the exception of London, the largest cities in each country were selected: Glasgow, Edinburgh, Dundee and Aberdeen in Scotland; Liverpool, Manchester, Birmingham, Leeds, Sheffield and Bristol in England; and Belfast in Northern Ireland. London was excluded as its size and ethnic diversity makes meaningful comparisons with other cities problematic[17]. Scottish and English cities were defined by

current local authority boundaries. Belfast was defined by its 1992 local government district (LGD) boundary.

Deprivation analyses employed the separate Scottish, English and Northern Irish area-based indices of deprivation: the Scottish Index of Multiple Deprivation (SIMD)[18], the (English) Index of Multiple Deprivation (IMD)[19], and the Northern Ireland Multiple Deprivation Measure (NIMDM)[20] respectively. In all three cases data were available for the period 2001-2017. The SIMD has been updated multiple times: thus, the 2004 version was used for analyses covering the years 2001-04, SIMD 2006 was used for 2005-07, SIMD 2009 for 2008-10, SIMD 2012 for 2011-13 and SIMD 2016 for 2014-17. Similarly, the (English) IMD 2004 was used for the years 2001-05, IMD 2007 for 2006-08, IMD 2010 for 2009-13, IMD 2015 for 2014-16 and IMD 2019 for 2017. For Northern Ireland, NIMDM 2010 was used for all years of analyses. Although there are differences in the spatial scale and the individual variables used in the construction of each nation's deprivation measure, all three share notable similarities in terms of their basic composition. The principal 'data domains' of each are effectively the same: income; employment; health; education, skills and training; crime; access to services; housing. In the Scottish index, housing is a separate category; in the English and Northern Irish indices it is instead contained within a 'living environment' domain. For all three measures of deprivation, similar methodologies are employed to calculate an overall index of relative deprivation, based on geographical area rankings across all data domains. Although the absolute values of the different indices cannot be directly compared, the similarity of composition and methodology associated with each provides helpful, and broadly comparable, overviews of inequality *within each setting.*

Statistical analyses

European age-standardised mortality rates (EASRs) per 100,000 population were calculated using the 2013 European Standard Population[21]. Analyses were undertaken by sex, age (all

ages, 0-64 years (the latter to examine premature deaths), and four broad groups across the life-course: 0-14 years, 15-44 years, 45-64 years, 65+ years), year, cause of death, city, country and deprivation quintile (see below). Three-year rolling average rates were derived; to quantify the rate of improvement over time, the percentage changes in rates between three-year averages at five-year intervals (i.e. between 1981/83 and 1985/87, 1986/88 and 1990/92… up to 2011/13 and 2015/17) were calculated. Three-year averages were used to overcome the issue of fluctuating rates (especially at city level). For simplicity, we use the expression 'five-year' interval to reflect the mid-points of the three-year average (e.g. 1982 to 1986 in relation to 1981/83 to 1985/87).

For the deprivation analyses, mortality rates by quintile were calculated on the basis of both *national* quintiles (based on levels of deprivation within individual countries) and – for Scottish cities only – *city-specific* quintiles (based on levels of deprivation *within each individual city*). City-specific quintiles are made publicly available by ISD Scotland (now Public Health Scotland) for all versions of the SIMD used in the analyses, and were downloaded from their website. Equivalent data were not available for the English cities. In all analyses Quintile 1 represented the *most deprived* fifth of the country's/city's small areas, and Quintile 5 the *least deprived* fifth. The aim was to compare quintile rates *within the same location* (country or city), not between different locations. Note that as the English IMD does not include Wales, for comparison all-cause mortality rates by year and sex for England alone (rather than England & Wales combined) were also calculated. Analyses by deprivation were undertaken for all-cause deaths for all geographies, and for cause-specific mortality for all Scottish areas.

To examine changes in both absolute and relative inequalities in mortality (for the countries, Scottish cities, and the causes of death), the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) respectively were calculated, based on the above deprivation

quintiles. The SII calculates the gap in mortality rates across groups (here, the five quintiles), taking into account each quintile's rate (not just those of the least and most deprived), and each quintile's population size. The RII expresses this as a relative measure by dividing the SII by the rate for the whole population[22].

Analyses were undertaken using IBM SPSS Statistics 25.

Patient and Public Involvement

Patients were not involved in this study

RESULTS

Figure 1 presents all-cause standardised mortality rates for all ages by country and city for (a) males and (b) females between 1981/83 and 2015/17. At the national level, a change in the male death trend appears visible from around 2011/13 for both Scotland and England, with no or little improvement observed in the periods after that; there is greater fluctuation in rates in Northern Ireland. A change in rates appears more apparent, occurring slightly earlier, for deaths among females including those in Northern Ireland. At the city level, greater fluctuation in rates is clearly evident, as would be expected given the smaller population sizes and associated numbers of deaths: nonetheless the majority of cities appear to have experienced a flattening, or worsening, of mortality rates in the last 3-4 time points shown.

[Figure 1 about here]

To quantify the changes shown above, Figure 2 shows the percentage change in rates between five-year periods for Scotland, England & Wales and Northern Ireland. For women, mortality rates were decreasing by approximately 4-6% during the 1980s and 1990s, with a faster improvement of approximately 7-9% during the 2000s, and a much slower decrease of <1% between 2011/13 and 2015/17. Amongst men, mortality rates were decreasing slightly

faster during the 1980s and early 1990s (by 4-7%), with a faster improvement of approximately 8-12% during the late 1990s and 2000s, and again a much slower decrease between 2011-13 and 2015/7 of 1-3%. Similar data for the cities are shown in the online appendix (Web Figure 1): these show a very similar overall pattern to the country-level analyses, albeit with greater fluctuation in the percentage change figures in some cities such as Dundee. However, it is also notable that – despite that fluctuation – in the most recent five-year period mortality rates actually worsened among both males and females in Dundee and Aberdeen, and among females in Manchester, while there was virtually no improvement among males in Liverpool and females in Birmingham (-0.3% for both).

Note that analyses based on more 'standard' five year periods (1981-85, 1986-90 up to 2011-15) produced very similar results (data not shown).

[Figure 2 about here]

Analyses of trends and changes in rates for ages 0-64 years (rather than all ages) are presented in Web Figure 2 for the countries of interest. While the results are broadly similar to those seen for all ages, the data suggest there has been a slight increase (rather than slow-down) in mortality rates for Scotland in the most recent period. Across the cities, a more notable change was observed in Dundee for males in this age group: a 26% increase in mortality between 2011/13 and 2015/17 (Web Figure 3). Notwithstanding the greater fluctuation in changes in rates in this age group at city level, it is also of note that there was an increase in female mortality rates in the last period in each English city.

Trends in all-cause rates for 45-64 years were similar to those described above for 0-64 years, and rates for 65+ years were broadly similar to those observed for all ages. For the 15-44 age group, rates were notably higher in Scotland than England & Wales, and the mortality gap had become wider in the most recent period. These data are all shown in Web Figure 4 (i). Although the principal focus of these analyses is adult mortality, Web Figure 4 (ii) shows

country level rates over time for ages 0-14 years. It is notable that child mortality rates in Scotland have been consistently lower than in England & Wales since the late 1990s for females and early-to-mid 2000s for males, a reversal of the position at the beginning of the period. Rates are highest in Northern Ireland, although they are also subject to greater fluctuation over time.

Figure 3 again shows male all-cause mortality rates for all ages but additionally presents the rates for the least and most deprived deprivation quintiles within Scotland, England, Northern Ireland and an illustrative selection of three Scottish cities. Increased mortality rates are observed in the most recent period for the most deprived fifth of the population in each country/city shown (albeit that there is again more fluctuation in rates at the city level). Similar trends were observed for female mortality rates, as shown in Web Figure 5. Summary measures of inequalities (SIIs, RIIs) confirm widening absolute and relative inequalities across deprivation quintiles since 2011/13 in all countries and cities analysed (Web Tables 2a and 2b). For example, for all-cause deaths among men in England, the absolute gap across quintiles (as measured by the SII) increased from 738.8 in 2010/12 to 784.6 in 2015/17, despite having decreased between 2001/03 and 2010/12; relative inequalities increased over the whole period.

[Figure 3 about here]

Mortality rates over time by deprivation quintile are explored in more detail for Scotland in Figure 4, which presents data for females for all ten causes of death analysed. A widening gap between the most and least deprived quintiles in the most recent years of analysis can be seen for the majority of causes, in particular respiratory disease, external causes, drug-related poisonings and alcohol-related causes. Different trends are observed for suicide (where the gap has narrowed) and MVTAs (where numbers of deaths are relatively small and there is considerable fluctuation in rates across quintiles of deprivation). Generally, the

same patterns, in terms of a widening gap between the most and least deprived deprivation quintiles for the majority of causes of death, are observed for male deaths (Web Figure 6). The main difference between the male and female trends relates to cancer mortality, in particular lung cancer, with a widening deprivation gap observed for females but not males. The general pattern of widening inequalities for the majority of causes is confirmed by analysis of SIIs and RIIs (Web Table 3a and 3b).

[Figure 4 about here]

Aside from evidence of a slow-down in mortality improvement and widening deprivation gaps (already shown in Figures 1 and 3), the analyses of city level mortality rates highlight a number of other issues. Foremost among them is that Glasgow stands out in terms of having the highest mortality rates of all the cities for all cause deaths and the majority of causes analysed (including strikingly different trends for alcohol related causes). Some exceptions do apply, however: for example, for all ages death rates from IHD are now marginally higher in Manchester for both males and females, while deaths from drug-related poisonings are now highest in Dundee. Some of these data are shown for males in Figure 5, and for females in Web Figure 7.

[Figure 5 about here]

Finally Figure 5/Web Figure 7 also highlight notable similarities and differences in long-term mortality trends between Scotland and England. For example: a narrowing of the gap between the countries for IHD; much higher drug-related poisonings in Scotland compared to England - although rates are increasing in both countries; and notably higher rates of death from alcohol related causes in Scotland, with the most recent increase in rates much more pronounced in Scotland than in England. The striking trends in drug-related poisonings are explored in more depth in Web Figure 8 (comparing the UK countries for selected age groups and by sex) and Web Figure 9 (showing data for Scotland and its most and least

deprived quintiles for age 0-64 years). There has been a widening divergence in death rates from this cause between Scotland and the rest of the UK over the period shown, and a further increase in rates is again observed since approximately 2012. Similar deprivation trends for drug-related poisonings are evident in the Scottish cities (data not shown).

DISCUSSION

Overall findings and implications

The study presents further evidence of a slow-down in mortality rate improvement over time within the UK. In some cases – deaths under 65 years in Scotland and all-age mortality in particular cities – rates have increased, rather than stalled, in recent years. These overall changes appear to be particularly driven by worsening mortality among the most socio-economically disadvantaged populations. Similar trends are observed across all countries and cities in the UK; however, particular issues apply in Scotland, for example in relation to drug-related mortality. The timing, geographical coverage and socio-economic gradients associated with the changes appear to further support suggestions that recent changes in mortality are at least partly a consequence of UK Government 'austerity' measures.

Strengths and weaknesses

The analyses were based on data covering the whole population, not samples. Mortality is a robust population health indicator and is not subject to the limitations and potential biases associated with self-reported measures[23,24]. We included the largest cities within Scotland and Northern Ireland and, with the exception of London, the six largest cities in England. We were able to examine recent changes in mortality in the context of much longer-term trends: almost 40 years in the case of Scotland and England & Wales. We analysed data for a broad set of causes of death, not just all-deaths combined.

The exclusion of London is arguably a weakness, although it was done to facilitate more meaningful comparisons across the other cities with more similar population sizes. Other limitations include the fact that time trend data for Northern Ireland were much more limited than for the rest of the UK. Interpretation of trends at city, rather than country level can also be problematic, given the fluctuation in rates that occur. Although the measures of area-based multiple deprivation that are employed within Scotland, England and Northern Ireland have many similarities, they are derived from different data sets and calculated at different spatial scales and are thus not directly comparable. We standardised mortality rates using 18 age groups (0-4 years to 85 years and above) while it is now recommended to standardise on the basis of 19 groups (0-4 years to 90 years and above)[25]: however, the impact of this is fairly minimal. Although our youngest age bracket is 0-14 years, we did not include infant mortality (deaths under 1 year of age) as a distinct category: as a major focus of the work was city-based analyses, data on infant deaths were not requested from the various statistical agencies as numbers of deaths at that geographical level in the UK are very small; however, given recent evidence of increasing infant mortality rates in England (linked to increased child poverty rates), this was arguably an oversight[26]. Finally, the definition of drug-related poisonings is a broader, less sophisticated, definition than that employed in official UK publications of drug-related mortality in the UK. In 2017, for example, there were 1,037 such drug-related poisonings in Scotland, 11% higher than the 934 drug-related deaths recorded by the National Records of Scotland[27].

Relevance to other studies

Slower improvement in mortality and life expectancy in the UK in recent years has been shown by various authors and organisations[1,2,5 -8]. Similar trends have been observed in a number of countries, although in a recent analysis of 20 high-income countries, only the USA had experienced a greater reduction in improvement than the UK[5]. As others have

proposed, it appears increasingly likely that these changes are at least in part attributable to UK Government policy which since 2010 have brought about dramatic cuts to social security budgets and other public services, particularly affecting the most vulnerable10-13. There is international evidence of the associations between such government measures and increased mortality rates[14,15] , and the particular model of austerity adopted in the UK (based on spending cuts rather than a taxation approach) is known to be more regressive[13]. UK research has highlighted associations between different UK austerity measures and increased child poverty[26, 28] , expansion of foodbanks[29], increased homelessness[30], poorer mental health among affected populations[31] and, ultimately, increased numbers of deaths among the poorest at different ages[8]. Interactions between such policy-driven factors and other influences such as high winter mortality in particular years have also been suggested[6].

The widening socio-economic inequalities in mortality since around 2012 have been shown previously for Scotland[8,9] and England[7,32], but only at national level, and only for all-cause mortality and life expectancy. The increase in drug-related deaths within Scotland has been the focus of much media attention, resulting in two recent Westminster Parliamentary Committee enquiries[33,34], and the establishment of 'drugs death task force' by the Scottish Government in 2019[35]. The increase is known to be the result of a 'perfect storm' of factors: a previously-described vulnerable cohort of drugs users who are now encountering multiple morbidities as they age; increased affordability and accessibility of chosen drugs; and the aforementioned UK Government austerity measures which have impacted on both individual income and funding of drug-related and other relevant social services[33,34,36]. These drug mortality trends are likely to have influenced the overall increasing death rates in Scotland (and in Dundee) among 0-64 year-olds.

Alcohol mortality trends have historically been impacted by changes in price and availability in combination with socioeconomic vulnerability[37,38], while the reasons for Glasgow's

particularly high mortality rates (including from alcohol, drugs and other causes) have been described in detail previously, being attributable to higher socio-economic deprivation alongside an additional vulnerability created by a combination of multiple historical factors including worse living conditions and adverse policy-making at different levels of government[39].

The contrasting trends in lung cancer mortality between males (decreasing rates) and females (increasing rates) living in the most deprived quintile in Scotland are also best explained in terms of different cohorts, with females having started smoking later than males: this has been shown in a number of other analyses[40]. In addition, one of the other notable differences between male and female trends – the apparent earlier slow-down in mortality improvement for females – is worthy of further analysis. Data presented here for both countries and cities suggest a change in female mortality rates from around 2010/12 or 2011/13, potentially suggesting women's circumstances might be more sensitive to government austerity policies. However, more detailed analysis of Scottish data by Fenton et al instead suggested a change between 2013 and 2014[2]. Finally, although the main focus of the paper is adult mortality, the extent to which Scotland's child mortality rate has improved relative to that of England & Wales may be associated with a similar widening gap in child poverty levels between the countries over a similar time period is worthy of further investigation[41].

Conclusions

These results add to the growing body of evidence of changing mortality rates within the UK in recent years and their likely political causes. With mortality rates rising among the UK's most deprived populations even prior to the COVID-19 pandemic, it is imperative that a range of policies are introduced to protect the health of the most vulnerable in society.

(3,687 words)

Figure 1. European age-standardised mortality rates (all ages, all causes) per 100,000 population, three-year rolling averages, by UK country and city, 1981-2017

Figure 2. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods

Figure 3. European age-standardised mortality rates (males, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles

Figure 4. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles

Figure 5. European age-standardised mortality rates (males, all ages) per 100,000 population, three-year rolling averages, for all-cause deaths, ischaemic heart disease, alcohol-related causes and drug-related poisonings, UK countries and cities, 1981-2017

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DECLARATIONS

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Contributions: D. Walsh originally conceived the study. The research questions and analysis plan were agreed by all authors (G. McCartney, J. Minton, J. Parkinson, D. Shipton and B. Whyte). D. Walsh undertook the analyses and drafted the manuscript. All authors provided substantial critical input to improve the manuscript and all authors approved the final draft.

Competing interests: None declared

Ethical approval: None required

Data sharing: No additional data available. The analysed data presented in the paper are not publicly available. However, the data on which the analyses were based can be requested from the national statistical agencies listed in the manuscript.

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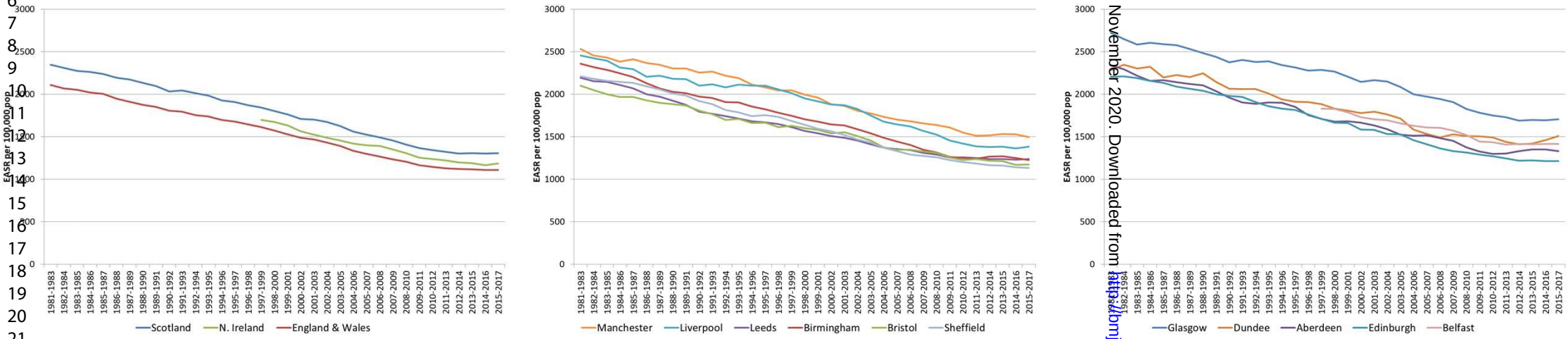
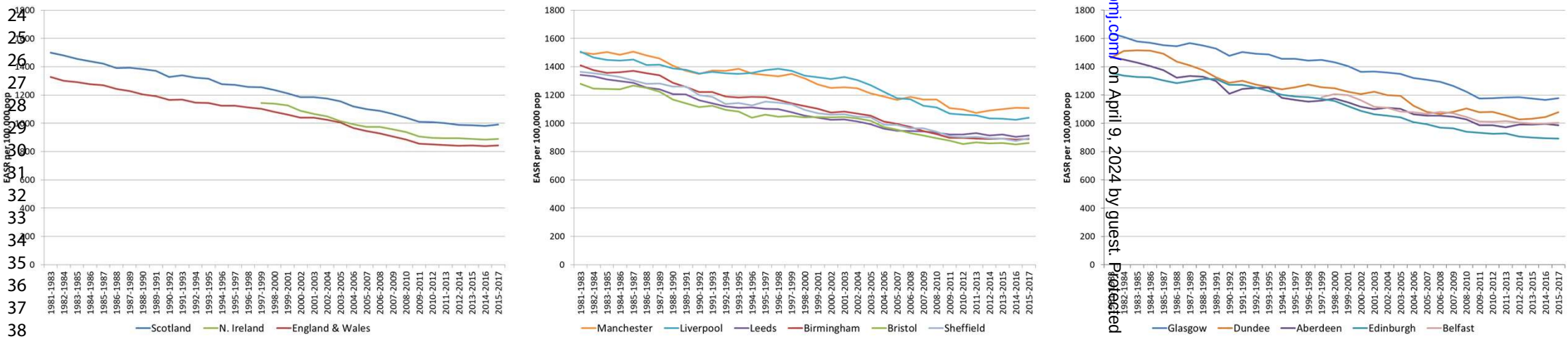
Figure 1. European age-standardised mortality rates (all ages, all causes) per 100,000 population, three-year rolling averages, by UK country and city, 1981-2017

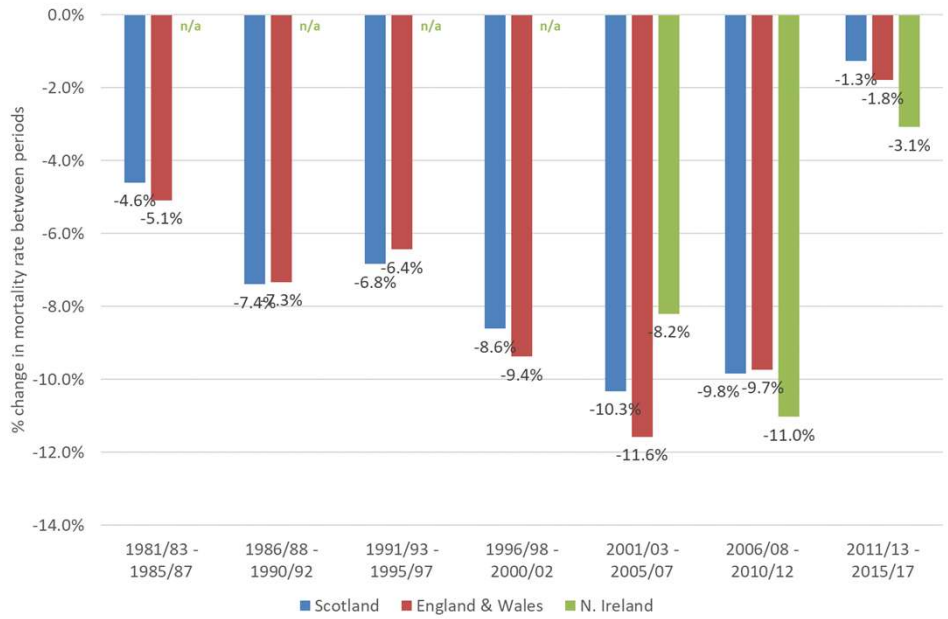
a) Males



b) Females



a) Males



b) Females

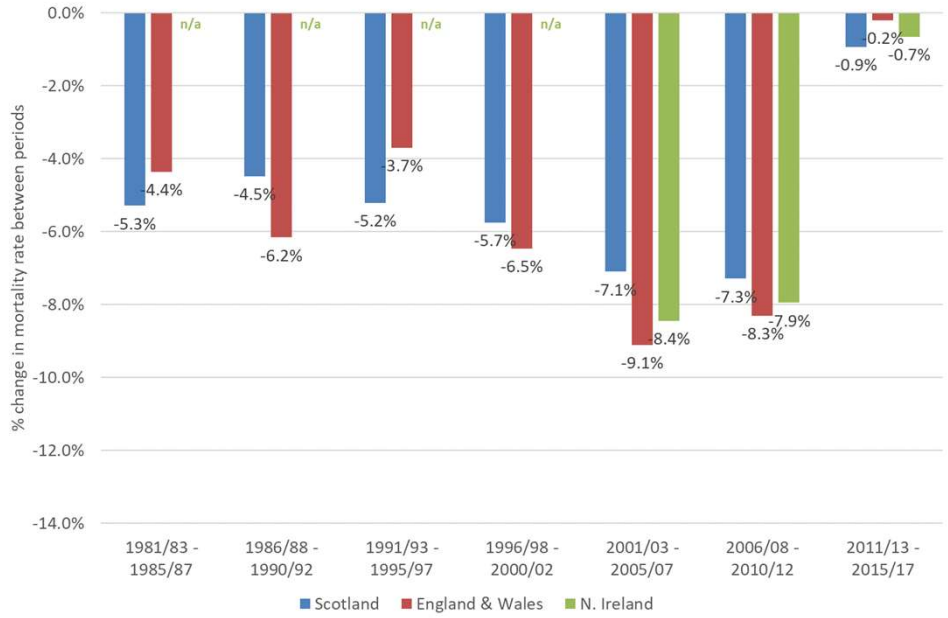


Figure 2. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods

Figure 3. European age-standardised mortality rates (males, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles

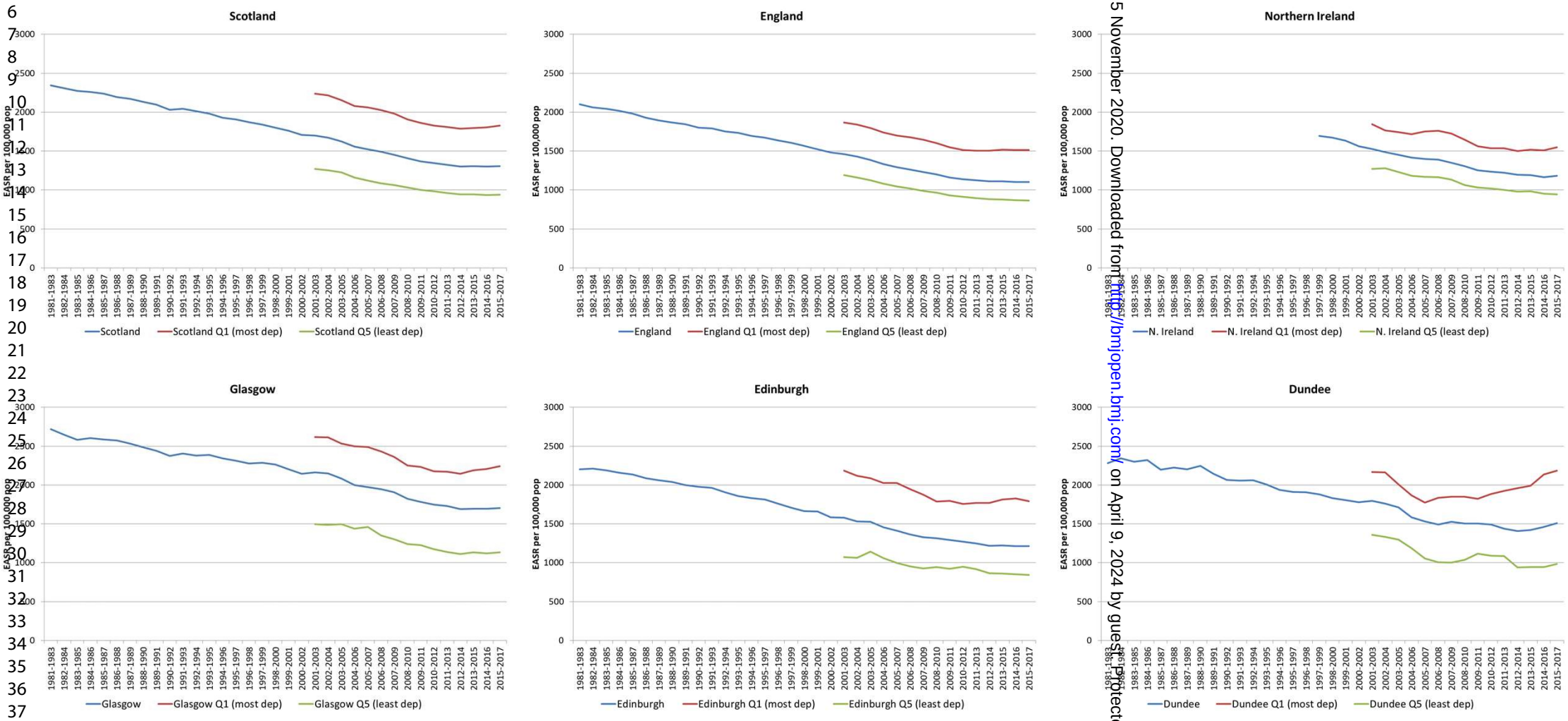
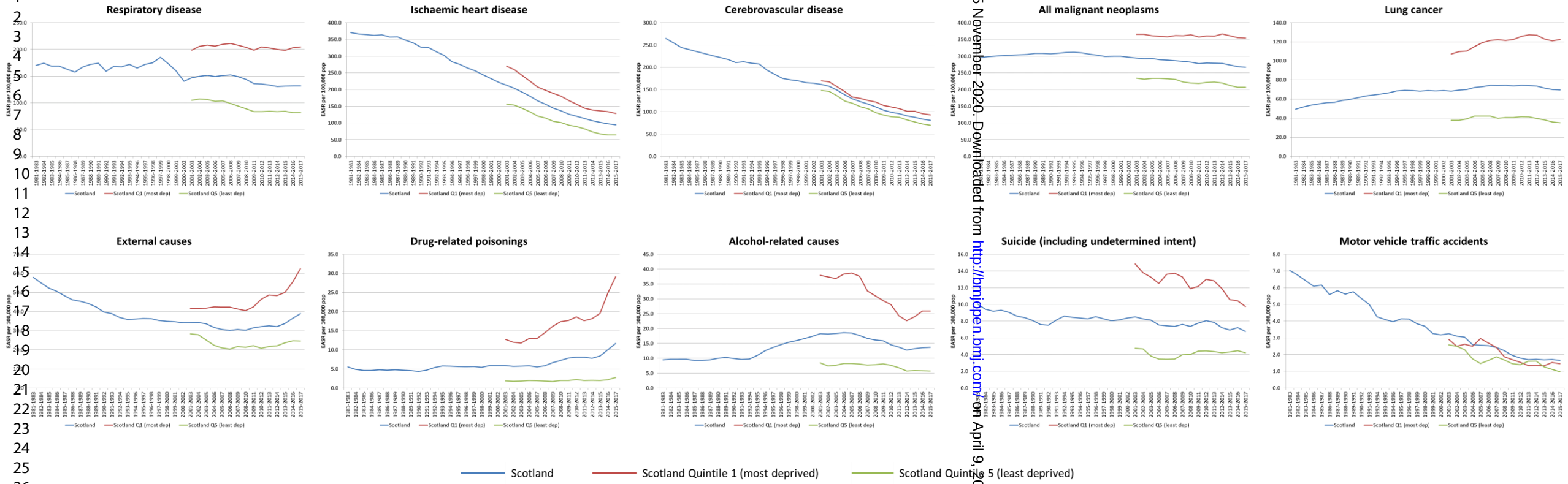
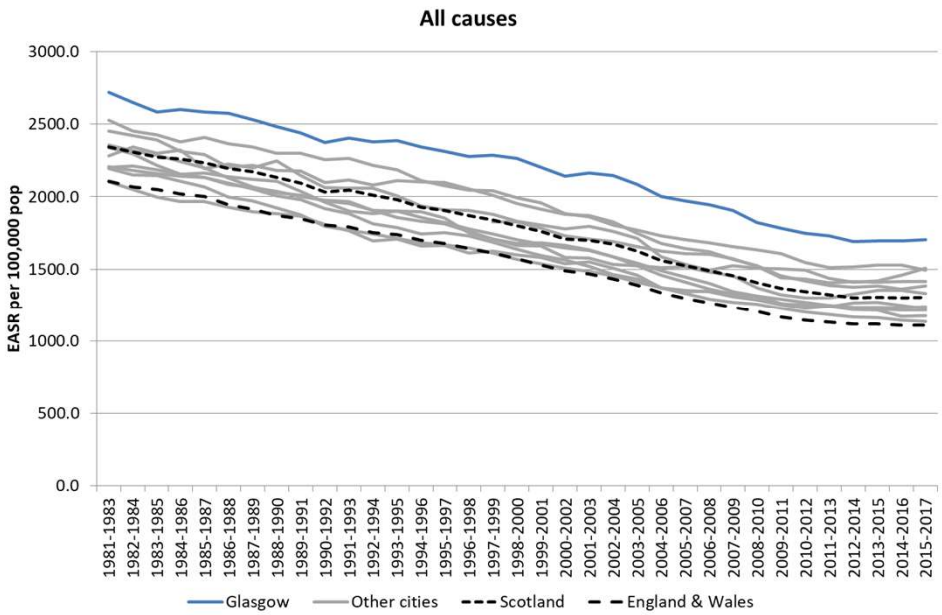
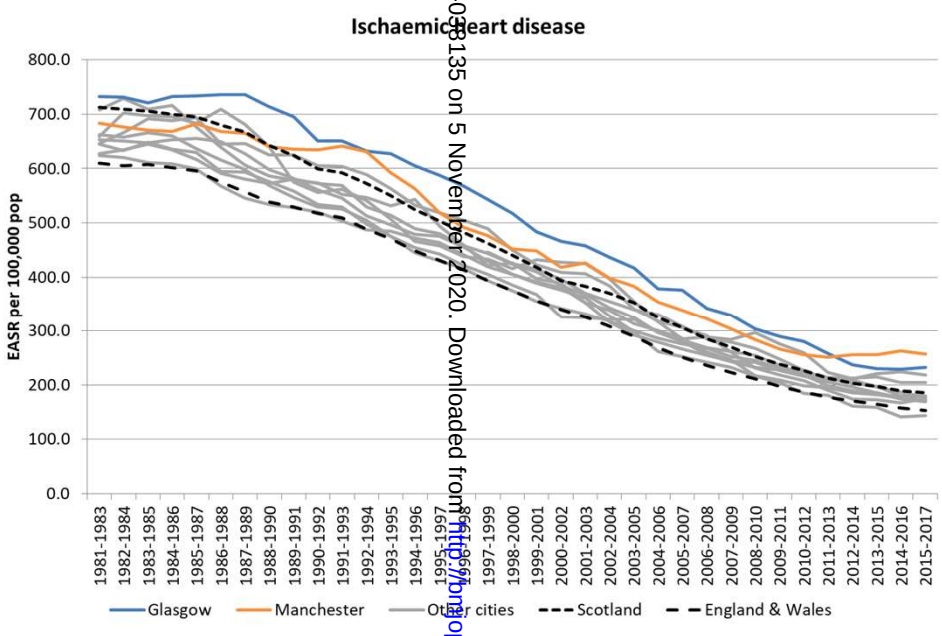


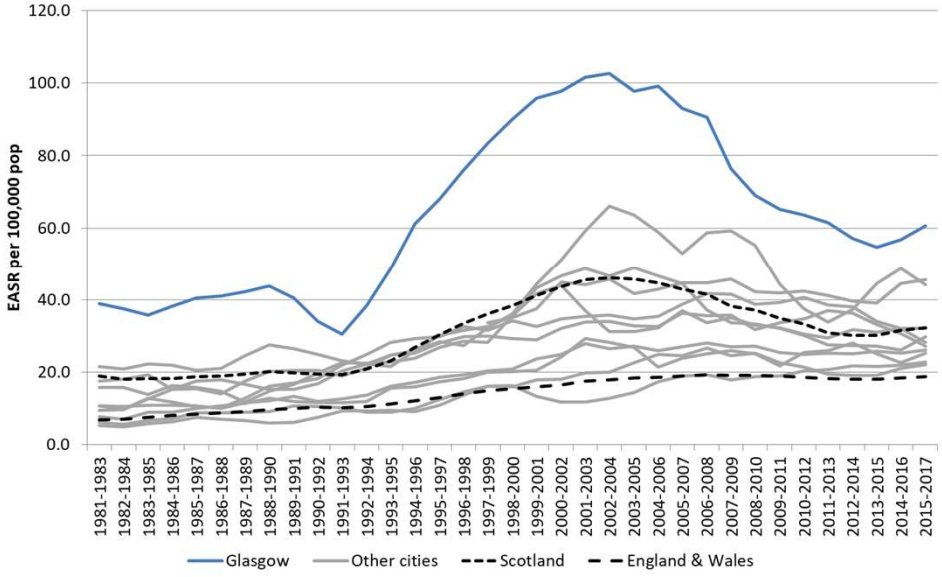
Fig. 4. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles

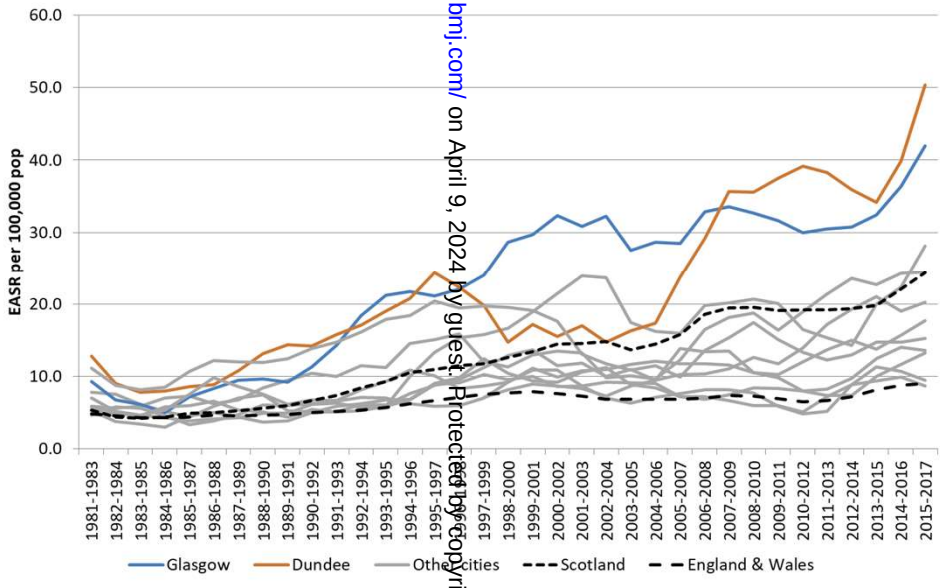


Note that there are some overlaps in the ICD code definitions for some causes of death e.g.: all cancers and lung cancer; all external causes, intentional self-harm and drug-related poisonings; external causes and MVTAs









Web Table 1. Causes of death and associated ICD codes

Cause	ICD8 code(s)	ICD9 code(s)	ICD10 codes
Respiratory disease	460-519	460–519	J00-J99
Ischaemic heart disease	410-414	410-414	I20-I25
Cerebrovascular disease	430-438	430-438	I60-I69
All malignant neoplasms	140-209	140-208	C00-C97
Lung cancer (malignant neoplasm of trachea/bronchus/lung)	162	162	C33-C34
Intentional self-harm (including events of undetermined intent)	E950-E959, E980-E989	E950-E959, E980-E989	X60-X84, Y10-Y34, Y87.0, Y87.2
External causes	E800-E999	E800-E999	ICD10 V01-Y98
Motor vehicle traffic accidents (MVTAs) [i]	E810-E819	E810-E819	V02-V04, V09, V12-V14,V19-V79, V86-V89
Alcohol related causes[ii]	262,291,303,571.0, 571.9, E860	291, 303, 305.0, 425.5, 571.0-571.5, 571.8, 571.9, E860	F10, G312, G621, I426, K292, K70, K73, K740-K742, K746-K749, K860, X45, X65, Y15
Drug related poisonings[iii]	304, E8530-E8539, E8540-E8549, E8550-E855.6, E8560-E8569, E950, E962, E980	304, 305.2-305.9, E850-E858, E950.0-E950.5, E9620, E980.0-E980.5	F11-F16, F18, F19, X40-X44, X60-X64, X85,Y10-Y14
Note that there are overlaps between a number of categories e.g.: all cancers and lung cancer; all external causes, intentional self-harm and drug-related poisonings; external causes and MVTAs			

[i] ICD9 and ICD10 codes as used in previous analyses e.g. Whyte B., Ajetunmobi T. Still 'The Sick Man of Europe'? Scottish mortality in a European context 1950-2010: an analysis of comparative mortality trends. Glasgow: GCPH; 2012

[ii] These are the groups of codes agreed by National Records of Scotland (NRS) and the (UK) Office for National Statistics (ONS) in 2007. They have since been updated, but the request for mortality data from national agencies pre-dated the change in codes.

[iii] These are the set of codes previously deemed most comparable between Scotland and England & Wales. See: Walsh D., Bendel N., Jones R., Hanlon P. It's not 'just deprivation': Why do equally deprived UK cities experience different health outcomes? Public Health 2010; 124: 487-495.

Web Table 2a. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for all-cause mortality rates by deprivation quintile - males

	Scotland		England		Northern Ireland	
	SII	RII	SII	RII	SII	RII
2001-2003	1168.8	0.69	823.3	0.56	620.7	0.41
2002-2004	1166.5	0.70	821.8	0.58	536.0	0.36
2003-2005	1118.8	0.69	811.7	0.59	562.0	0.39
2004-2006	1102.6	0.71	796.5	0.60	593.3	0.42
2005-2007	1133.7	0.74	792.7	0.61	639.2	0.46
2006-2008	1129.6	0.76	797.3	0.63	653.7	0.47
2007-2009	1106.7	0.76	795.0	0.65	629.1	0.47
2008-2010	1044.7	0.74	776.0	0.65	615.4	0.47
2009-2011	1030.8	0.75	755.6	0.65	569.9	0.45
2010-2012	1018.7	0.76	738.8	0.65	586.9	0.48
2011-2013	1019.2	0.77	743.0	0.66	615.6	0.50
2012-2014	1012.4	0.78	745.6	0.67	609.3	0.51
2013-2015	1022.8	0.78	766.9	0.69	606.7	0.51
2014-2016	1050.7	0.81	778.2	0.71	616.5	0.53
2015-2017	1078.2	0.83	784.6	0.71	656.0	0.55

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	1373.7	0.64	1365.7	0.87	1023.4	0.57	942.5	0.58
2002-2004	1383.3	0.64	1292.4	0.84	993.9	0.56	983.6	0.62
2003-2005	1270.9	0.61	1198.3	0.79	877.8	0.51	999.4	0.66
2004-2006	1294.3	0.65	1229.5	0.84	778.1	0.49	1061.9	0.70
2005-2007	1279.0	0.65	1314.4	0.93	943.0	0.62	1076.5	0.71
2006-2008	1299.4	0.67	1265.2	0.93	1041.7	0.70	1207.9	0.82
2007-2009	1239.5	0.65	1193.2	0.90	1044.4	0.68	1200.6	0.83
2008-2010	1138.2	0.62	1068.5	0.81	912.2	0.61	1161.8	0.85
2009-2011	1187.1	0.67	1127.3	0.87	848.4	0.56	1061.8	0.80
2010-2012	1238.5	0.71	1045.7	0.82	986.1	0.66	905.0	0.70
2011-2013	1300.2	0.75	1081.5	0.87	1061.9	0.74	865.9	0.66
2012-2014	1266.5	0.75	1120.2	0.92	1235.2	0.88	844.7	0.64
2013-2015	1248.0	0.74	1187.1	0.97	1249.0	0.88	936.0	0.69
2014-2016	1278.6	0.76	1211.4	1.00	1422.1	0.97	1001.7	0.74
2015-2017	1329.8	0.78	1178.6	0.97	1443.5	0.96	1108.3	0.83

Web Table 2b. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for all-cause mortality rates by deprivation quintile - females

	Scotland		England		Northern Ireland	
	SII	RII	SII	RII	SII	RII
2001-2003	568.3	0.48	453.0	0.44	226.3	0.21
2002-2004	580.2	0.49	465.9	0.46	247.1	0.24
2003-2005	581.9	0.50	473.7	0.47	289.7	0.29
2004-2006	587.7	0.53	461.6	0.48	337.1	0.34
2005-2007	585.8	0.53	455.5	0.48	329.6	0.34
2006-2008	603.7	0.56	457.8	0.50	333.4	0.34
2007-2009	616.0	0.58	461.2	0.51	341.8	0.36
2008-2010	617.8	0.59	459.3	0.52	339.4	0.36
2009-2011	599.1	0.59	453.9	0.53	329.2	0.36
2010-2012	607.3	0.60	454.5	0.54	323.0	0.36
2011-2013	607.4	0.61	469.5	0.56	331.6	0.37
2012-2014	628.6	0.63	478.3	0.57	342.5	0.38
2013-2015	643.4	0.65	502.3	0.60	368.3	0.41
2014-2016	662.5	0.67	512.9	0.61	374.3	0.42
2015-2017	685.7	0.69	528.6	0.63	367.6	0.41

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	562.8	0.41	579.4	0.54	445.9	0.36	493.1	0.45
2002-2004	676.4	0.50	606.3	0.57	534.1	0.45	543.6	0.49
2003-2005	620.7	0.46	575.0	0.55	570.7	0.48	445.1	0.40
2004-2006	683.0	0.52	538.4	0.53	612.9	0.54	481.0	0.45
2005-2007	656.8	0.50	515.7	0.52	605.7	0.56	498.0	0.47
2006-2008	678.3	0.52	589.1	0.61	585.4	0.55	576.5	0.55
2007-2009	694.3	0.55	639.7	0.66	556.6	0.51	526.2	0.50
2008-2010	709.5	0.58	676.2	0.72	493.5	0.45	520.1	0.51
2009-2011	757.4	0.64	676.8	0.73	536.6	0.50	483.6	0.49
2010-2012	781.4	0.66	698.6	0.75	643.8	0.60	394.3	0.40
2011-2013	795.7	0.67	692.6	0.75	624.7	0.59	442.3	0.46
2012-2014	744.4	0.63	665.3	0.73	605.3	0.59	512.1	0.52
2013-2015	740.9	0.63	704.1	0.78	498.5	0.48	665.4	0.67
2014-2016	794.7	0.68	726.0	0.81	684.7	0.66	637.8	0.64
2015-2017	887.7	0.75	767.0	0.86	783.1	0.73	597.3	0.61

Web Table 3a. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for mortality rates by deprivation quintile: 10 major causes of death, Scotland, males

	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	197.1	0.90	283.8	0.74	62.7	0.37	269.4	0.59	152.3	1.18
2002-2004	202.0	0.93	267.4	0.72	60.1	0.36	269.7	0.60	146.6	1.18
2003-2005	197.2	0.91	256.1	0.73	61.6	0.39	262.1	0.60	147.4	1.22
2004-2006	183.9	0.90	225.0	0.69	52.2	0.36	276.9	0.64	152.3	1.29
2005-2007	185.4	0.90	233.0	0.76	50.0	0.37	289.5	0.68	158.0	1.33
2006-2008	189.1	0.93	215.6	0.76	53.0	0.41	280.1	0.67	155.7	1.35
2007-2009	196.8	0.98	211.3	0.78	55.2	0.45	268.9	0.65	154.6	1.36
2008-2010	189.4	0.99	190.2	0.75	50.9	0.44	254.0	0.63	146.6	1.34
2009-2011	185.0	1.01	182.7	0.77	45.7	0.43	268.0	0.67	144.3	1.33
2010-2012	177.8	1.00	187.1	0.83	39.9	0.40	270.8	0.68	140.1	1.33
2011-2013	184.0	1.05	180.3	0.85	41.3	0.43	269.7	0.68	143.2	1.39
2012-2014	174.4	1.02	182.7	0.90	34.7	0.38	262.5	0.68	140.8	1.41
2013-2015	179.8	1.05	174.6	0.89	39.0	0.44	253.6	0.66	136.3	1.40
2014-2016	178.9	1.06	169.4	0.90	42.0	0.49	255.9	0.67	127.8	1.35
2015-2017	185.3	1.12	165.6	0.89	45.1	0.54	254.3	0.67	126.4	1.38

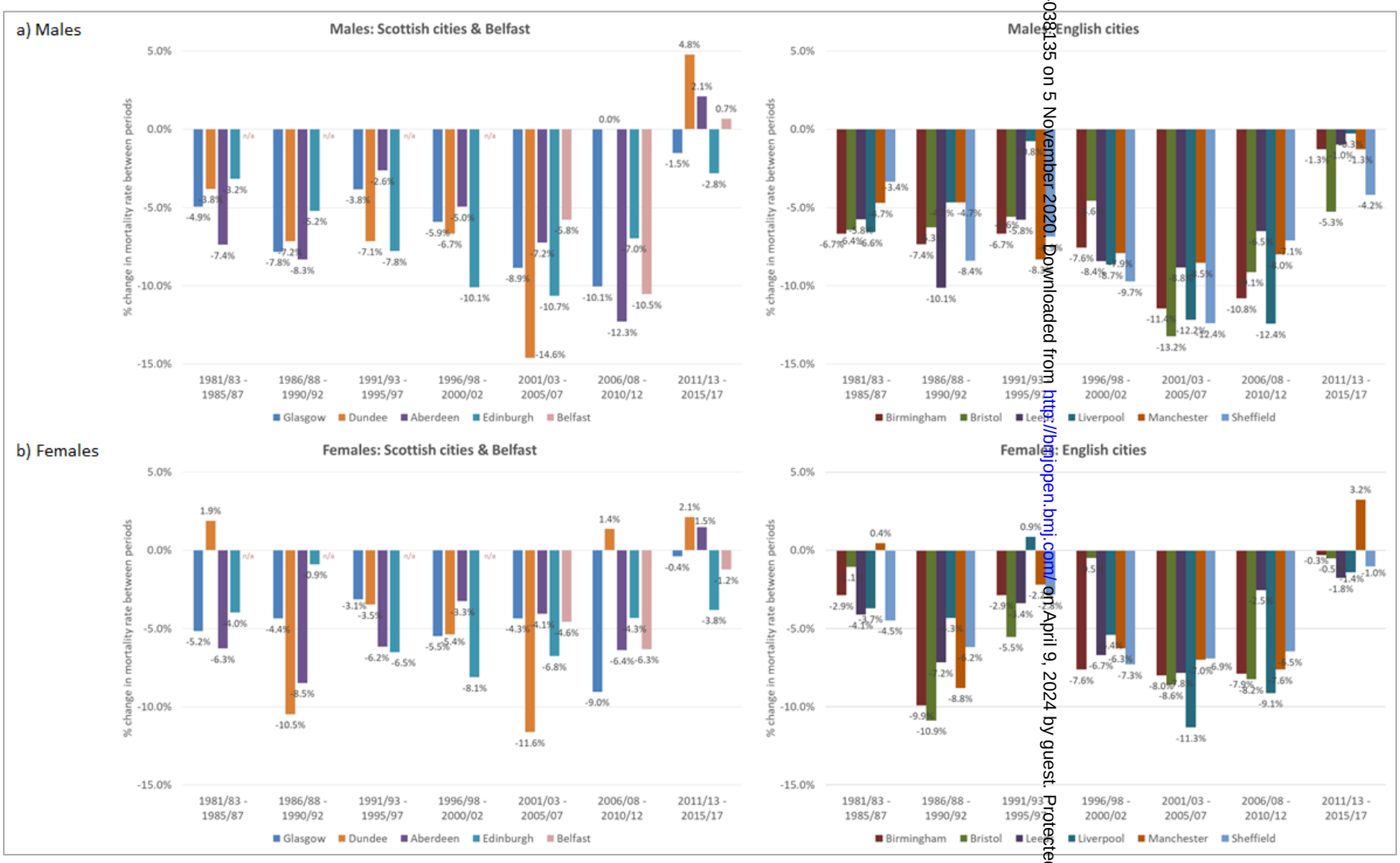
	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	77.6	1.16	37.5	2.58	106.5	2.33	35.7	1.4	1.0	0.10
2002-2004	79.3	1.17	36.6	2.47	110.8	2.40	34.3	1.4	-0.6	-0.07
2003-2005	72.7	1.10	32.1	2.36	106.3	2.33	29.4	1.3	-1.0	-0.11
2004-2006	72.9	1.11	36.0	2.49	106.9	2.40	30.1	1.3	1.5	0.16
2005-2007	69.7	1.11	39.4	2.50	102.7	2.40	29.8	1.3	2.4	0.29
2006-2008	69.4	1.11	47.0	2.53	102.0	2.46	31.8	1.3	3.1	0.38
2007-2009	67.1	1.11	48.3	2.49	91.5	2.40	31.9	1.4	1.8	0.25
2008-2010	64.8	1.11	48.4	2.48	87.3	2.35	31.6	1.4	1.3	0.20
2009-2011	72.9	1.17	46.3	2.43	76.5	2.20	32.8	1.5	2.1	0.36
2010-2012	80.0	1.21	47.1	2.46	72.6	2.18	31.3	1.3	1.5	0.28
2011-2013	89.7	1.28	47.5	2.47	65.0	2.11	30.4	1.3	2.7	0.51
2012-2014	89.8	1.32	49.7	2.56	66.4	2.20	25.9	1.2	2.0	0.38
2013-2015	89.5	1.33	51.4	2.59	64.3	2.13	22.9	1.1	2.7	0.53
2014-2016	101.0	1.43	58.7	2.66	67.4	2.14	22.7	1.2	2.9	0.57
2015-2017	112.4	1.50	65.9	2.71	67.0	2.08	23.5	1.2	2.9	0.65

Web Table 3b. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for mortality rates by deprivation quintile: 10 major causes of death, Scotland, females

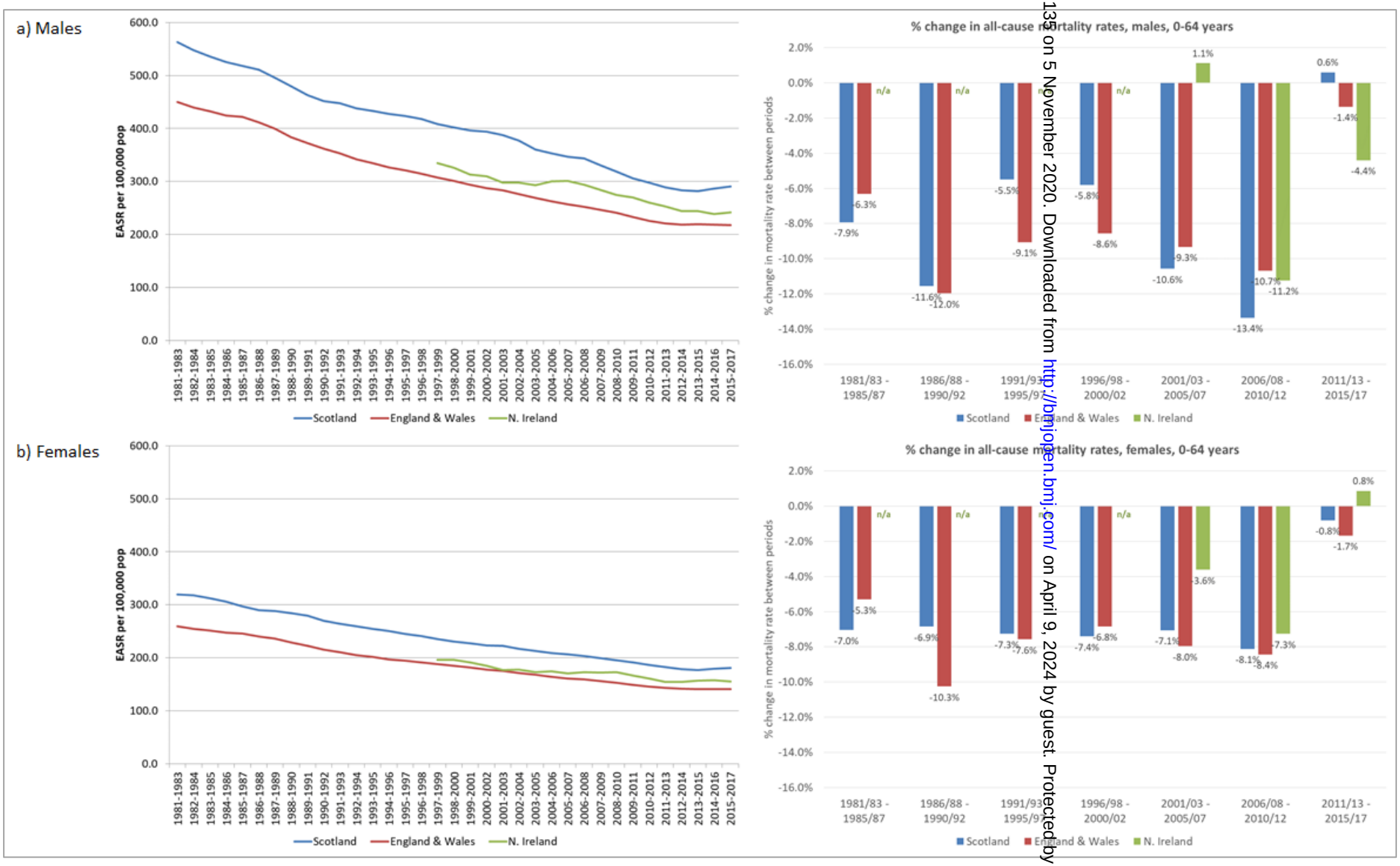
	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	110.5	0.75	135.7	0.64	24.3	0.15	154.0	0.52	84.3	1.24
2002-2004	116.7	0.78	125.1	0.61	24.8	0.16	160.7	0.55	87.5	1.26
2003-2005	121.1	0.80	119.8	0.62	22.6	0.15	157.1	0.54	86.5	1.23
2004-2006	124.3	0.83	111.9	0.62	19.5	0.14	155.5	0.54	88.7	1.23
2005-2007	127.1	0.84	109.4	0.66	10.2	0.08	155.4	0.54	93.3	1.28
2006-2008	133.5	0.88	103.8	0.67	17.6	0.14	158.2	0.55	96.2	1.29
2007-2009	136.3	0.92	102.6	0.71	18.5	0.16	169.6	0.60	99.7	1.34
2008-2010	137.8	0.96	96.2	0.71	24.5	0.22	174.3	0.62	98.4	1.32
2009-2011	137.4	1.01	87.4	0.69	22.2	0.21	175.6	0.63	99.7	1.35
2010-2012	147.2	1.09	80.9	0.67	22.7	0.23	173.9	0.62	104.2	1.40
2011-2013	146.3	1.10	76.1	0.67	20.3	0.21	174.7	0.63	107.5	1.45
2012-2014	143.6	1.10	83.9	0.79	19.5	0.21	183.7	0.66	109.6	1.49
2013-2015	139.5	1.06	84.9	0.83	23.9	0.27	186.3	0.68	106.7	1.49
2014-2016	146.9	1.12	87.4	0.90	24.0	0.29	184.8	0.69	105.6	1.51
2015-2017	150.8	1.14	80.7	0.86	25.5	0.32	180.6	0.68	106.7	1.53

	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	17.0	0.50	13.2	2.26	35.9	1.96	12.5	1.47	0.1	0.04
2002-2004	18.1	0.53	12.7	2.25	35.2	1.94	11.5	1.39	0.2	0.06
2003-2005	18.7	0.56	12.0	2.10	35.0	1.91	10.9	1.34	0.1	0.02
2004-2006	21.7	0.68	12.6	2.17	35.4	1.90	10.1	1.34	0.5	0.19
2005-2007	23.5	0.76	12.6	2.28	35.6	1.93	11.6	1.57	0.7	0.27
2006-2008	25.2	0.84	14.6	2.50	34.5	1.95	12.1	1.64	0.4	0.14
2007-2009	22.7	0.74	16.8	2.55	30.6	1.84	11.3	1.48	0.1	0.04
2008-2010	21.1	0.70	17.9	2.49	29.0	1.80	9.6	1.30	-0.4	-0.17
2009-2011	23.4	0.74	18.7	2.39	26.5	1.66	9.7	1.25	0.0	0.02
2010-2012	29.6	0.92	19.5	2.41	25.7	1.77	10.5	1.31	-0.5	-0.26
2011-2013	32.9	1.01	19.0	2.35	23.1	1.68	10.0	1.27	-0.8	-0.49
2012-2014	31.8	0.99	19.3	2.47	21.8	1.70	9.2	1.28	-0.8	-0.48
2013-2015	32.7	0.97	21.1	2.52	23.0	1.74	7.8	1.12	-0.2	-0.10
2014-2016	37.6	1.03	27.1	2.71	24.2	1.78	7.5	1.04	0.3	0.20
2015-2017	46.1	1.18	31.3	2.69	24.3	1.77	6.6	0.98	0.6	0.33

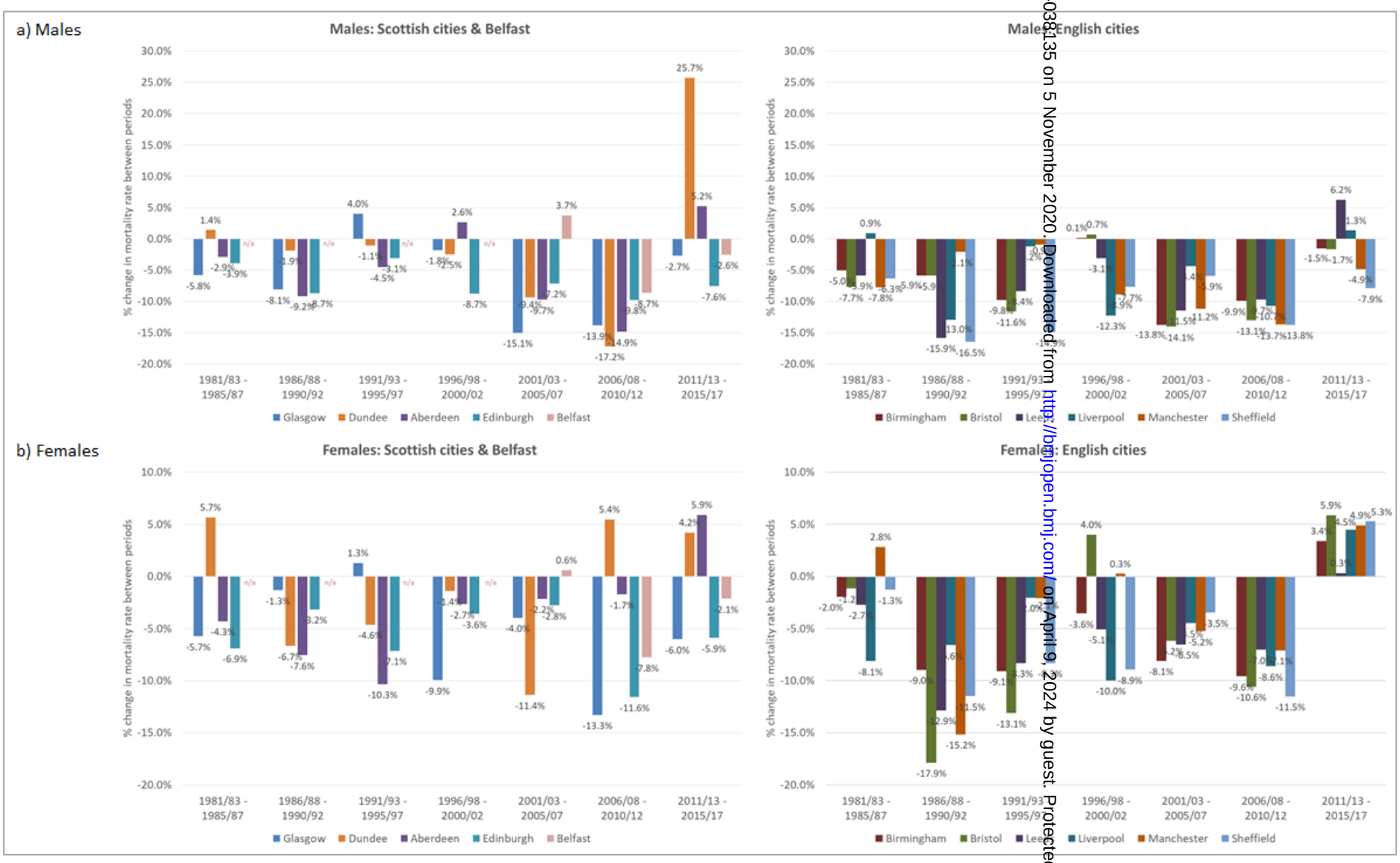
Web Figure 1. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods - cities



Web Figure 2. European age-standardised mortality rates (0-64 years, all causes) per 100,000 population, three-year rolling averages, by UK country, 1981-2017; and percentage change in standardised mortality rates between five year periods

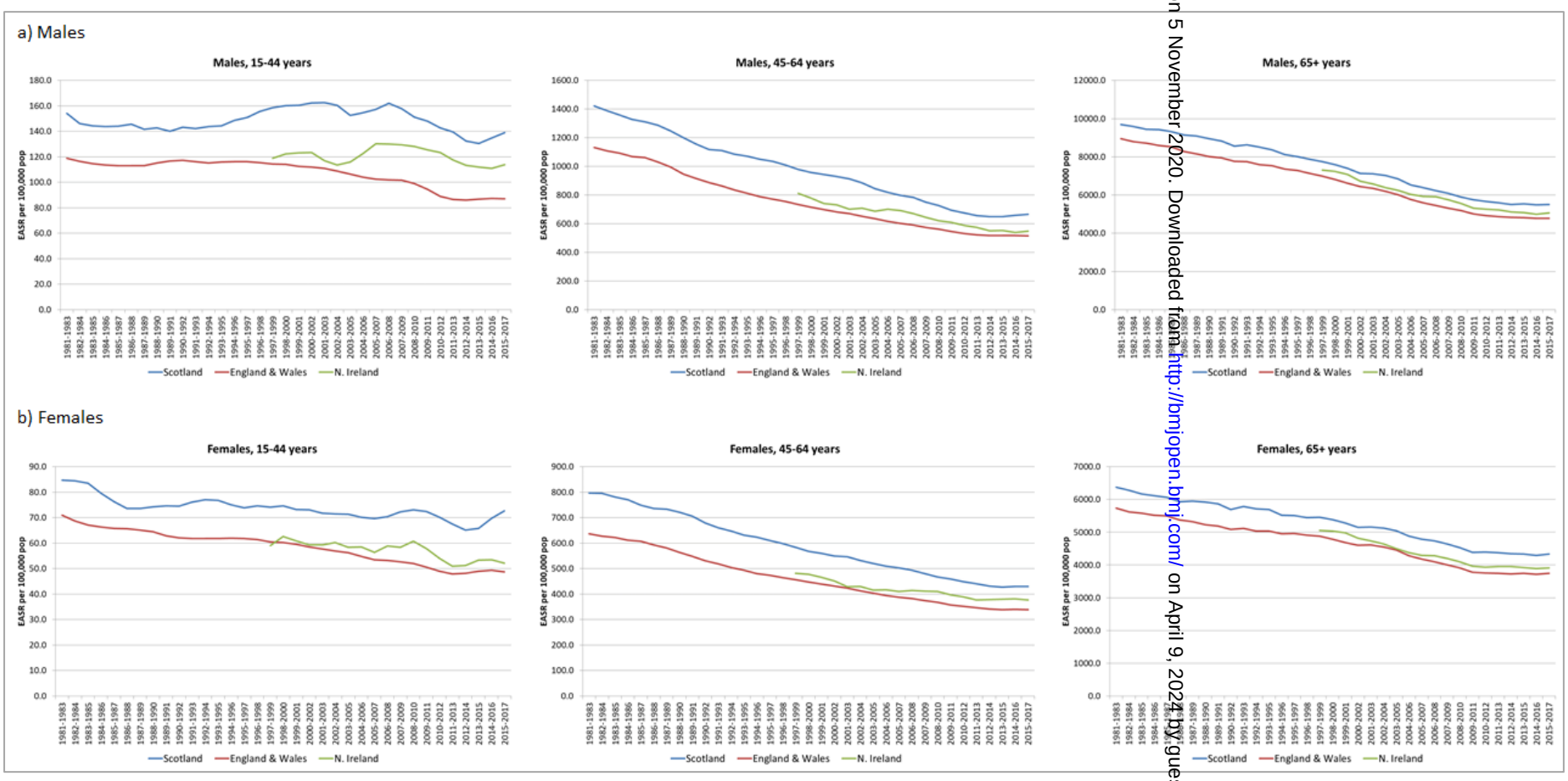


Web Figure 3. All cause deaths, 0-64 years: percentage change in standardised mortality rates between five year periods – cities

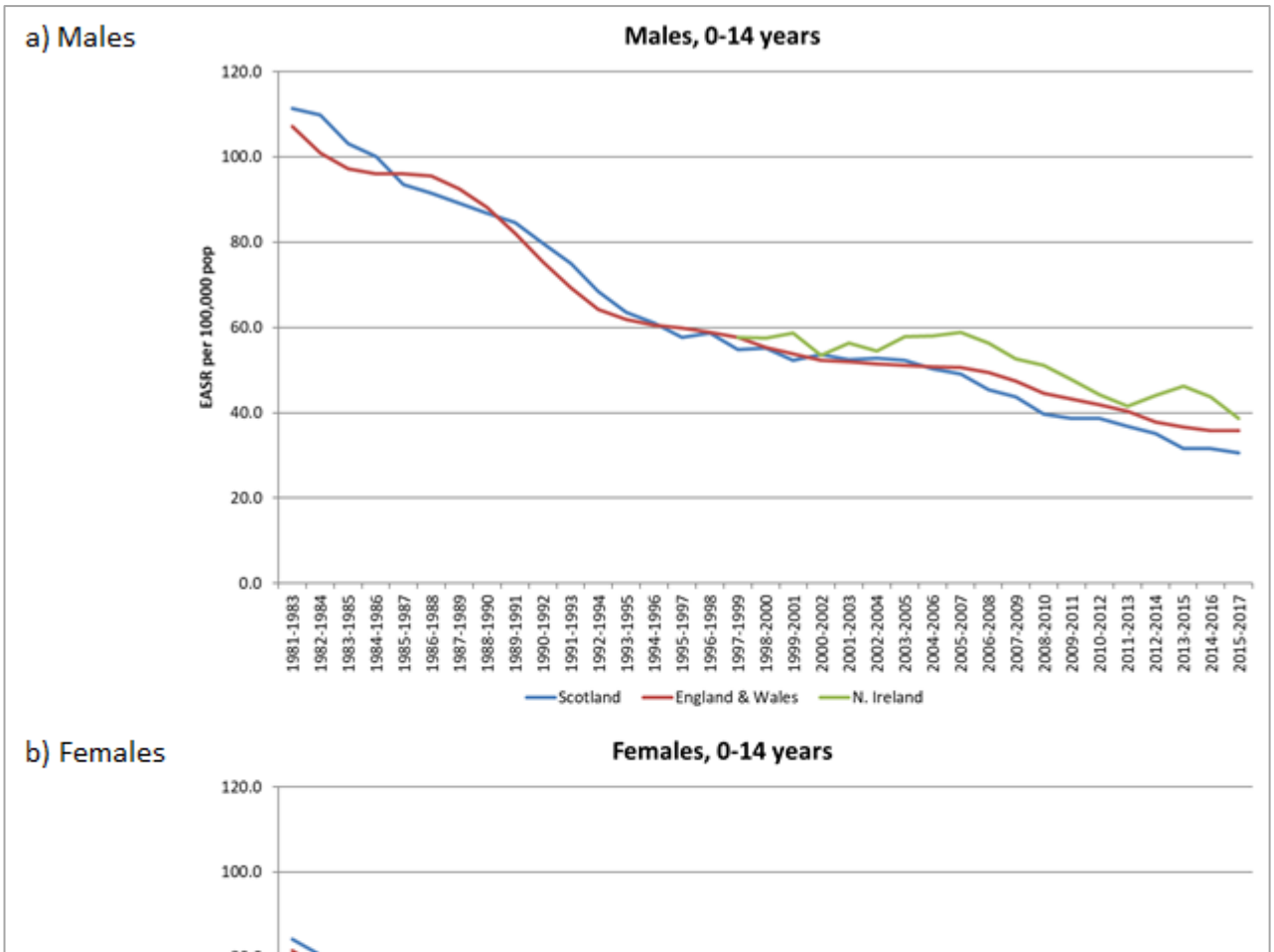


Web Figure 4. European age-standardised mortality rates (all causes) per 100,000 population, three-year rolling averages, by age group and UK country, 1981-2017 (note different axis scales on each chart)

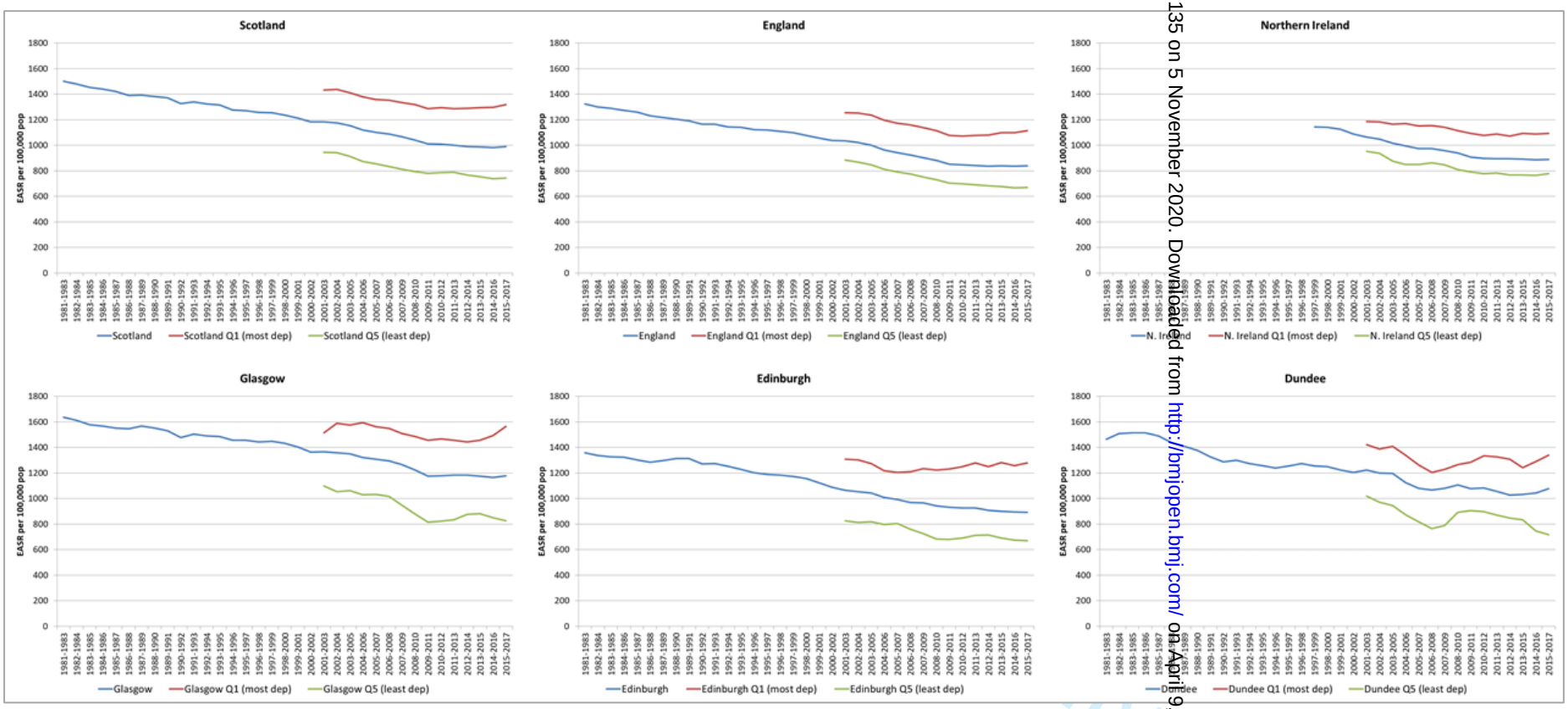
Web Figure 4 (i) adult age groups



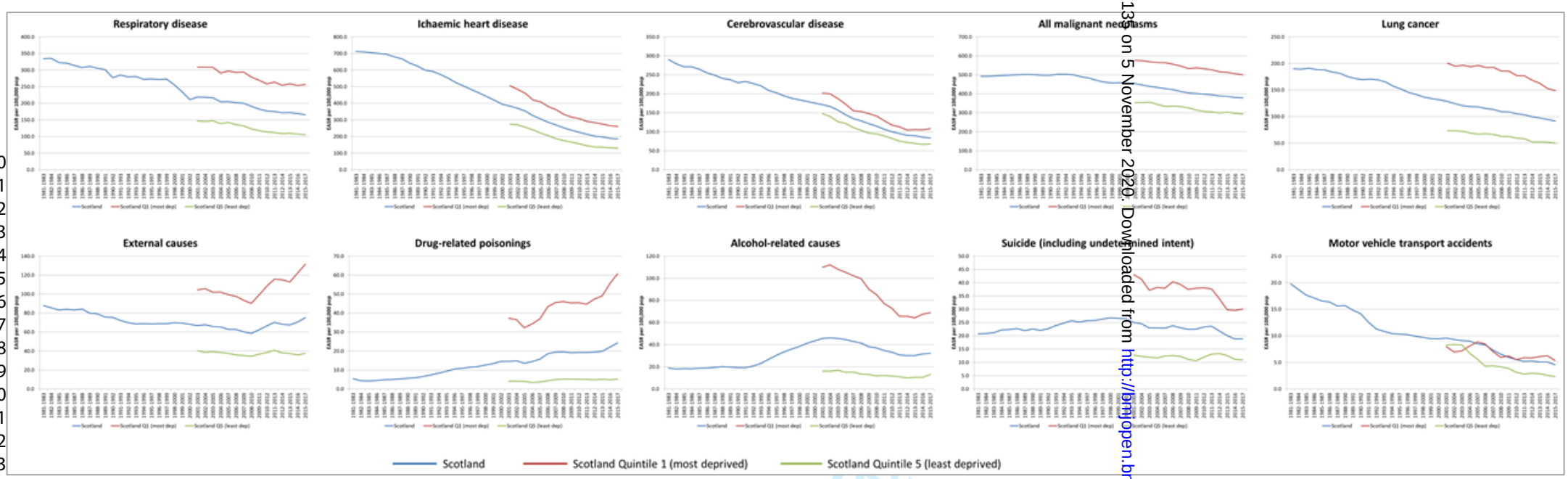
Web Figure 4 (ii) 0-14 years



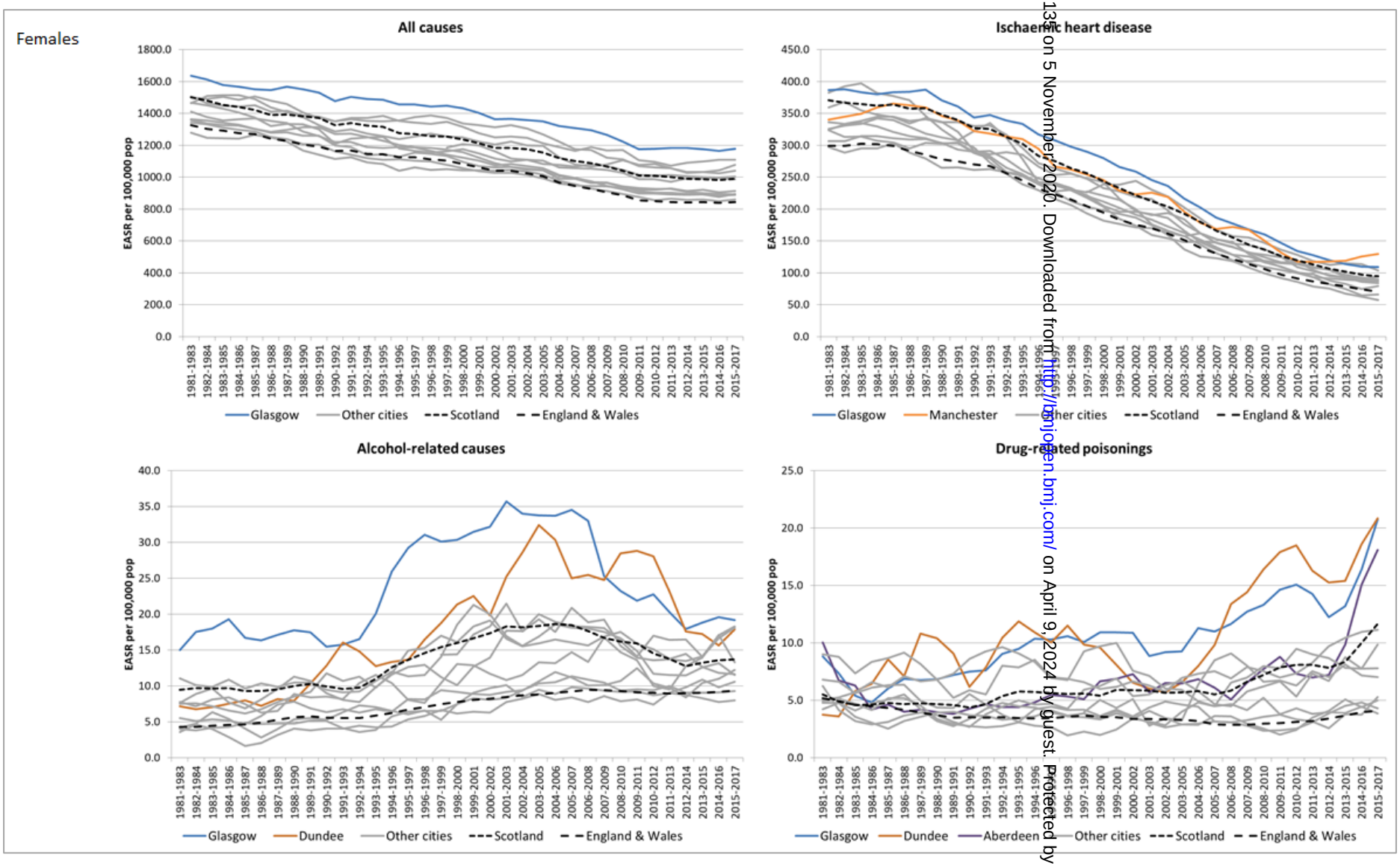
Web Figure 5. European age-standardised mortality rates (females, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles



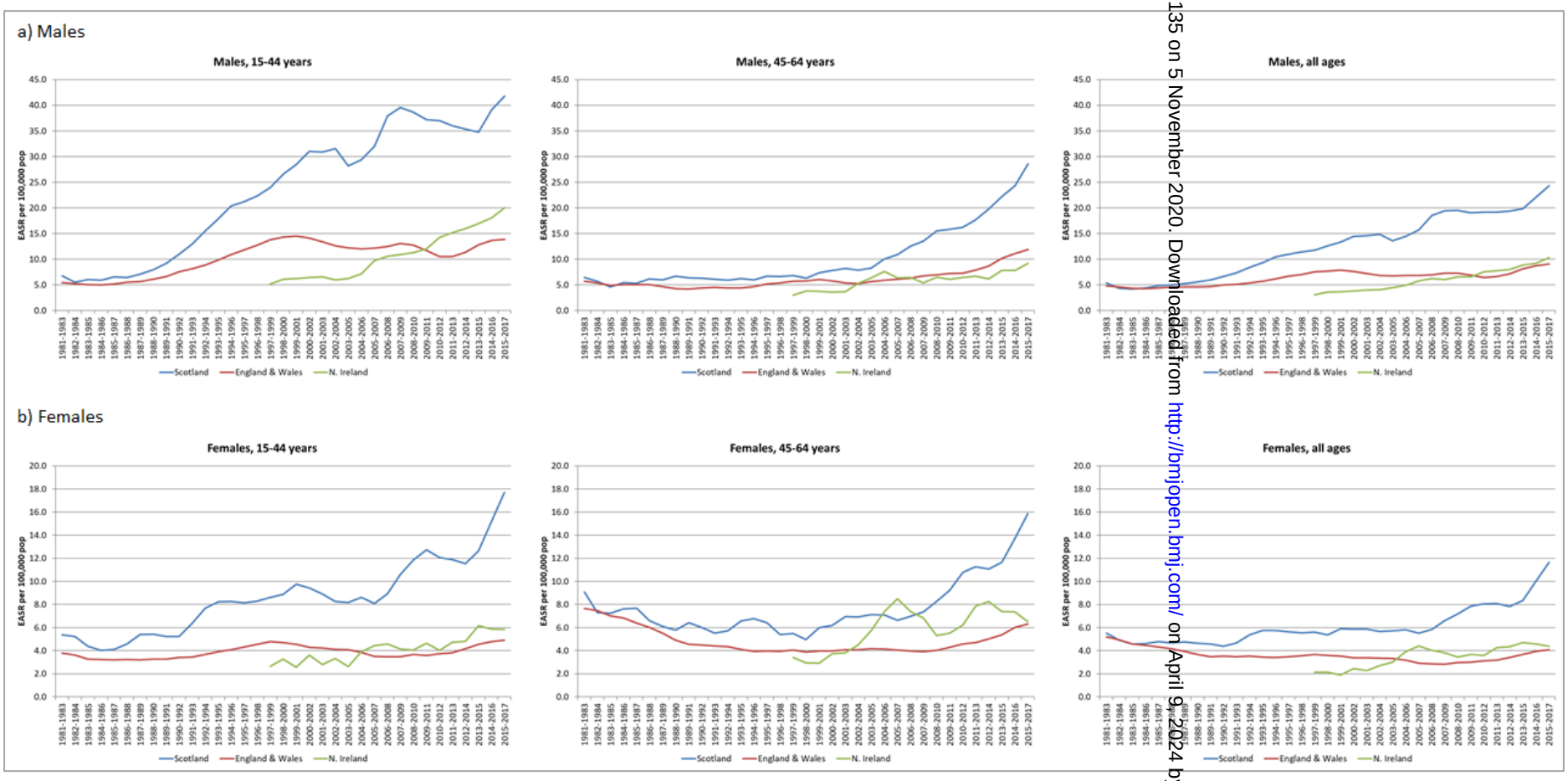
Web Figure 6. European age-standardised mortality rates (males, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles



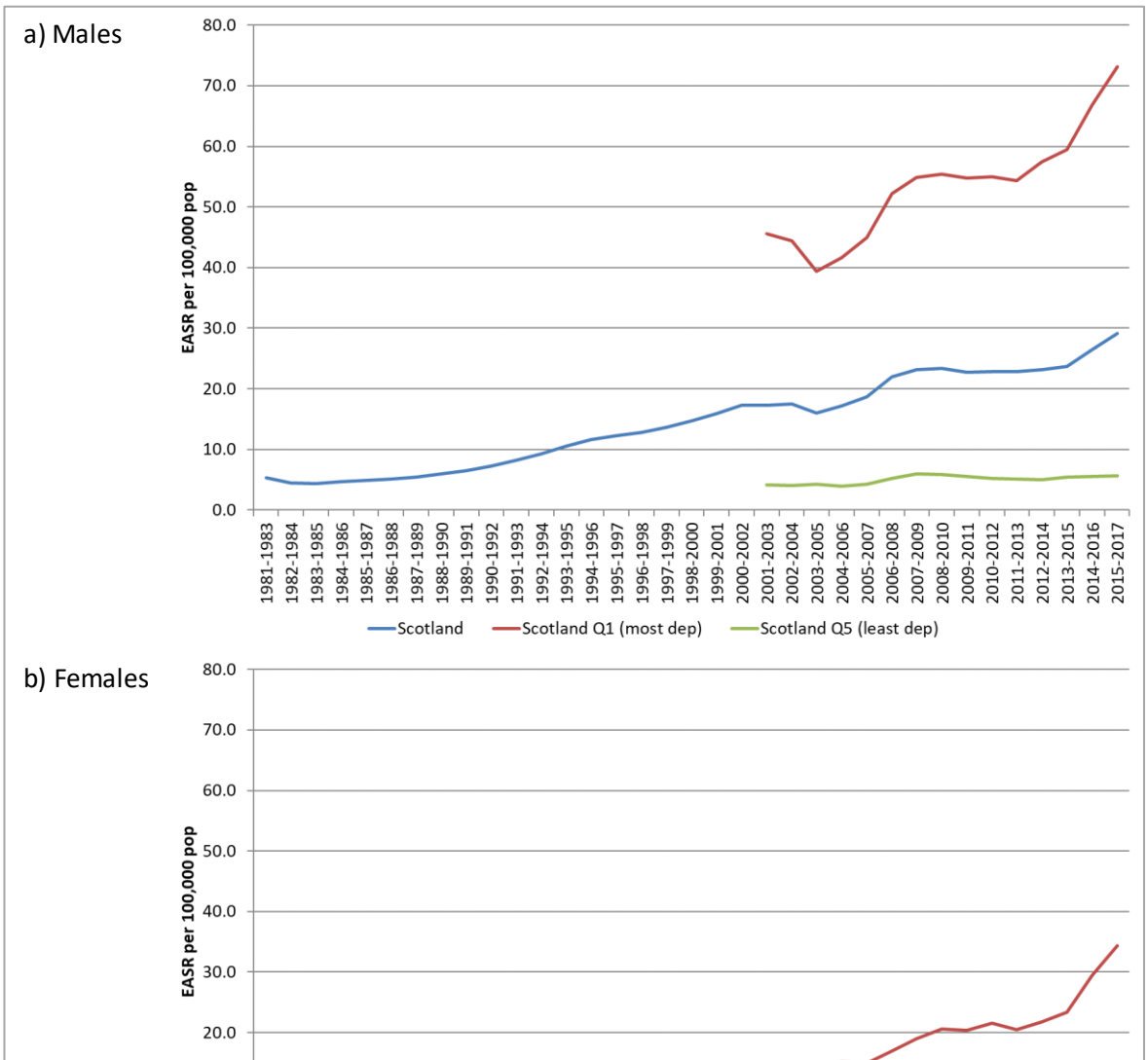
Web Figure 7. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages, for all-cause deaths, ischaemic heart disease, alcohol-related causes and drug-related poisonings, UK countries and cities, 1981-2017



Web Figure 8. European age-standardised mortality rates per 100,000 population, three-year rolling averages, for drug-related poisonings by selected age group, sex, and UK country 1981-2017



Web Figure 9. European age-standardised mortality rates per 100,000 population for drug-related poisonings, three-year rolling averages, Scotland and most and least by deprivation quintiles, 1981-2017



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
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	4-5
Bias	9	Describe any efforts to address potential sources of bias	4-6; 11
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	n/a (total population)
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	n/a
		(b) Indicate number of participants with missing data for each variable of interest	n/a (total population)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	Figs 1-5
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	Figs 1-5
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10; 11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-13
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	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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

Changing mortality trends in countries and cities of the United Kingdom (UK): a population-based trend analysis.

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Changing mortality trends in countries and cities of the United Kingdom (UK): a population-based trend analysis.

David Walsh[1], Gerry McCartney[2], Jon Minton[3], Jane Parkinson[3], Deborah Shipton[4], Bruce Whyte[1]

1. Public Health Programme Manager, Glasgow Centre for Population Health, Olympia Building, 2-16 Orr Street, Bridgeton Cross, Glasgow G40 2QH, Scotland. Tel: 0141 330 2793

2. Consultant in Public Health and Head of the Public Health Observatory team, Public Health Scotland, Glasgow, Scotland

3. Public Health Intelligence Adviser, Public Health Scotland, Glasgow, Scotland

4. Public Health Intelligence Principal, Public Health Scotland, Glasgow, Scotland

Correspondence to: david.walsh.2@glasgow.ac.uk

Keywords: mortality, trends, inequalities, austerity, UK cities

Abstract

Objectives

Previously improving life expectancy and all-cause mortality in the UK has stalled since the early 2010s. National analyses have demonstrated changes in mortality rates for most age groups and causes of death, and with deprived populations most affected. The aims here were to establish whether similar changes have occurred across different parts of the UK (countries, cities), and to examine cause-specific trends in more detail.

Design

Population-based trend analysis.

Participants/setting

Whole population of countries and selected cities of the United Kingdom (UK).

Primary & secondary outcome measures

European age-standardised mortality rates (calculated by cause of death, country, city, year (1981-2017), age group, sex, and - for all countries and Scottish cities - deprivation quintiles); changes in rates between five-year periods; summary measures of both relative (Relative Index of Inequality (RII)) and absolute (Slope Index of Inequality (SII)) inequality.

Results

Changes in mortality from around 2011/13 were observed throughout the UK for all adult age groups. For example, all-age female rates decreased by c. 4-6% during the 1980s and 1990s, c. 7-9% during the 2000s, but by <1% between 2011/13 and 2015/17. Equivalent figures for men were 4-7%, 8-12% and 1-3% respectively. This later period saw increased mortality among the most deprived populations, something observed in all countries and cities analysed, and for most causes of death: absolute and relative inequalities therefore

increased. Although similar trends were seen across all parts of the UK, particular issues apply in Scotland e.g. higher and increasing drug-related mortality (with the highest rates observed in Dundee and Glasgow).

Conclusions

The study presents further evidence of changing mortality in the UK. The timing, geography and socio-economic gradients associated with the changes appear to support suggestions that they may result, at least in part, from UK Government 'austerity' measures which have disproportionately affected the poorest.

(299 Words)

ARTICLE SUMMARY

Strengths and limitations of this study

- We examine recent changes in mortality in the UK in the context of much longer-term trends: almost 40 years in most cases.
- Given the importance of urban health to national outcomes, we include the largest cities in Scotland, England (London excepted) and Northern Ireland.
- We analyse data for 10 major causes of death (not just all-causes combined), and by country-specific and (for Scotland) city-specific deprivation levels.
- Limitations include the fact that interpretation of trends at city level can be problematic, given the fluctuation in rates.

INTRODUCTION

The recent (pre-COVID-19 pandemic) slow-down in improvement in life expectancy and mortality rates in the UK has been highlighted by researchers[1,2] and media[3,4] alike. Similar changing trends have been observed in many other high-income countries, although the slow-down has been particularly marked in the UK and the USA[5]. Other high-income countries with higher life expectancy have seen continued improvements[2,5].

Data from Scotland and England (92% of the UK population) have shown that these changing mortality patterns have been observed for almost all age groups and for most causes of death[6,7]. Worryingly, *increasing* mortality rates among the most socio-economically deprived populations have also been observed; as a result, inequalities in all-cause mortality have widened considerably since around 2012[7-9]. An emerging body of UK[1,10-13] and international[14,15] work suggests the recent stalling is likely to be associated with the implementation from 2010 of UK Government 'austerity' measures – cuts to public services and social security – which have particularly affected the most vulnerable populations.

The principal aim of this project was to establish whether similar changing mortality trends (in terms of rates of improvement, causes of death, and socio-economic inequalities) have occurred ubiquitously across the UK. This included examining cause-specific trends in more detail, and focussing on selected individual cities, given the importance of urban health to national outcomes[16].

METHODS

Mortality & population data

Numbers of deaths by year of registration, age, sex, underlying cause, city and country for Scotland, England & Wales and Northern Ireland were obtained from, respectively, the National Records of Scotland (NRS), the Office for National Statistics (ONS), and the

Northern Ireland Statistics and Research Agency (NISRA). Data were available for the following years: 1974-2017 (Scotland); 1981-2017 (England & Wales); and 1997-2017 (Northern Ireland).

Data were obtained for all-cause deaths, and for the following 10 major individual causes: respiratory disease; ischaemic heart disease (IHD); cerebrovascular disease; all malignant neoplasms; lung cancer (malignant neoplasm of trachea, bronchus and lung); intentional self-harm (including events of undetermined intent); external causes; motor vehicle traffic accidents (MVTAs); alcohol-related causes; and drug-related poisonings. Causes were defined by groups of ICD8, ICD9 and ICD10 codes: these are listed in the online appendix (Web Table 1). As stated in Web Table 1, the definition of external causes overlaps with other causes of death i.e. MVTAs, intentional self-harm, drug-related poisonings. ICD9 codes were used for the years 1979-1999 in Scotland, and for 1981-2000 in England & Wales and Northern Ireland; ICD10 codes were used for all later years. ICD8 codes were used for 1974-1978 (Scotland only) but the data for those years are not presented here.

Matching population data by year, five-year age group, sex, city and country were obtained from the same national statistical agencies.

Geography

Scotland, England & Wales (combined) and Northern Ireland were the countries used in the main analyses. For analysis by deprivation quintiles (discussed further below), England alone, rather than England & Wales, was used. With the exception of London, the largest cities in each country were selected: Glasgow, Edinburgh, Dundee and Aberdeen in Scotland; Liverpool, Manchester, Birmingham, Leeds, Sheffield and Bristol in England; and Belfast in Northern Ireland. London was excluded as its size and ethnic diversity makes meaningful comparisons with other cities problematic[17]. Scottish and English cities were defined by

current local authority boundaries. Belfast was defined by its 1992 local government district (LGD) boundary.

Deprivation analyses employed the separate Scottish, English and Northern Irish area-based indices of deprivation: the Scottish Index of Multiple Deprivation (SIMD)[18], the (English) Index of Multiple Deprivation (IMD)[19], and the Northern Ireland Multiple Deprivation Measure (NIMDM)[20] respectively. In all three cases data were available for the period 2001-2017. The SIMD has been updated multiple times: thus, the 2004 version was used for analyses covering the years 2001-04, SIMD 2006 was used for 2005-07, SIMD 2009 for 2008-10, SIMD 2012 for 2011-13 and SIMD 2016 for 2014-17. Similarly, the (English) IMD 2004 was used for the years 2001-05, IMD 2007 for 2006-08, IMD 2010 for 2009-13, IMD 2015 for 2014-16 and IMD 2019 for 2017. For Northern Ireland, NIMDM 2010 was used for all years of analyses. Although there are differences in the spatial scale and the individual variables used in the construction of each nation's deprivation measure, all three share notable similarities in terms of their basic composition. The principal 'data domains' of each are effectively the same: income; employment; health; education, skills and training; crime; access to services; housing. In the Scottish index, housing is a separate category; in the English and Northern Irish indices it is instead contained within a 'living environment' domain. For all three measures of deprivation, similar methodologies are employed to calculate an overall index of relative deprivation, based on geographical area rankings across all data domains. Although the absolute values of the different indices cannot be directly compared, the similarity of composition and methodology associated with each provides helpful, and broadly comparable, overviews of inequality *within each setting.*

Statistical analyses

European age-standardised mortality rates (EASRs) per 100,000 population were calculated using the 2013 European Standard Population[21]. Analyses were undertaken by sex, age (all

ages, 0-64 years (the latter to examine premature deaths), and four broad groups across the life-course: 0-14 years, 15-44 years, 45-64 years, 65+ years), year, cause of death, city, country and deprivation quintile (see below). Three-year rolling average rates were derived; to quantify the rate of improvement over time, the percentage changes in rates between three-year averages at five-year intervals (i.e. between 1981/83 and 1985/87, 1986/88 and 1990/92… up to 2011/13 and 2015/17) were calculated. Three-year averages were used to overcome the issue of fluctuating rates (especially at city level). For simplicity, we use the expression 'five-year' interval to reflect the mid-points of the three-year average (e.g. 1982 to 1986 in relation to 1981/83 to 1985/87).

For the deprivation analyses, mortality rates by quintile were calculated on the basis of both *national* quintiles (based on levels of deprivation within individual countries) and – for Scottish cities only – *city-specific* quintiles (based on levels of deprivation *within each individual city*). City-specific quintiles are made publicly available by ISD Scotland (now Public Health Scotland) for all versions of the SIMD used in the analyses, and were downloaded from their website. Equivalent data were not available for the English cities. In all analyses Quintile 1 represented the *most deprived* fifth of the country's/city's small areas, and Quintile 5 the *least deprived* fifth. The aim was to compare quintile rates *within the same location* (country or city), not between different locations. Note that as the English IMD does not include Wales, for comparison all-cause mortality rates by year and sex for England alone (rather than England & Wales combined) were also calculated. Analyses by deprivation were undertaken for all-cause deaths for all geographies, and for cause-specific mortality for all Scottish areas.

To examine changes in both absolute and relative inequalities in mortality (for the countries, Scottish cities, and the causes of death), the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) respectively were calculated, based on the above deprivation

quintiles. The SII calculates the gap in mortality rates across groups (here, the five quintiles), taking into account each quintile's rate (not just those of the least and most deprived), and each quintile's population size. The RII expresses this as a relative measure by dividing the SII by the rate for the whole population[22].

Analyses were undertaken using IBM SPSS Statistics 25.

Patient and Public Involvement

Patients were not involved in this study

RESULTS

Figure 1 presents all-cause standardised mortality rates for all ages by country and city for (a) males and (b) females between 1981/83 and 2015/17. At the national level, a change in the male death trend appears visible from around 2011/13 for both Scotland and England, with no or little improvement observed in the periods after that; there is greater fluctuation in rates in Northern Ireland. A change in rates appears more apparent, occurring slightly earlier, for deaths among females including those in Northern Ireland. At the city level, greater fluctuation in rates is clearly evident, as would be expected given the smaller population sizes and associated numbers of deaths: nonetheless the majority of cities appear to have experienced a flattening, or worsening, of mortality rates in the last 3-4 time points shown.

[Figure 1 about here]

To quantify the changes shown above, Figure 2 shows the percentage change in rates between five-year periods for Scotland, England & Wales and Northern Ireland. For women, mortality rates were decreasing by approximately 4-6% during the 1980s and 1990s, with a faster improvement of approximately 7-9% during the 2000s, and a much slower decrease of <1% between 2011/13 and 2015/17. Amongst men, mortality rates were decreasing slightly

faster during the 1980s and early 1990s (by 4-7%), with a faster improvement of approximately 8-12% during the late 1990s and 2000s, and again a much slower decrease between 2011-13 and 2015/7 of 1-3%. Similar data for the cities are shown in the online appendix (Web Figure 1): these show a very similar overall pattern to the country-level analyses, albeit with greater fluctuation in the percentage change figures in some cities such as Dundee. However, it is also notable that – despite that fluctuation – in the most recent five-year period mortality rates actually worsened among both males and females in Dundee and Aberdeen, and among females in Manchester, while there was virtually no improvement among males in Liverpool and females in Birmingham (-0.3% for both).

Note that analyses based on more 'standard' five year periods (1981-85, 1986-90 up to 2011-15) produced very similar results (data not shown).

[Figure 2 about here]

Analyses of trends and changes in rates for ages 0-64 years (rather than all ages) are presented in Web Figure 2 for the countries of interest. While the results are broadly similar to those seen for all ages, the data suggest there has been a slight increase (rather than slow-down) in mortality rates for Scotland in the most recent period. Across the cities, a more notable change was observed in Dundee for males in this age group: a 26% increase in mortality between 2011/13 and 2015/17 (Web Figure 3). Notwithstanding the greater fluctuation in changes in rates in this age group at city level, it is also of note that there was an increase in female mortality rates in the last period in each English city.

Trends in all-cause rates for 45-64 years were similar to those described above for 0-64 years, and rates for 65+ years were broadly similar to those observed for all ages. For the 15-44 age group, rates were notably higher in Scotland than England & Wales, and the mortality gap had become wider in the most recent period. These data are all shown in Web Figure 4 (i). Although the principal focus of these analyses is adult mortality, Web Figure 4 (ii) shows

country level rates over time for ages 0-14 years. It is notable that child mortality rates in Scotland have been consistently lower than in England & Wales since the late 1990s for females and early-to-mid 2000s for males, a reversal of the position at the beginning of the period. Rates are highest in Northern Ireland, although they are also subject to greater fluctuation over time.

Figure 3 again shows male all-cause mortality rates for all ages but additionally presents the rates for the least and most deprived deprivation quintiles within Scotland, England, Northern Ireland and an illustrative selection of three Scottish cities. Increased mortality rates are observed in the most recent period for the most deprived fifth of the population in each country/city shown (albeit that there is again more fluctuation in rates at the city level). Similar trends were observed for female mortality rates, as shown in Web Figure 5. Summary measures of inequalities (SIIs, RIIs) confirm widening absolute and relative inequalities across deprivation quintiles since 2011/13 in all countries and cities analysed (Web Tables 2a and 2b). For example, for all-cause deaths among men in England, the absolute gap across quintiles (as measured by the SII) increased from 738.8 in 2010/12 to 784.6 in 2015/17, despite having decreased between 2001/03 and 2010/12; relative inequalities increased over the whole period.

[Figure 3 about here]

Mortality rates over time by deprivation quintile are explored in more detail for Scotland in Figure 4, which presents data for females for all ten causes of death analysed. A widening gap between the most and least deprived quintiles in the most recent years of analysis can be seen for the majority of causes, in particular respiratory disease, external causes, drug-related poisonings and alcohol-related causes. Different trends are observed for suicide (where the gap has narrowed) and MVTAs (where numbers of deaths are relatively small and there is considerable fluctuation in rates across quintiles of deprivation). Generally, the

same patterns, in terms of a widening gap between the most and least deprived deprivation quintiles for the majority of causes of death, are observed for male deaths (Web Figure 6). The main difference between the male and female trends relates to cancer mortality, in particular lung cancer, with a widening deprivation gap observed for females but not males. The general pattern of widening inequalities for the majority of causes is confirmed by analysis of SIIs and RIIs (Web Table 3a and 3b).

[Figure 4 about here]

Aside from evidence of a slow-down in mortality improvement and widening deprivation gaps (already shown in Figures 1 and 3), the analyses of city level mortality rates highlight a number of other issues. Foremost among them is that Glasgow stands out in terms of having the highest mortality rates of all the cities for all cause deaths and the majority of causes analysed (including strikingly different trends for alcohol related causes). Some exceptions do apply, however: for example, for all ages death rates from IHD are now marginally higher in Manchester for both males and females, while deaths from drug-related poisonings are now highest in Dundee. Some of these data are shown for males in Figure 5, and for females in Web Figure 7.

[Figure 5 about here]

Finally Figure 5/Web Figure 7 also highlight notable similarities and differences in long-term mortality trends between Scotland and England. For example: a narrowing of the gap between the countries for IHD; much higher drug-related poisonings in Scotland compared to England - although rates are increasing in both countries; and notably higher rates of death from alcohol related causes in Scotland, with the most recent increase in rates much more pronounced in Scotland than in England. The striking trends in drug-related poisonings are explored in more depth in Web Figure 8 (comparing the UK countries for selected age groups and by sex) and Web Figure 9 (showing data for Scotland and its most and least

deprived quintiles for age 0-64 years). There has been a widening divergence in death rates from this cause between Scotland and the rest of the UK over the period shown, and a further increase in rates is again observed since approximately 2012. Similar deprivation trends for drug-related poisonings are evident in the Scottish cities (data not shown).

DISCUSSION

Overall findings and implications

The study presents further evidence of a slow-down in mortality rate improvement over time within the UK. In some cases – deaths under 65 years in Scotland and all-age mortality in particular cities – rates have increased, rather than stalled, in recent years. These overall changes appear to be particularly driven by worsening mortality among the most socio-economically disadvantaged populations. Similar trends are observed across all countries and cities in the UK; however, particular issues apply in Scotland, for example in relation to drug-related mortality. The timing, geographical coverage and socio-economic gradients associated with the changes appear to further support suggestions that recent changes in mortality are at least partly a consequence of UK Government 'austerity' measures.

Strengths and weaknesses

The analyses were based on data covering the whole population, not samples. Mortality is a robust population health indicator and is not subject to the limitations and potential biases associated with self-reported measures[23,24]. We included the largest cities within Scotland and Northern Ireland and, with the exception of London, the six largest cities in England. We were able to examine recent changes in mortality in the context of much longer-term trends: almost 40 years in the case of Scotland and England & Wales. We analysed data for a broad set of causes of death, not just all-deaths combined.

The exclusion of London is arguably a weakness, although it was done to facilitate more meaningful comparisons across the other cities with more similar population sizes. Other limitations include the fact that time trend data for Northern Ireland were much more limited than for the rest of the UK. Interpretation of trends at city, rather than country level can also be problematic, given the fluctuation in rates that occur. Although the measures of area-based multiple deprivation that are employed within Scotland, England and Northern Ireland have many similarities, they are derived from different data sets and calculated at different spatial scales and are thus not directly comparable. We standardised mortality rates using 18 age groups (0-4 years to 85 years and above) while it is now recommended to standardise on the basis of 19 groups (0-4 years to 90 years and above)[25]: however, the impact of this is fairly minimal. Although our youngest age bracket is 0-14 years, we did not include infant mortality (deaths under 1 year of age) as a distinct category: as a major focus of the work was city-based analyses, data on infant deaths were not requested from the various statistical agencies as numbers of deaths at that geographical level in the UK are very small; however, given recent evidence of increasing infant mortality rates in England (linked to increased child poverty rates), this was arguably an oversight[26]. Finally, the definition of drug-related poisonings is a broader, less sophisticated, definition than that employed in official UK publications of drug-related mortality in the UK. In 2017, for example, there were 1,037 such drug-related poisonings in Scotland, 11% higher than the 934 drug-related deaths recorded by the National Records of Scotland[27].

Relevance to other studies

Slower improvement in mortality and life expectancy in the UK in recent years has been shown by various authors and organisations[1,2,5 -8]. Similar trends have been observed in a number of countries, although in a recent analysis of 20 high-income countries, only the USA had experienced a greater reduction in improvement than the UK[5]. As others have

proposed, it appears increasingly likely that these changes are at least in part attributable to UK Government policy which since 2010 have brought about dramatic cuts to social security budgets and other public services, particularly affecting the most vulnerable10-13. There is international evidence of the associations between such government measures and increased mortality rates[14,15] , and the particular model of austerity adopted in the UK (based on spending cuts rather than a taxation approach) is known to be more regressive[13]. UK research has highlighted associations between different UK austerity measures and increased child poverty[26, 28] , expansion of foodbanks[29], increased homelessness[30], poorer mental health among affected populations[31] and, ultimately, increased numbers of deaths among the poorest at different ages[8]. Interactions between such policy-driven factors and other influences such as high winter mortality in particular years have also been suggested[6].

The widening socio-economic inequalities in mortality since around 2012 have been shown previously for Scotland[8,9] and England[7,32], but only at national level, and only for all-cause mortality and life expectancy. The increase in drug-related deaths within Scotland has been the focus of much media attention, resulting in two recent Westminster Parliamentary Committee enquiries[33,34], and the establishment of 'drugs death task force' by the Scottish Government in 2019[35]. The increase is known to be the result of a 'perfect storm' of factors: a previously-described vulnerable cohort of drugs users who are now encountering multiple morbidities as they age; increased affordability and accessibility of chosen drugs; and the aforementioned UK Government austerity measures which have impacted on both individual income and funding of drug-related and other relevant social services[33,34,36]. These drug mortality trends are likely to have influenced the overall increasing death rates in Scotland (and in Dundee) among 0-64 year-olds.

Alcohol mortality trends have historically been impacted by changes in price and availability in combination with socioeconomic vulnerability[37,38], while the reasons for Glasgow's

particularly high mortality rates (including from alcohol, drugs and other causes) have been described in detail previously, being attributable to higher socio-economic deprivation alongside an additional vulnerability created by a combination of multiple historical factors including worse living conditions and adverse policy-making at different levels of government[39].

The contrasting trends in lung cancer mortality between males (decreasing rates) and females (increasing rates) living in the most deprived quintile in Scotland are also best explained in terms of different cohorts, with females having started smoking later than males: this has been shown in a number of other analyses[40]. In addition, one of the other notable differences between male and female trends – the apparent earlier slow-down in mortality improvement for females – is worthy of further analysis. Data presented here for both countries and cities suggest a change in female mortality rates from around 2010/12 or 2011/13, potentially suggesting women's circumstances might be more sensitive to government austerity policies. However, more detailed analysis of Scottish data by Fenton et al instead suggested a change between 2013 and 2014[2]. Finally, although the main focus of the paper is adult mortality, the extent to which Scotland's child mortality rate has improved relative to that of England & Wales may be associated with a similar widening gap in child poverty levels between the countries over a similar time period is worthy of further investigation[41].

Conclusions

These results add to the growing body of evidence of changing mortality rates within the UK in recent years and their likely political causes. With mortality rates rising among the UK's most deprived populations even prior to the COVID-19 pandemic, it is imperative that a range of policies are introduced to protect the health of the most vulnerable in society.

(3,687 words)

Figure 1. European age-standardised mortality rates (all ages, all causes) per 100,000 population, three-year rolling averages, by UK country and city, 1981-2017

Figure 2. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods

Figure 3. European age-standardised mortality rates (males, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles

Figure 4. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles

Figure 5. European age-standardised mortality rates (males, all ages) per 100,000 population, three-year rolling averages, for all-cause deaths, ischaemic heart disease, alcohol-related causes and drug-related poisonings, UK countries and cities, 1981-2017

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DECLARATIONS

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Contributions: D. Walsh originally conceived the study. The research questions and analysis plan were agreed by all authors (G. McCartney, J. Minton, J. Parkinson, D. Shipton and B. Whyte). D. Walsh undertook the analyses and drafted the manuscript. All authors provided substantial critical input to improve the manuscript and all authors approved the final draft.

Competing interests: None declared

Ethical approval: None required

Data sharing: No additional data available. The analysed data presented in the paper are not publicly available. However, the data on which the analyses were based can be requested from the national statistical agencies listed in the manuscript.

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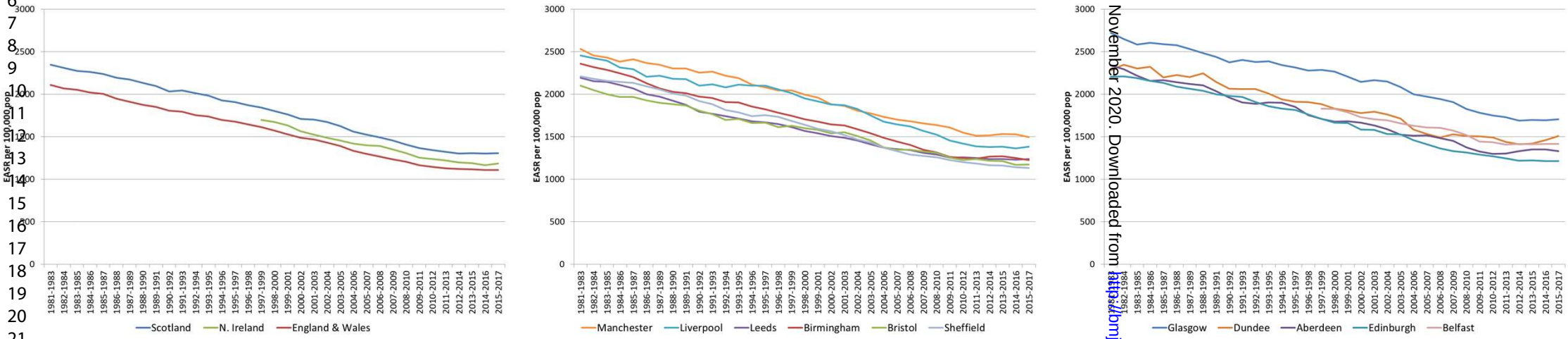
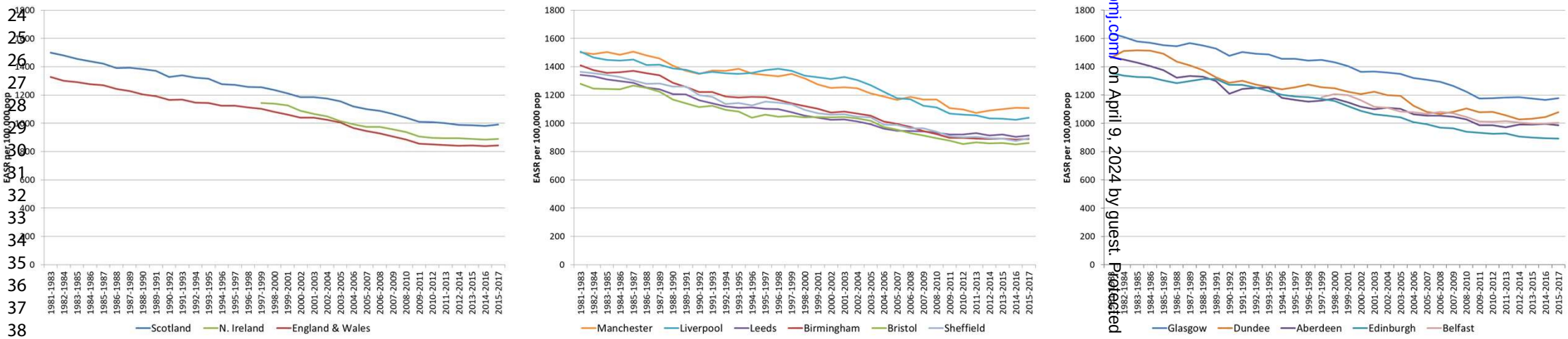
Figure 1. European age-standardised mortality rates (all ages, all causes) per 100,000 population, three-year rolling averages, by UK country and city, 1981-2017

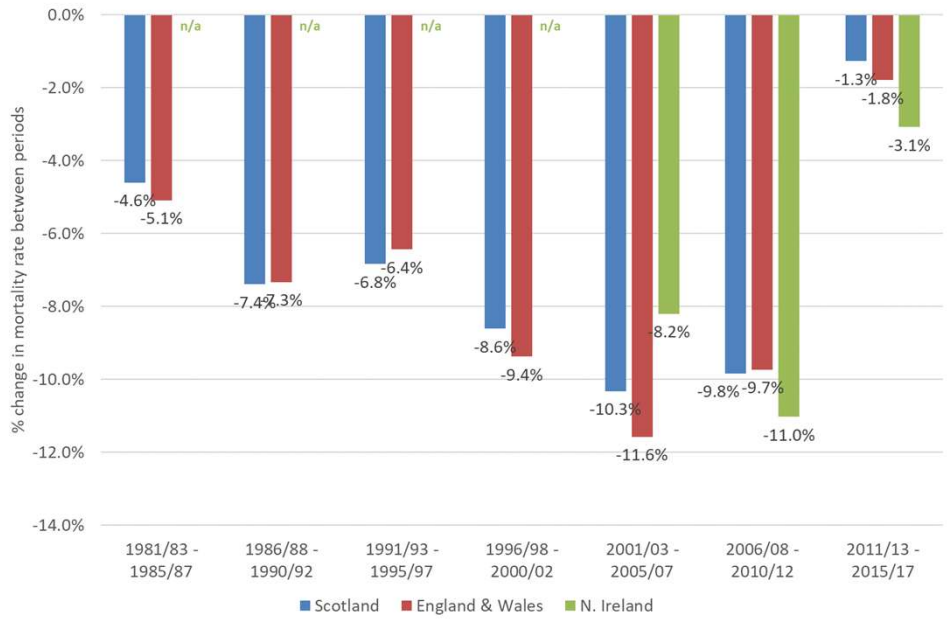
a) Males



b) Females



a) Males



b) Females

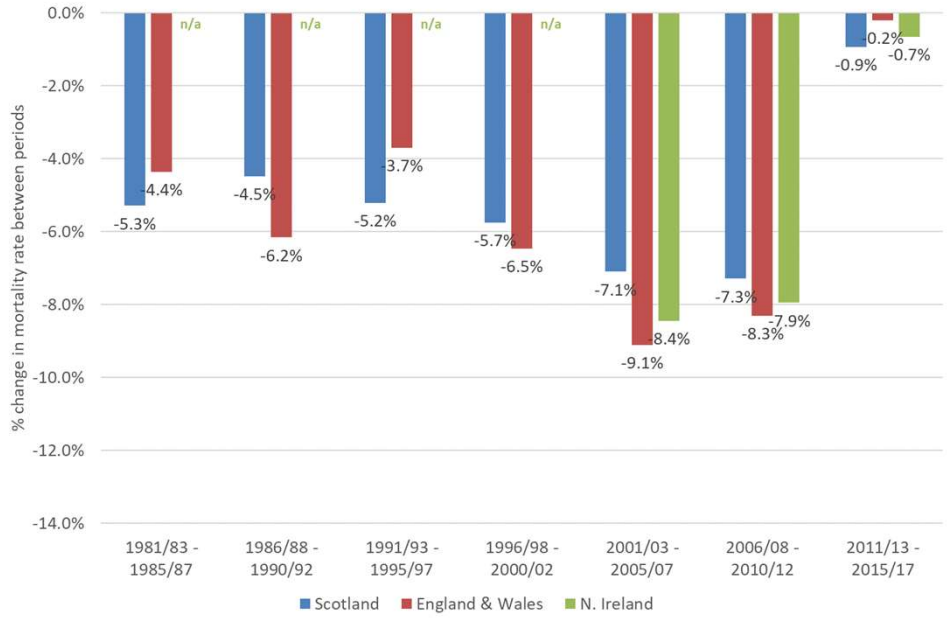


Figure 2. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods

Figure 3. European age-standardised mortality rates (males, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles

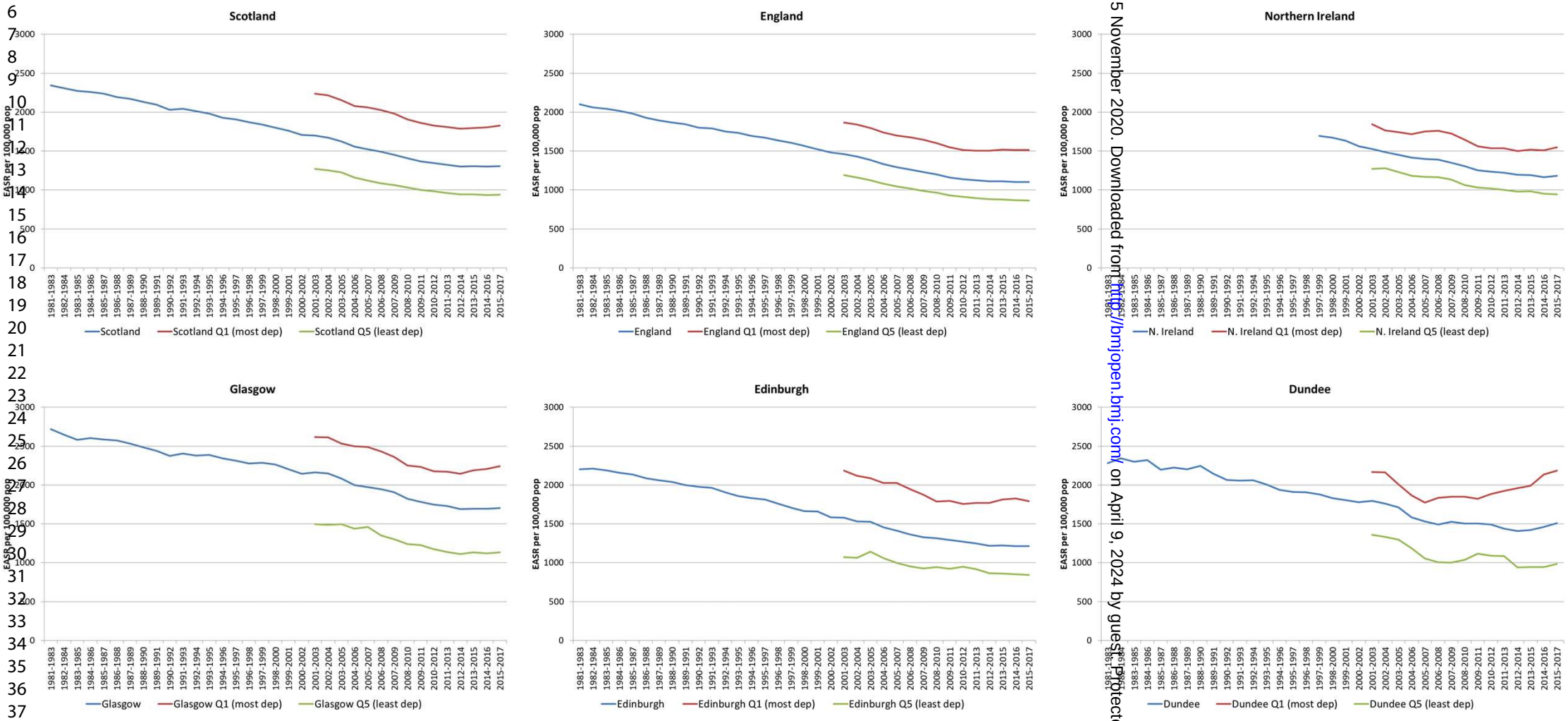
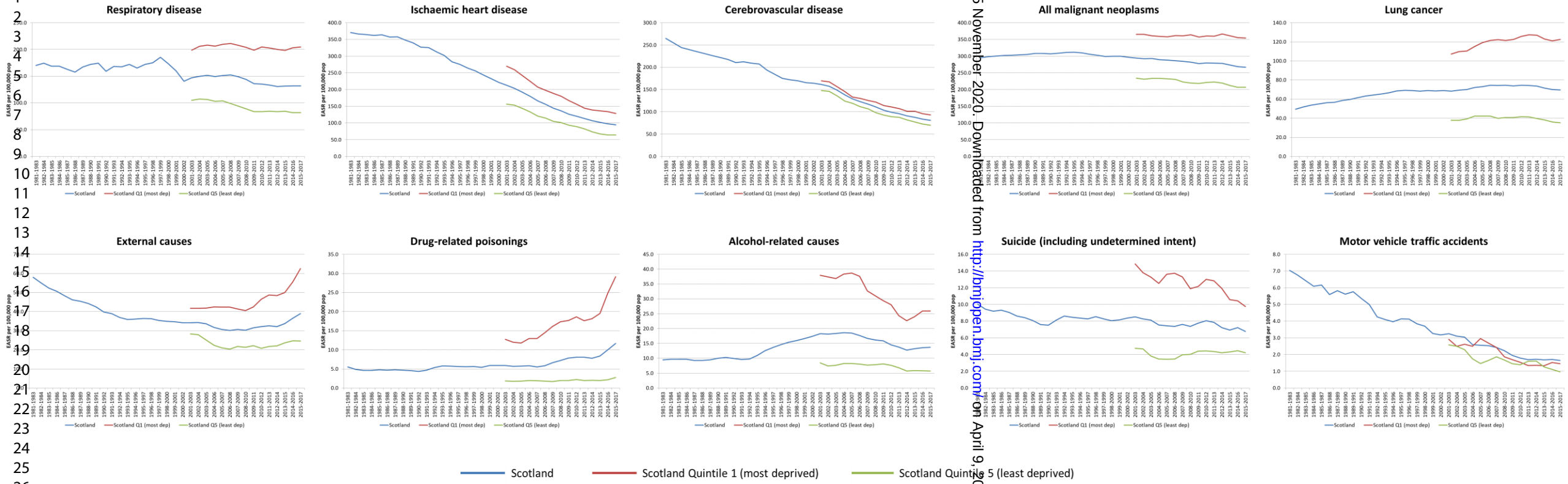
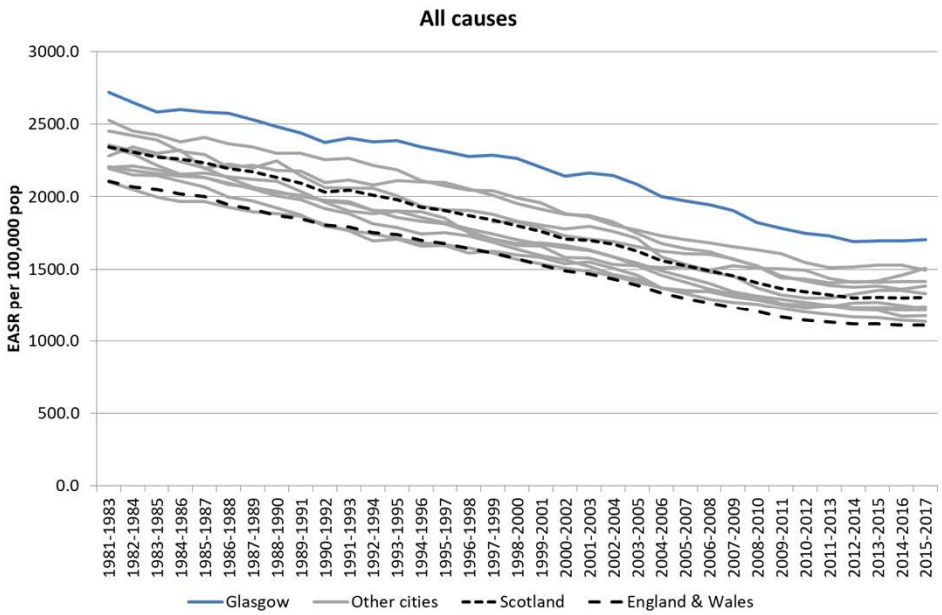
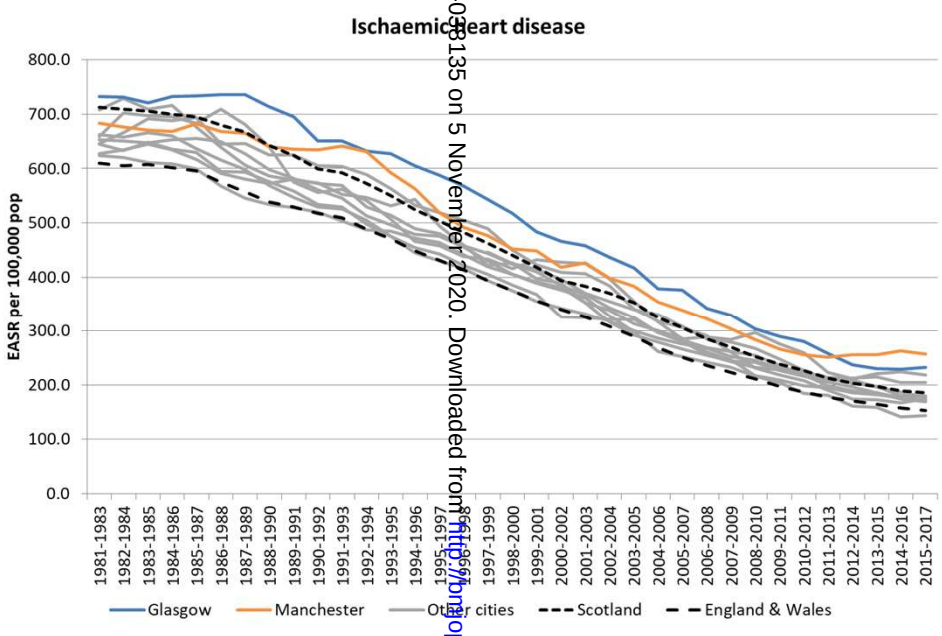


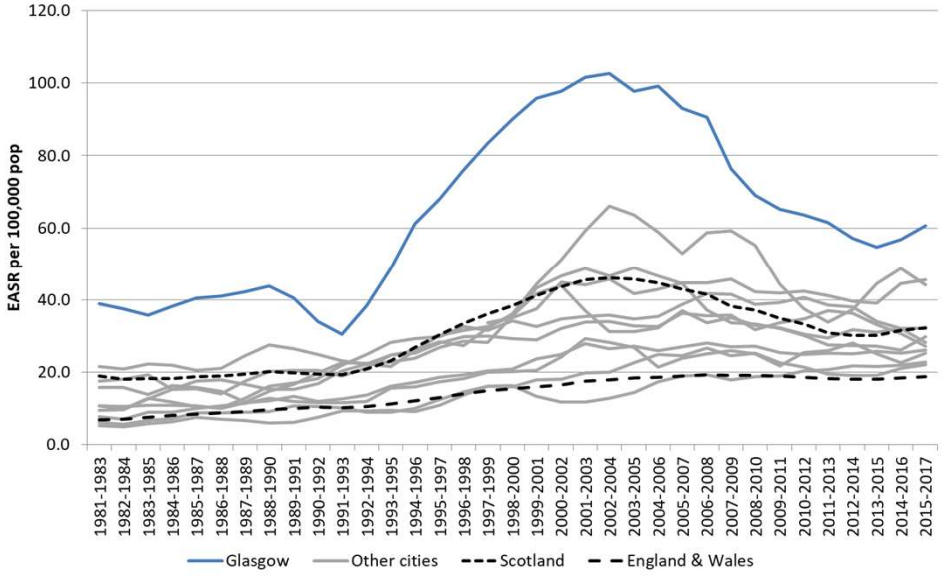
Fig. 4. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles

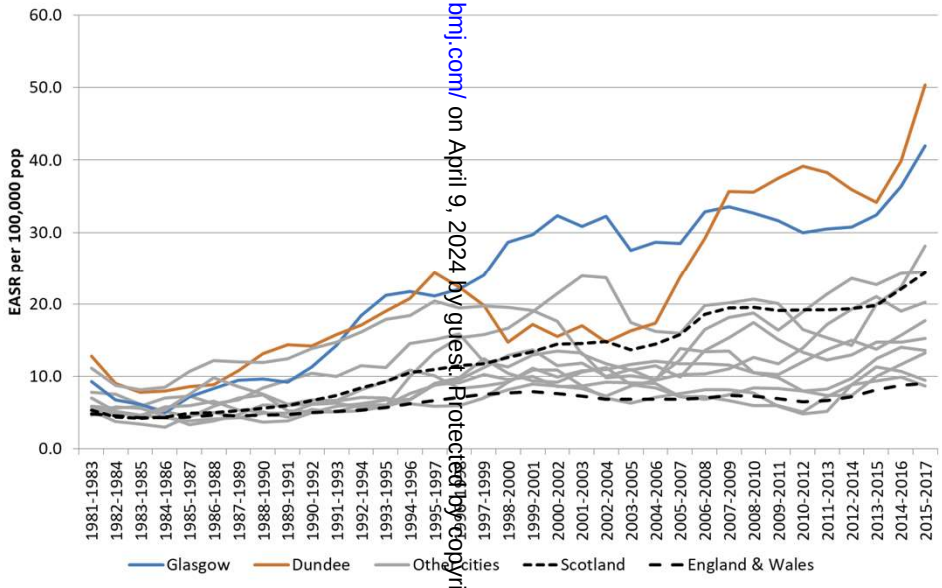


Note that there are some overlaps in the ICD code definitions for some causes of death e.g.: all cancers and lung cancer; all external causes, intentional self-harm and drug-related poisonings; external causes and MVTAs









Web Table 1. Causes of death and associated ICD codes

Cause	ICD8 code(s)	ICD9 code(s)	ICD10 codes
Respiratory disease	460-519	460–519	J00-J99
Ischaemic heart disease	410-414	410-414	I20-I25
Cerebrovascular disease	430-438	430-438	I60-I69
All malignant neoplasms	140-209	140-208	C00-C97
Lung cancer (malignant neoplasm of trachea/bronchus/lung)	162	162	C33-C34
Intentional self-harm (including events of undetermined intent)	E950-E959, E980-E989	E950-E959, E980-E989	X60-X84, Y10-Y34, Y87.0, Y87.2
External causes	E800-E999	E800-E999	ICD10 V01-Y98
Motor vehicle traffic accidents (MVTAs) [i]	E810-E819	E810-E819	V02-V04, V09, V12-V14,V19-V79, V86-V89
Alcohol related causes[ii]	262,291,303,571.0, 571.9, E860	291, 303, 305.0, 425.5, 571.0-571.5, 571.8, 571.9, E860	F10, G312, G621, I426, K292, K70, K73, K740-K742, K746-K749, K860, X45, X65, Y15
Drug related poisonings[iii]	304, E8530-E8539, E8540-E8549, E8550-E855.6, E8560-E8569, E950, E962, E980	304, 305.2-305.9, E850-E858, E950.0-E950.5, E9620, E980.0-E980.5	F11-F16, F18, F19, X40-X44, X60-X64, X85,Y10-Y14
Note that there are overlaps between a number of categories e.g.: all cancers and lung cancer; all external causes, intentional self-harm and drug-related poisonings; external causes and MVTAs			

[i] ICD9 and ICD10 codes as used in previous analyses e.g. Whyte B., Ajetunmobi T. Still 'The Sick Man of Europe'? Scottish mortality in a European context 1950-2010: an analysis of comparative mortality trends. Glasgow: GCPH; 2012

[ii] These are the groups of codes agreed by National Records of Scotland (NRS) and the (UK) Office for National Statistics (ONS) in 2007. They have since been updated, but the request for mortality data from national agencies pre-dated the change in codes.

[iii] These are the set of codes previously deemed most comparable between Scotland and England & Wales. See: Walsh D., Bendel N., Jones R., Hanlon P. It's not 'just deprivation': Why do equally deprived UK cities experience different health outcomes? Public Health 2010; 124: 487-495.

Web Table 2a. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for all-cause mortality rates by deprivation quintile - males

	Scotland		England		Northern Ireland	
	SII	RII	SII	RII	SII	RII
2001-2003	1168.8	0.69	823.3	0.56	620.7	0.41
2002-2004	1166.5	0.70	821.8	0.58	536.0	0.36
2003-2005	1118.8	0.69	811.7	0.59	562.0	0.39
2004-2006	1102.6	0.71	796.5	0.60	593.3	0.42
2005-2007	1133.7	0.74	792.7	0.61	639.2	0.46
2006-2008	1129.6	0.76	797.3	0.63	653.7	0.47
2007-2009	1106.7	0.76	795.0	0.65	629.1	0.47
2008-2010	1044.7	0.74	776.0	0.65	615.4	0.47
2009-2011	1030.8	0.75	755.6	0.65	569.9	0.45
2010-2012	1018.7	0.76	738.8	0.65	586.9	0.48
2011-2013	1019.2	0.77	743.0	0.66	615.6	0.50
2012-2014	1012.4	0.78	745.6	0.67	609.3	0.51
2013-2015	1022.8	0.78	766.9	0.69	606.7	0.51
2014-2016	1050.7	0.81	778.2	0.71	616.5	0.53
2015-2017	1078.2	0.83	784.6	0.71	656.0	0.55

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	1373.7	0.64	1365.7	0.87	1023.4	0.57	942.5	0.58
2002-2004	1383.3	0.64	1292.4	0.84	993.9	0.56	983.6	0.62
2003-2005	1270.9	0.61	1198.3	0.79	877.8	0.51	999.4	0.66
2004-2006	1294.3	0.65	1229.5	0.84	778.1	0.49	1061.9	0.70
2005-2007	1279.0	0.65	1314.4	0.93	943.0	0.62	1076.5	0.71
2006-2008	1299.4	0.67	1265.2	0.93	1041.7	0.70	1207.9	0.82
2007-2009	1239.5	0.65	1193.2	0.90	1044.4	0.68	1200.6	0.83
2008-2010	1138.2	0.62	1068.5	0.81	912.2	0.61	1161.8	0.85
2009-2011	1187.1	0.67	1127.3	0.87	848.4	0.56	1061.8	0.80
2010-2012	1238.5	0.71	1045.7	0.82	986.1	0.66	905.0	0.70
2011-2013	1300.2	0.75	1081.5	0.87	1061.9	0.74	865.9	0.66
2012-2014	1266.5	0.75	1120.2	0.92	1235.2	0.88	844.7	0.64
2013-2015	1248.0	0.74	1187.1	0.97	1249.0	0.88	936.0	0.69
2014-2016	1278.6	0.76	1211.4	1.00	1422.1	0.97	1001.7	0.74
2015-2017	1329.8	0.78	1178.6	0.97	1443.5	0.96	1108.3	0.83

Web Table 2b. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for all-cause mortality rates by deprivation quintile - females

	Scotland		England		Northern Ireland	
	SII	RII	SII	RII	SII	RII
2001-2003	568.3	0.48	453.0	0.44	226.3	0.21
2002-2004	580.2	0.49	465.9	0.46	247.1	0.24
2003-2005	581.9	0.50	473.7	0.47	289.7	0.29
2004-2006	587.7	0.53	461.6	0.48	337.1	0.34
2005-2007	585.8	0.53	455.5	0.48	329.6	0.34
2006-2008	603.7	0.56	457.8	0.50	333.4	0.34
2007-2009	616.0	0.58	461.2	0.51	341.8	0.36
2008-2010	617.8	0.59	459.3	0.52	339.4	0.36
2009-2011	599.1	0.59	453.9	0.53	329.2	0.36
2010-2012	607.3	0.60	454.5	0.54	323.0	0.36
2011-2013	607.4	0.61	469.5	0.56	331.6	0.37
2012-2014	628.6	0.63	478.3	0.57	342.5	0.38
2013-2015	643.4	0.65	502.3	0.60	368.3	0.41
2014-2016	662.5	0.67	512.9	0.61	374.3	0.42
2015-2017	685.7	0.69	528.6	0.63	367.6	0.41

	Glasgow		Edinburgh		Dundee		Aberdeen	
	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	562.8	0.41	579.4	0.54	445.9	0.36	493.1	0.45
2002-2004	676.4	0.50	606.3	0.57	534.1	0.45	543.6	0.49
2003-2005	620.7	0.46	575.0	0.55	570.7	0.48	445.1	0.40
2004-2006	683.0	0.52	538.4	0.53	612.9	0.54	481.0	0.45
2005-2007	656.8	0.50	515.7	0.52	605.7	0.56	498.0	0.47
2006-2008	678.3	0.52	589.1	0.61	585.4	0.55	576.5	0.55
2007-2009	694.3	0.55	639.7	0.66	556.6	0.51	526.2	0.50
2008-2010	709.5	0.58	676.2	0.72	493.5	0.45	520.1	0.51
2009-2011	757.4	0.64	676.8	0.73	536.6	0.50	483.6	0.49
2010-2012	781.4	0.66	698.6	0.75	643.8	0.60	394.3	0.40
2011-2013	795.7	0.67	692.6	0.75	624.7	0.59	442.3	0.46
2012-2014	744.4	0.63	665.3	0.73	605.3	0.59	512.1	0.52
2013-2015	740.9	0.63	704.1	0.78	498.5	0.48	665.4	0.67
2014-2016	794.7	0.68	726.0	0.81	684.7	0.66	637.8	0.64
2015-2017	887.7	0.75	767.0	0.86	783.1	0.73	597.3	0.61

Web Table 3a. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for mortality rates by deprivation quintile: 10 major causes of death, Scotland, males

	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	197.1	0.90	283.8	0.74	62.7	0.37	269.4	0.59	152.3	1.18
2002-2004	202.0	0.93	267.4	0.72	60.1	0.36	269.7	0.60	146.6	1.18
2003-2005	197.2	0.91	256.1	0.73	61.6	0.39	262.1	0.60	147.4	1.22
2004-2006	183.9	0.90	225.0	0.69	52.2	0.36	276.9	0.64	152.3	1.29
2005-2007	185.4	0.90	233.0	0.76	50.0	0.37	289.5	0.68	158.0	1.33
2006-2008	189.1	0.93	215.6	0.76	53.0	0.41	280.1	0.67	155.7	1.35
2007-2009	196.8	0.98	211.3	0.78	55.2	0.45	268.9	0.65	154.6	1.36
2008-2010	189.4	0.99	190.2	0.75	50.9	0.44	254.0	0.63	146.6	1.34
2009-2011	185.0	1.01	182.7	0.77	45.7	0.43	268.0	0.67	144.3	1.33
2010-2012	177.8	1.00	187.1	0.83	39.9	0.40	270.8	0.68	140.1	1.33
2011-2013	184.0	1.05	180.3	0.85	41.3	0.43	269.7	0.68	143.2	1.39
2012-2014	174.4	1.02	182.7	0.90	34.7	0.38	262.5	0.68	140.8	1.41
2013-2015	179.8	1.05	174.6	0.89	39.0	0.44	253.6	0.66	136.3	1.40
2014-2016	178.9	1.06	169.4	0.90	42.0	0.49	255.9	0.67	127.8	1.35
2015-2017	185.3	1.12	165.6	0.89	45.1	0.54	254.3	0.67	126.4	1.38

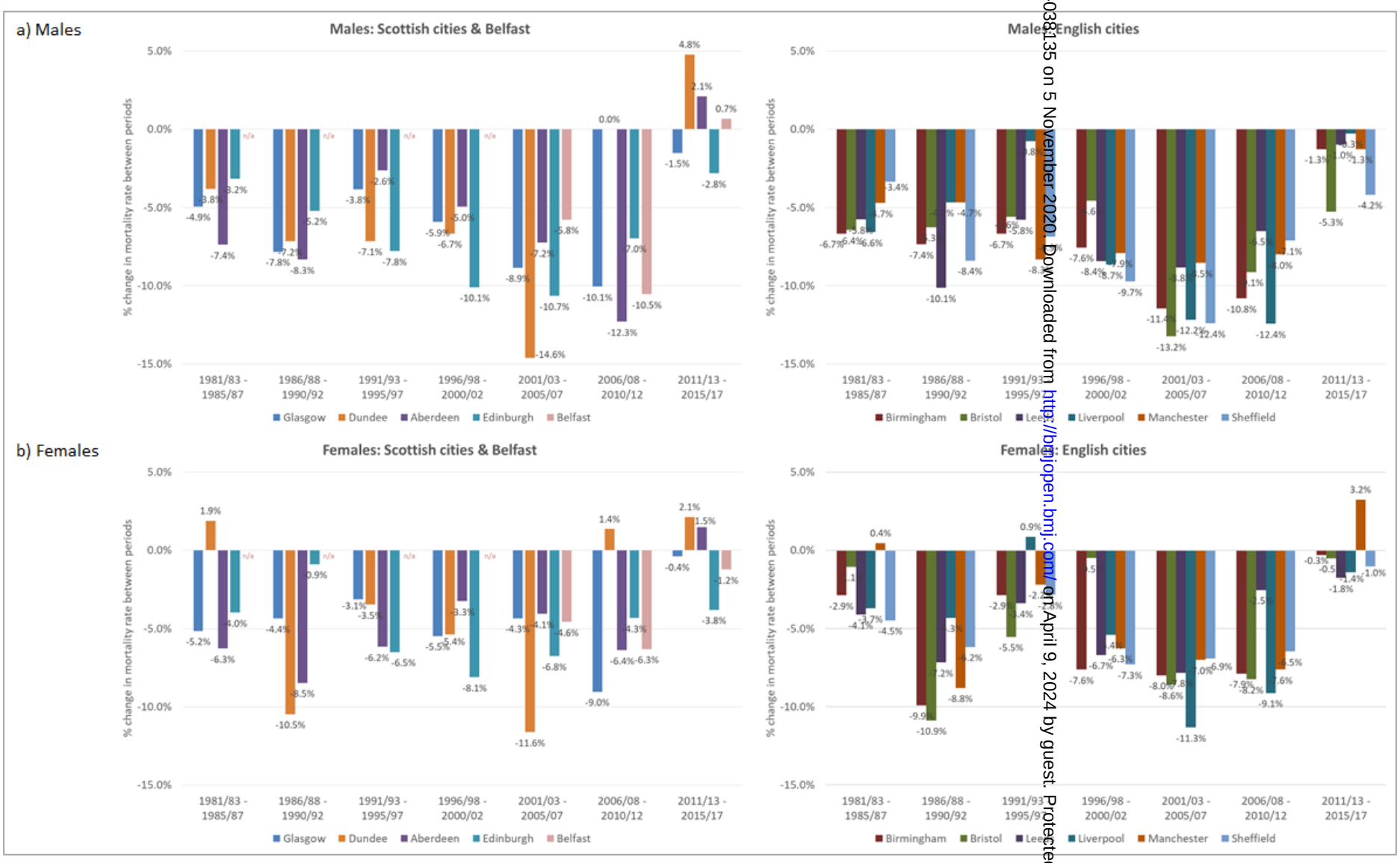
	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	77.6	1.16	37.5	2.58	106.5	2.33	35.7	1.4	1.0	0.10
2002-2004	79.3	1.17	36.6	2.47	110.8	2.40	34.3	1.4	-0.6	-0.07
2003-2005	72.7	1.10	32.1	2.36	106.3	2.33	29.4	1.3	-1.0	-0.11
2004-2006	72.9	1.11	36.0	2.49	106.9	2.40	30.1	1.3	1.5	0.16
2005-2007	69.7	1.11	39.4	2.50	102.7	2.40	29.8	1.3	2.4	0.29
2006-2008	69.4	1.11	47.0	2.53	102.0	2.46	31.8	1.3	3.1	0.38
2007-2009	67.1	1.11	48.3	2.49	91.5	2.40	31.9	1.4	1.8	0.25
2008-2010	64.8	1.11	48.4	2.48	87.3	2.35	31.6	1.4	1.3	0.20
2009-2011	72.9	1.17	46.3	2.43	76.5	2.20	32.8	1.5	2.1	0.36
2010-2012	80.0	1.21	47.1	2.46	72.6	2.18	31.3	1.3	1.5	0.28
2011-2013	89.7	1.28	47.5	2.47	65.0	2.11	30.4	1.3	2.7	0.51
2012-2014	89.8	1.32	49.7	2.56	66.4	2.20	25.9	1.2	2.0	0.38
2013-2015	89.5	1.33	51.4	2.59	64.3	2.13	22.9	1.1	2.7	0.53
2014-2016	101.0	1.43	58.7	2.66	67.4	2.14	22.7	1.2	2.9	0.57
2015-2017	112.4	1.50	65.9	2.71	67.0	2.08	23.5	1.2	2.9	0.65

Web Table 3b. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for mortality rates by deprivation quintile: 10 major causes of death, Scotland, females

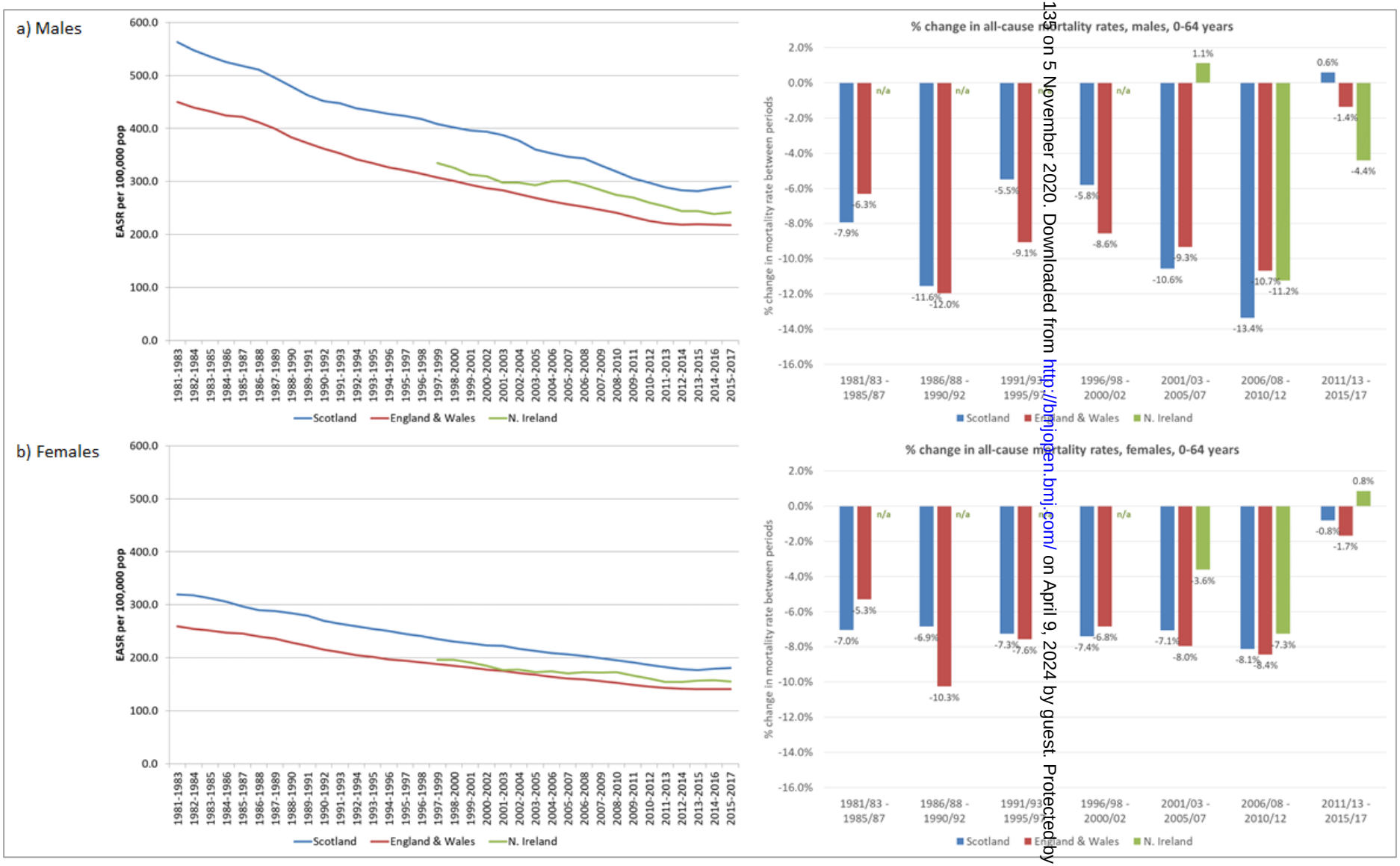
	Respiratory disease		Ischaemic heart disease		Cerebrovascular disease		All malignant neoplasms		Lung cancer	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	110.5	0.75	135.7	0.64	24.3	0.15	154.0	0.52	84.3	1.24
2002-2004	116.7	0.78	125.1	0.61	24.8	0.16	160.7	0.55	87.5	1.26
2003-2005	121.1	0.80	119.8	0.62	22.6	0.15	157.1	0.54	86.5	1.23
2004-2006	124.3	0.83	111.9	0.62	19.5	0.14	155.5	0.54	88.7	1.23
2005-2007	127.1	0.84	109.4	0.66	10.2	0.08	155.4	0.54	93.3	1.28
2006-2008	133.5	0.88	103.8	0.67	17.6	0.14	158.2	0.55	96.2	1.29
2007-2009	136.3	0.92	102.6	0.71	18.5	0.16	169.6	0.60	99.7	1.34
2008-2010	137.8	0.96	96.2	0.71	24.5	0.22	174.3	0.62	98.4	1.32
2009-2011	137.4	1.01	87.4	0.69	22.2	0.21	175.6	0.63	99.7	1.35
2010-2012	147.2	1.09	80.9	0.67	22.7	0.23	173.9	0.62	104.2	1.40
2011-2013	146.3	1.10	76.1	0.67	20.3	0.21	174.7	0.63	107.5	1.45
2012-2014	143.6	1.10	83.9	0.79	19.5	0.21	183.7	0.66	109.6	1.49
2013-2015	139.5	1.06	84.9	0.83	23.9	0.27	186.3	0.68	106.7	1.49
2014-2016	146.9	1.12	87.4	0.90	24.0	0.29	184.8	0.69	105.6	1.51
2015-2017	150.8	1.14	80.7	0.86	25.5	0.32	180.6	0.68	106.7	1.53

	External causes		Drug related poisonings		Alcohol-related causes		Suicide (incl. undetermined		Motor vehicle traffic accidents	
	SII	RII	SII	RII	SII	RII	SII	RII	SII	RII
2001-2003	17.0	0.50	13.2	2.26	35.9	1.96	12.5	1.47	0.1	0.04
2002-2004	18.1	0.53	12.7	2.25	35.2	1.94	11.5	1.39	0.2	0.06
2003-2005	18.7	0.56	12.0	2.10	35.0	1.91	10.9	1.34	0.1	0.02
2004-2006	21.7	0.68	12.6	2.17	35.4	1.90	10.1	1.34	0.5	0.19
2005-2007	23.5	0.76	12.6	2.28	35.6	1.93	11.6	1.57	0.7	0.27
2006-2008	25.2	0.84	14.6	2.50	34.5	1.95	12.1	1.64	0.4	0.14
2007-2009	22.7	0.74	16.8	2.55	30.6	1.84	11.3	1.48	0.1	0.04
2008-2010	21.1	0.70	17.9	2.49	29.0	1.80	9.6	1.30	-0.4	-0.17
2009-2011	23.4	0.74	18.7	2.39	26.5	1.66	9.7	1.25	0.0	0.02
2010-2012	29.6	0.92	19.5	2.41	25.7	1.77	10.5	1.31	-0.5	-0.26
2011-2013	32.9	1.01	19.0	2.35	23.1	1.68	10.0	1.27	-0.8	-0.49
2012-2014	31.8	0.99	19.3	2.47	21.8	1.70	9.2	1.28	-0.8	-0.48
2013-2015	32.7	0.97	21.1	2.52	23.0	1.74	7.8	1.12	-0.2	-0.10
2014-2016	37.6	1.03	27.1	2.71	24.2	1.78	7.5	1.04	0.3	0.20
2015-2017	46.1	1.18	31.3	2.69	24.3	1.77	6.6	0.98	0.6	0.33

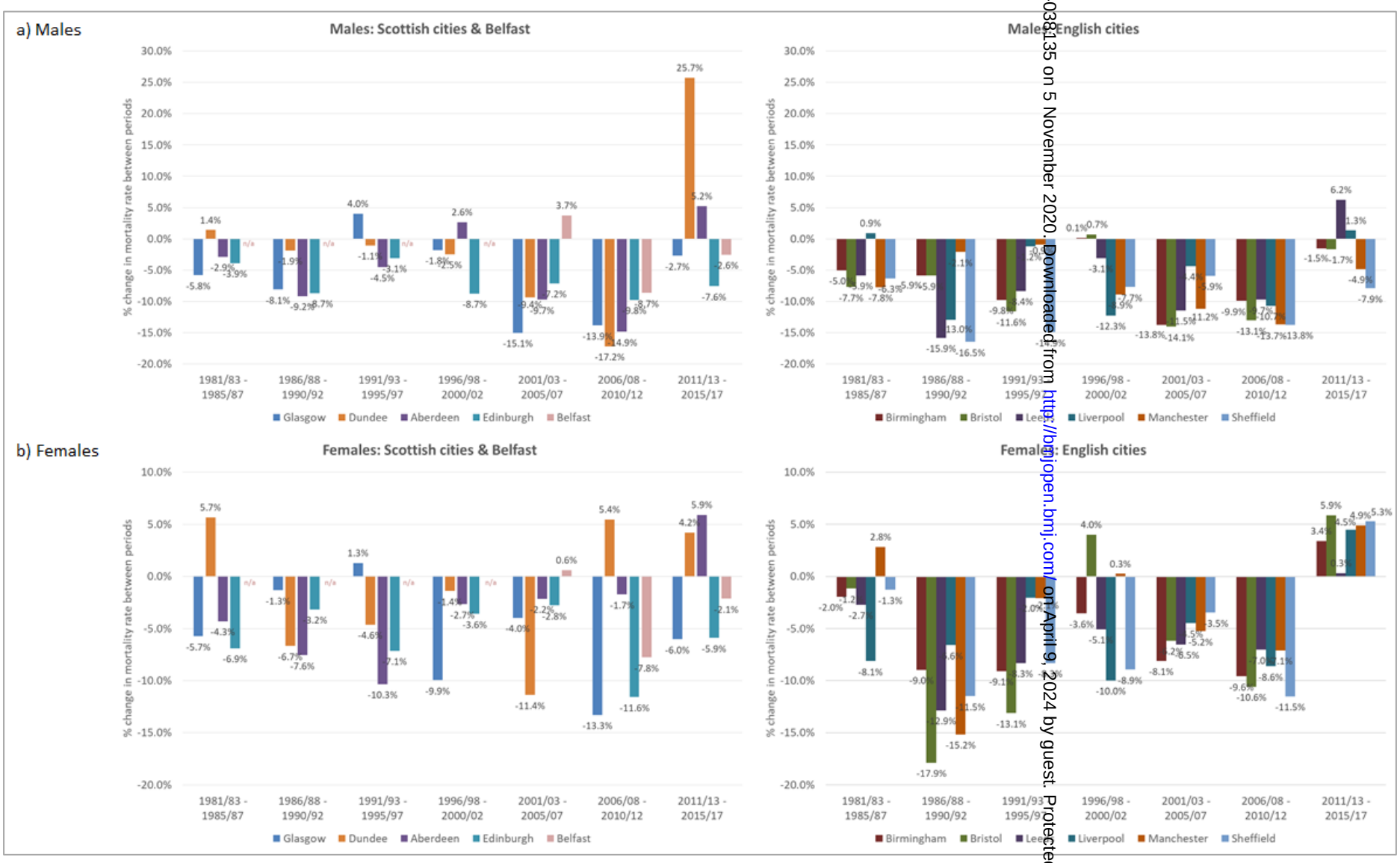
Web Figure 1. All cause deaths, all ages: percentage change in standardised mortality rates between five year periods - cities



Web Figure 2. European age-standardised mortality rates (0-64 years, all causes) per 100,000 population, three-year rolling averages, by UK country, 1981-2017; and percentage change in standardised mortality rates between five year periods

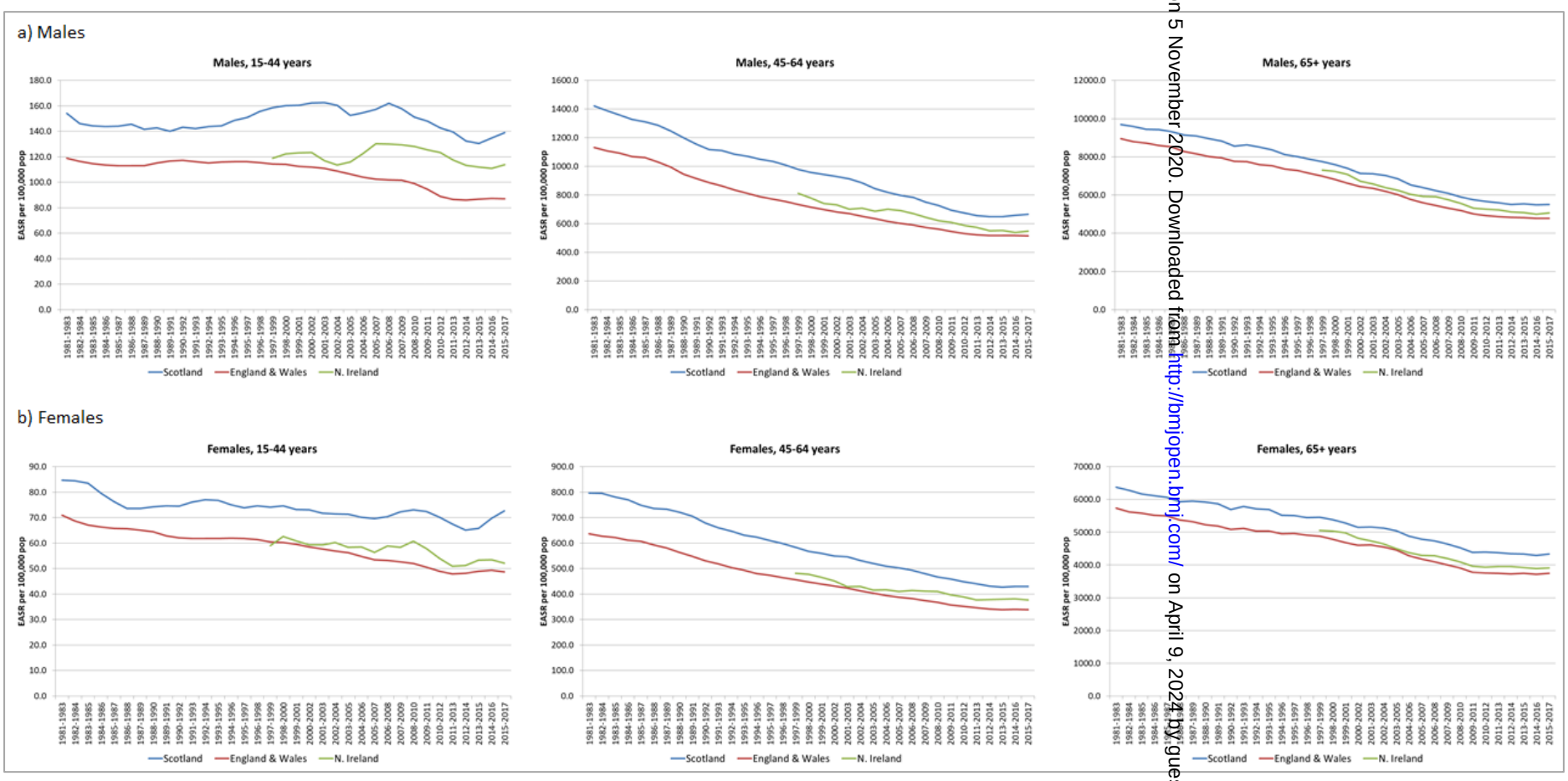


Web Figure 3. All cause deaths, 0-64 years: percentage change in standardised mortality rates between five year periods – cities

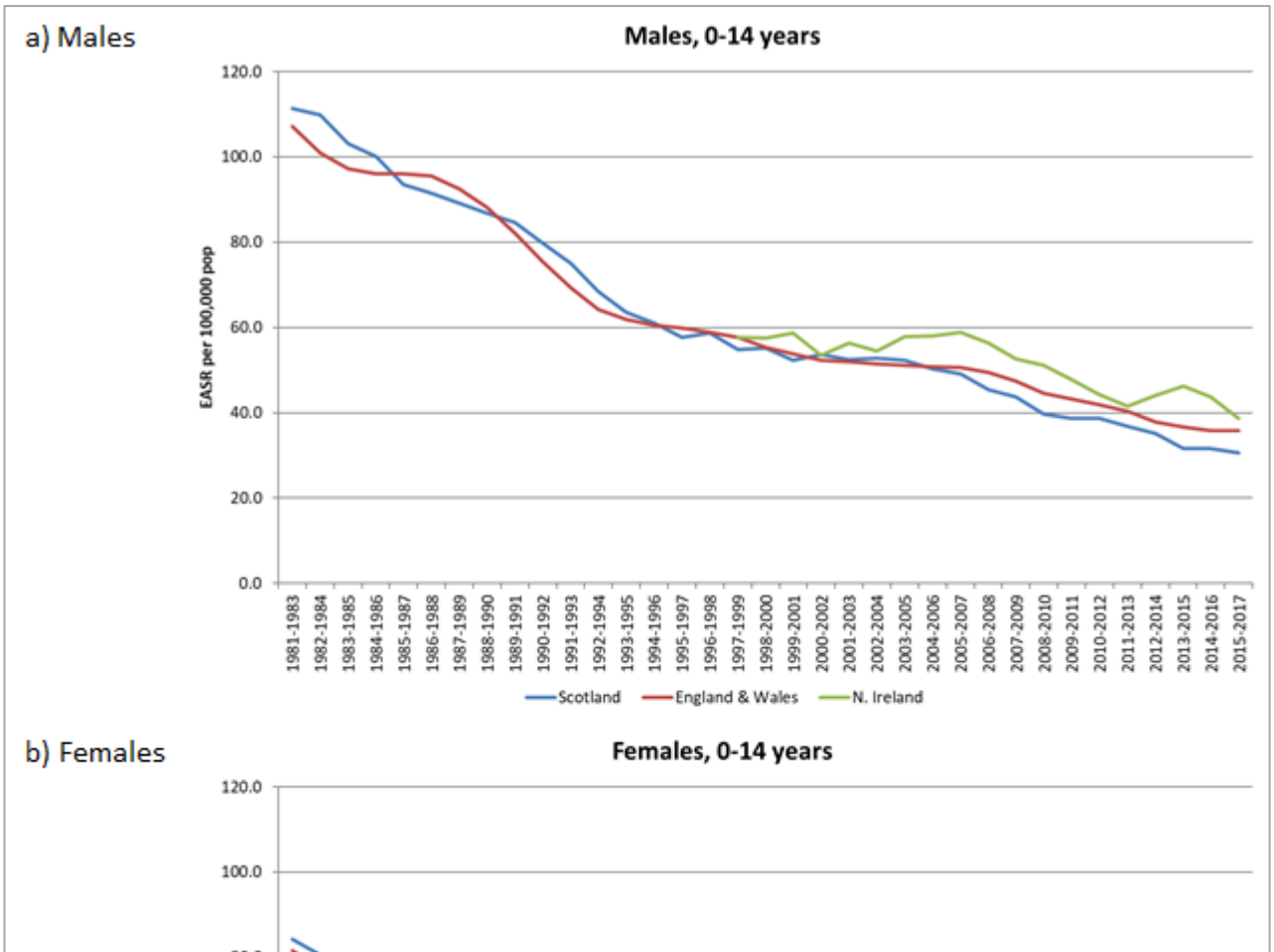


Web Figure 4. European age-standardised mortality rates (all causes) per 100,000 population, three-year rolling averages, by age group and UK country, 1981-2017 (note different axis scales on each chart)

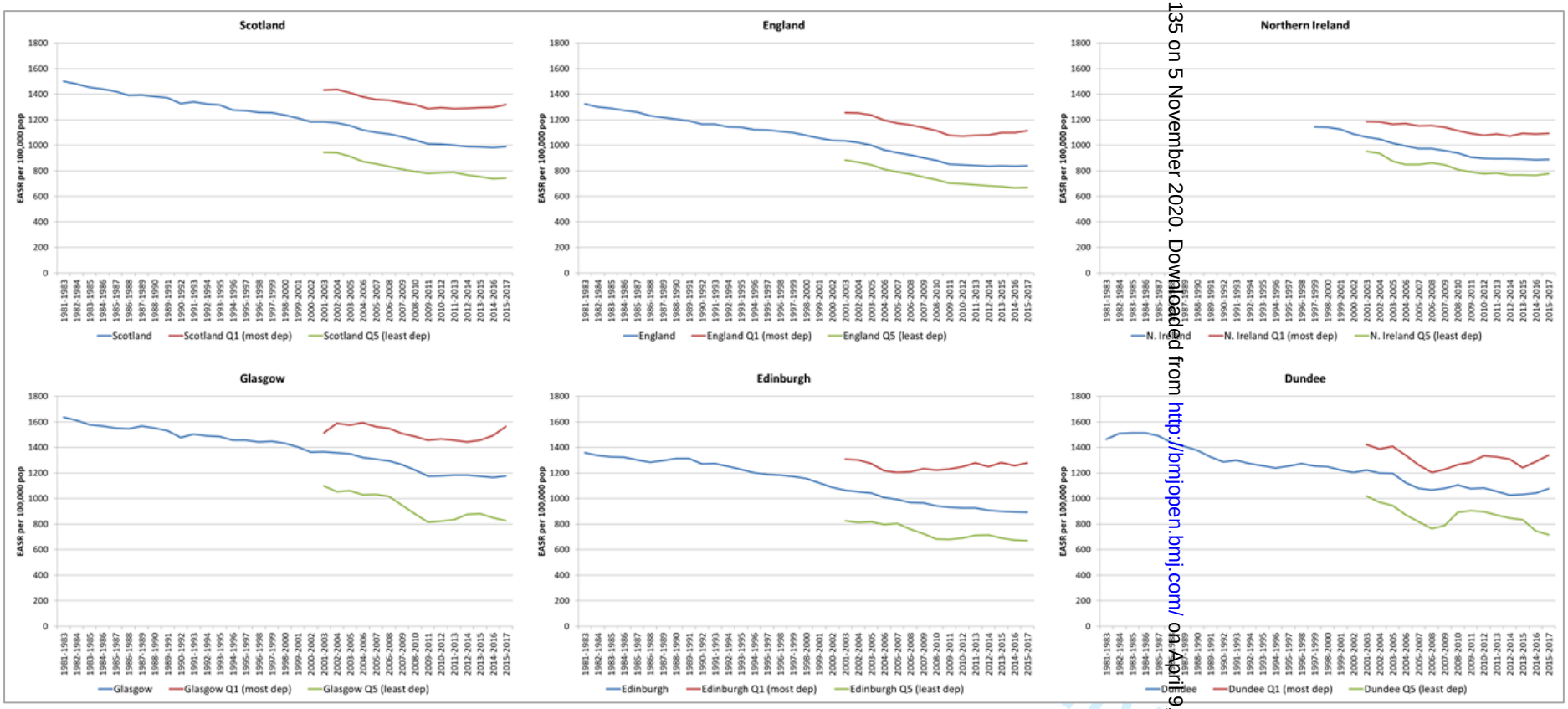
Web Figure 4 (i) adult age groups



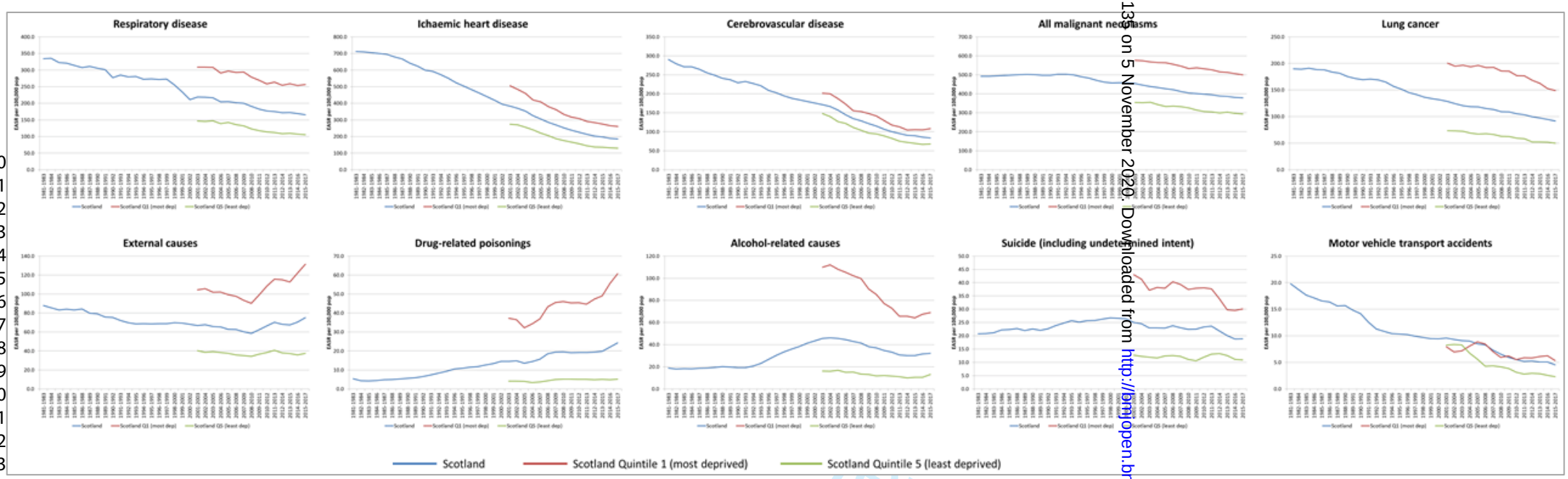
Web Figure 4 (ii) 0-14 years



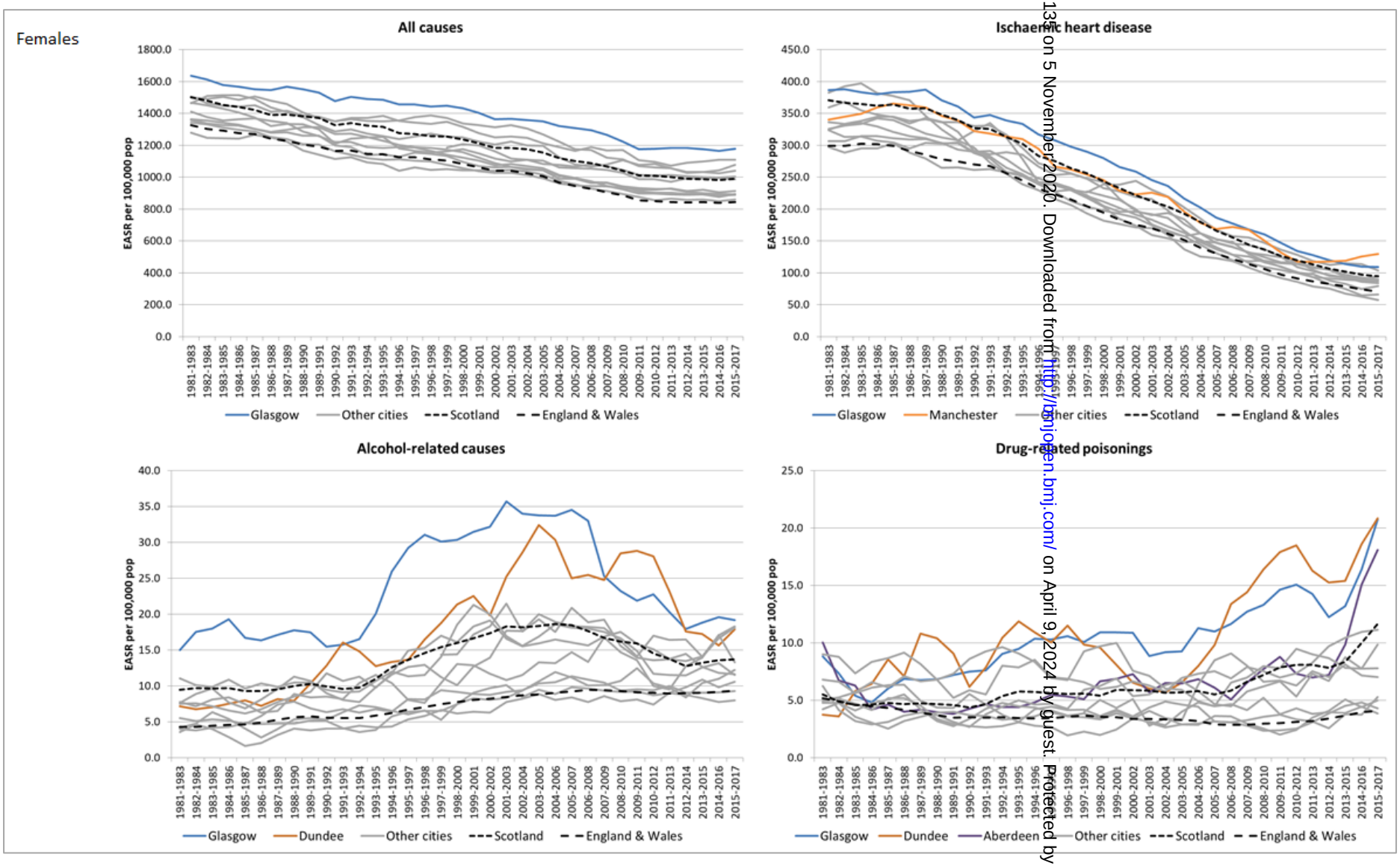
Web Figure 5. European age-standardised mortality rates (females, all ages, all causes) per 100,000 population, three-year rolling averages by selected country, city and country/city-specific deprivation quintiles



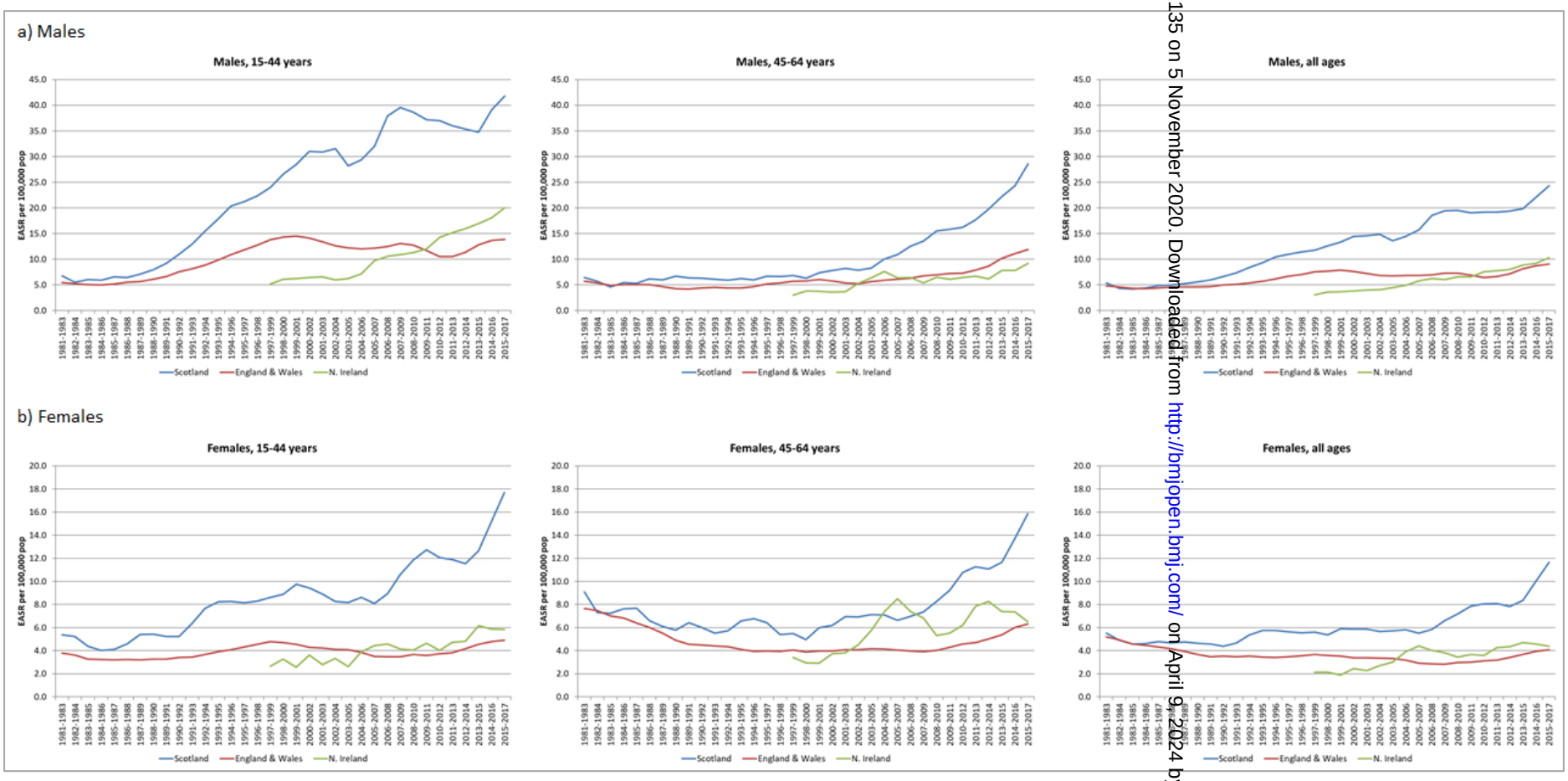
Web Figure 6. European age-standardised mortality rates (males, all ages) per 100,000 population, three-year rolling averages for 10 causes of death, Scotland and most and least deprived deprivation quintiles



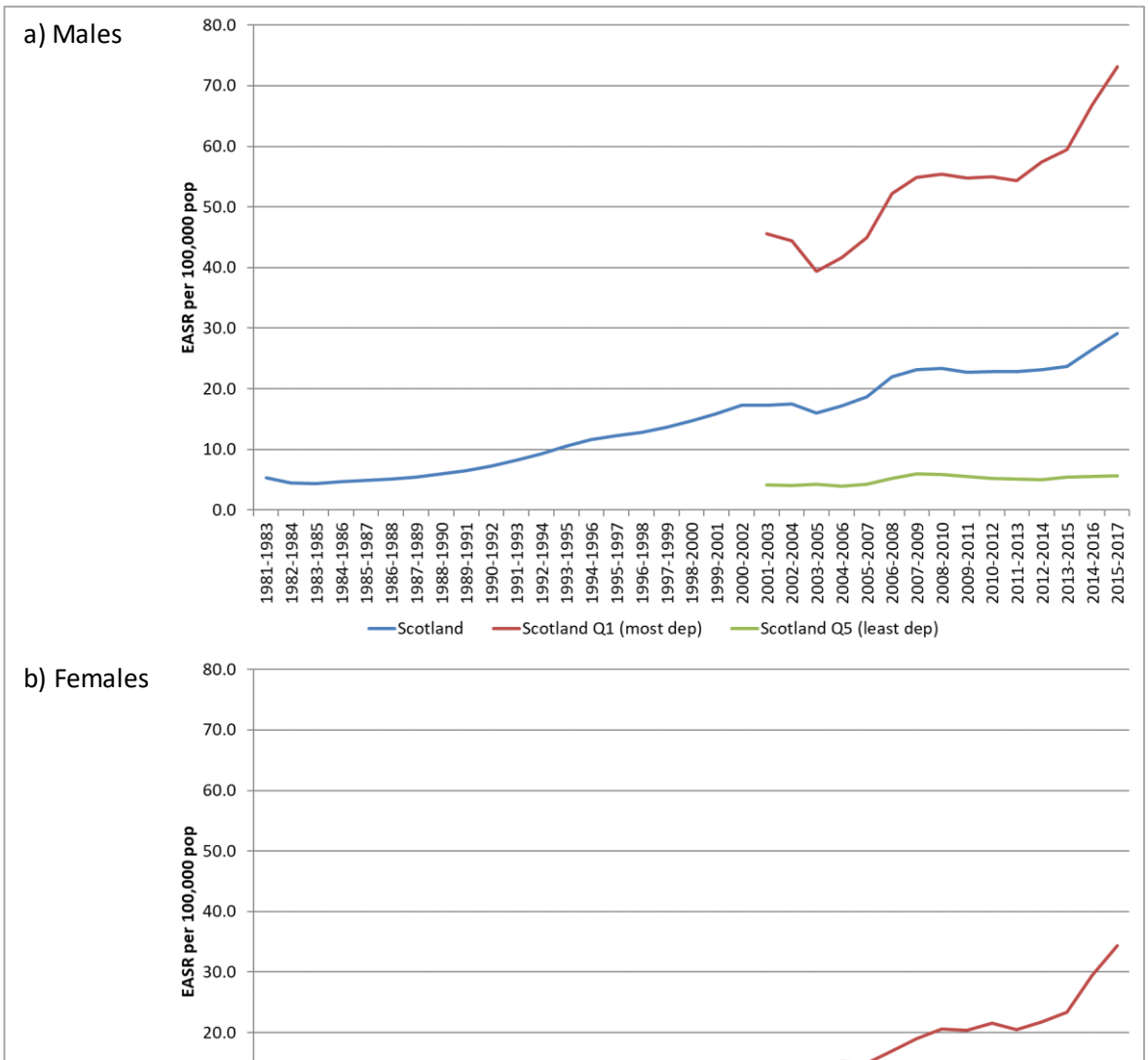
Web Figure 7. European age-standardised mortality rates (females, all ages) per 100,000 population, three-year rolling averages, for all-cause deaths, ischaemic heart disease, alcohol-related causes and drug-related poisonings, UK countries and cities, 1981-2017



Web Figure 8. European age-standardised mortality rates per 100,000 population, three-year rolling averages, for drug-related poisonings by selected age group, sex, and UK country 1981-2017



Web Figure 9. European age-standardised mortality rates per 100,000 population for drug-related poisonings, three-year rolling averages, Scotland and most and least by deprivation quintiles, 1981-2017



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
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	4-5
Bias	9	Describe any efforts to address potential sources of bias	4-6; 11
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	n/a (total population)
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	n/a
		(b) Indicate number of participants with missing data for each variable of interest	n/a (total population)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	Figs 1-5
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	Figs 1-5
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10; 11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-13
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	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.