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Research Paper

Excess mortality in England and Scotland in 2022: The long shadow of austerity and the return to an unacceptable pre-pandemic baseline

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Concerns exist that mortality remains elevated after COVID-19 peaks. This study examined whether mortality in England and Scotland in 2022 exceeded predictions from austerity-era (2012–2019) and pre-austerity (2001–2010) trends. Time trend analysis was conducted using data from 2001–2022. The outcomes were observed and expected age- and sex-standardised mortality rates (ASMRs). Expected 2022 ASMRs were calculated from austerity-era and pre-austerity trends. Excess deaths were estimated by comparing observed and expected ASMRs. Observed ASMRs were higher than austerity-era predictions and substantially higher than pre-austerity predictions. In England, excesses for females were 4.4% (4.0–4.8) and 38.2% (95% CI: 37.7–38.7), and 7.2% (6.8–7.6) and 57.0% (56.4–57.6) for males. In Scotland, excesses for females were 3.4% (2.2–4.5) and 26.6% (25.2–28.0), and 2.6% (1.5–3.8) and 45.2% (43.6–46.9) for males. COVID-19 accounted for 5.3–6.5% of deaths in 2022 and explained much of the excess compared to austerity-era trends. ASMRs were 1.68–1.94 times higher in the most versus least deprived areas. Deaths attributable to COVID-19 explain much of the excess compared to austerity-era trends. However, 879,430 excess deaths relative to pre-austerity trends, even excluding COVID-19 deaths, highlights the devastating impacts of austerity on public health.

Introduction

There are concerns that UK mortality rates remained elevated after the COVID-19 peaks in 2020 and 2021 compared to the preceding years (Mostert et al. 2024, National Records of Scotland 2023, Office for National Statistics 2023a, Raleigh 2022). Before considering potential causes of continuing increased mortality, it is essential to determine whether an excess exists. Whether a rate is deemed excessive depends on the definition of the expected counterfactual rate. In defining the counterfactual, both temporal trends

in mortality before the pandemic and changes in the population's age and sex structure must be considered. Prior studies have not always done so. For example, the Organisation for Economic Co-operation and Development (OECD) and the Office for National Statistics (ONS) used mean crude death counts from the five years before the pandemic as a baseline for estimating excess deaths (OECD 2023, Office for National Statistics 2023a). The recently updated ONS methodology relies on only the most recent five years of data, and therefore cannot account for the major shift in mortality trends that began around 2012 in the UK (Fenton et al. 2019a, Walsh, Dundas et al. 2022, Office for National Statistics 2024a, De Haro Moro et al. 2025). The purpose of this study was to compare mortality in England and Scotland in 2022 with expected rates extrapolated from longer-term pre-pandemic trends in age- and sex-standardised mortality rates (ASMRs).

Any examination of recent mortality trends must consider the changes observed in the UK from around 2012 onwards (Public Health England 2018, Fenton et al. 2019a, Minton et al. 2020, McCartney et al. 2022, Walsh, Dundas et al. 2022). Around this time, national mortality rates stopped declining, reversing over a century of improvement except during the World Wars and the 1918 influenza pandemic (Fenton et al. 2019b, Office for National Statistics 2022, Public Health England 2018). These altered trends have been seen across nearly all age groups and causes of death, and for both sexes (Bennett et al. 2018, Ramsay et al. 2020). However, the impact has not been uniform: mortality rates in the most socioeconomically disadvantaged areas have increased, and inequalities between the most and least disadvantaged areas have widened (Walsh, Dundas et al. 2022). The scale of these latter changes has differed by both sex (Bennett et al. 2018, Walsh, Dundas et al. 2022) and age (Loopstra et al. 2016, Walsh et al. 2020). This study examines mortality trend changes at the population level by sex as well as for selected combinations of sex, area deprivation, and age groups to characterise how these changes are distributed across society.

There is now an overwhelming body of evidence attributing these unprecedented changes in mortality to the imposition of 'austerity' by the UK Government from 2010 onwards (Martin et al. 2021, McCartney, McMaster et al. 2022, Prędkiewicz et al. 2022, Seaman et al. 2024, Walsh & McCartney 2024). Austerity has been implemented through enormous public spending cuts, particularly affecting poorer populations via reductions in social security and the defunding of vital public services. Consequently, using trends in ASMRs in the years immediately prior to the pandemic to predict expected counterfactual ASMRs in 2022 (as is the case in ONS publications) is based on a faulty assumption i.e., that trends in the period just before the pandemic were 'normal' and were simply a continuation of the previous trajectory. This assumption obscures the true scale of excess mortality observed since austerity was introduced. This study therefore estimated expected counterfactual ASMRs in 2022 predicted by trends observed both before and after the imposition of austerity.

Several hypotheses have been proposed to explain persistently high mortality following the COVID-19 peaks in high-income countries, as summarised in a recent scoping review (Scott et al. 2024). One hypothesis is that the excesses are caused by direct COVID-19 deaths. This study therefore also considered the contribution of direct COVID-19 deaths in England and Scotland in 2022.

The research questions addressed were:

1. How did observed ASMRs in England and Scotland in 2022 compare to expected ASMRs predicted by a continuation of austerity-era trends (2012-2019)?
2. How did observed ASMRs in England and Scotland in 2022 compare to expected ASMRs predicted by a continuation of pre-austerity trends (2001-2010)?
3. Were differences in observed and expected ASMRs based on the two prediction periods consistent across subgroups of age, sex, and area deprivation?
4. What proportion of deaths in England and Scotland in 2022 were attributable to COVID-19?

Methods

This study followed REporting of studies Conducted using Observational Routinely-collected Data (RECORD) guidelines (see Appendix I for checklist; Benchimol et al. 2015).

Population

We focus on the total populations of England and Scotland. England and Scotland are two of the four 'nations' that make up the UK (Wales and Northern Ireland being the other two). Together, England and Scotland constitute 93% of the population of the UK (Office for National Statistics, n.d.). The Scottish, Welsh and Northern Irish parliaments and assemblies have varying levels of devolved legislative powers. Scotland has tended to make the most extensive use of devolved powers to pursue mitigating policies where feasible, partly offsetting UK-wide measures. However, austerity policies have been implemented UK-wide by the UK Westminster Government, as it has power over most social security legislation, as well as control of overall spending. Thus, the effects of austerity on mortality have been observed in all four nations (De Haro Moro et al. 2025, Walsh & McCartney 2024) but here we focus on England and Scotland principally for reasons of data availability.

Data

Mortality

Annual mortality data for England and Scotland for 2001-2022 were obtained from the Office for National Statistics and National Records of Scotland (Office for National Statistics 2023b). Scottish data included cause of death, while English data provided only counts of deaths mentioning COVID-19 without details on other causes (Office for National Statistics 2024b). In this study, a COVID-19 death was defined for both nations as any death where COVID-19 was mentioned on the death certificate, not necessarily as the underlying cause.

Population

Population data for England and Scotland for 2001–2022 were obtained from the Office for National Statistics and National Records of Scotland (Office for National Statistics 2023b). For most years, data were disaggregated by five-year age group, sex, and deprivation level. However, the national statistical agencies had not published population data by deprivation level for 2021–2022 in England, and for 2022 in Scotland. Data for these years were only available by age and sex, with an unknown distribution by deprivation. To estimate counts for each age–sex–deprivation group in the missing years, we assumed that the relative distribution of the observed total population across the deprivation levels within each age–sex group remained unchanged from the most recent published data (2020 for England and 2021 for Scotland) and applied these proportions to the available age–sex data (i.e., the total national population data for all years and all nations are observed values, only the relative distribution of the population across deprivation groups was assumed for 2021–2022 in England and 2022 in Scotland; all mortality data are observed, including the distribution by deprivation).

Deprivation

Deprivation was measured using national indices: the Index of Multiple Deprivation (IMD) for England and the Scottish Index of Multiple Deprivation (SIMD). These indices use indicators of deprivation grouped into seven domains: income, employment, health, education, housing, living

environment/geographic access to local facilities, and crime. A deprivation score is calculated as a weighted combination of scores in these domains. Although derived separately using slightly different indicators and spatial scales, the two measures have been shown to be comparable (Walsh et al. 2020). Standardised mortality rates are included in both the English and Scottish overall IMD, but previous work has shown the effect of this circularity to be negligible (Bradford et al. 2023, McCartney et al. 2023a). Deprivation was measured at the small-area level using geographic units with populations of around 1,000. Areas were ranked by composite deprivation scores and grouped into five categories from most to least deprived. Each group contained approximately 20% of the national population. Small deviations from exactly 20% arose because deprivation groups are constructed from whole geographic units, which cannot always be divided perfectly equally. The most deprived category represents the 20% of population experiencing the greatest overall disadvantage across the seven deprivation domains. As both the IMD and SIMD are periodically updated, mortality data were linked to the chronologically-nearest version (see Tables A1a and A1b in Appendix II).

Analysis

ASMRs and 95% confidence intervals were calculated using the phe_dsr function from the *PHEindicatormethods* package v2.0.2 in R v4.2.0 (Georgina 2020, R Core Team 2022). This function calculates ASMRs directly standardised to the 2013 European Standard Population (ESP2013). The upper age group comprised individuals aged 85 or older. In addition to all-age rates, ASMRs were computed for subgroups—premature mortality (0–74 years), older adults (>74 years), older working age (45–64 years), and younger working age (20–44 years). Note that the 'working age' groups included all people in these age groups, regardless of employment status. These age groups were selected to characterise how changes in ASMRs have affected different parts of society. ASMRs were calculated by nation and sex, with additional stratification by deprivation and age group. Rate ratios were calculated as the ratio of ASMRs between deprivation groups to measure relative inequalities reference against the least deprived group.

Counterfactual Estimation

Expected ASMRs were calculated from two baseline counterfactuals based on extended pre-pandemic trends in the pre-austerity (2001–2010) and austerity (2012–2019) periods, rather than relying on the most recent five years of data as in ONS reports. Data were plotted to check for linearity, and linear regression models were extrapolated to 2022 with year as the independent variable and ASMRs as the dependent variable. Independent linear regression models were fitted for each combination of nation, sex, age, and area deprivation to generate expected ASMRs. Confidence intervals were not calculated for expected ASMRs as the number of datapoints used in each model did not meet normality assumptions, though trends are clearly linear (see the period 1981—2010 in Figure 1). The start of 2001 was chosen to provide a similar number of data years for both periods and because mortality data disaggregated by deprivation level were available from that year. The terminal year of 2010 was selected to coincide with the imposition of austerity, and 2012 was chosen based on inflection points in trends observed in 2011–2013 (Walsh, Dundas et al. 2022). A sensitivity analysis was conducted using start years of 2011, 2012, and 2013, while 2019 was chosen to omit peak COVID-19 mortality.

Excess Mortality

Excess mortality was defined as observed ASMR exceeding the expected ASMR. Relative excess mortality was expressed as a percentage relative to the expected ASMR for each combination of nation, sex, age subgroup, area deprivation and year. This was calculated as 100*((observed ASMR – expected

ASMR)/expected ASMR). Confidence intervals for observed ASMRs were calculated using Dobson's method (Dobson et al. 1991). Expected death counts were computed by multiplying ASMRs by the relevant population and adjusting for age structure differences relative to the ESP2013. The correction factor was determined by dividing observed deaths by the product of the observed ASMR and the relevant population (see Table A4 in the Appendix II for further details and numerical examples). This factor was calculated for each combination of nation, sex, five-year age group, area deprivation, and year. Excess deaths were estimated by subtracting expected counts from observed counts.

Findings

In 2022, relative excess ASMRs were 5.6% in England and 2.9% in Scotland compared to predictions from austerity-era trends (2012–2019), and 44.5% and 33.1% respectively compared to pre-austerity trends (2001–2010). Figure 1 shows ASMRs from 2001–2022, summarising 21,431,282 deaths in England and 2,475,589 in Scotland. Table 1 presents the related ASMRs for 2022. Across both nations and all age subgroups, males had higher ASMRs. Excesses were observed in most age subgroups except younger working age adults in Scotland (see Figures A1a–A1d in Appendix II). Males in the older working (45–64 years) and older adult (>74 years) groups experienced the highest relative excess mortality compared to both baseline trends.

Inequalities

Excess mortality in 2022 relative to both counterfactual baselines was observed across all deprivation groups. However, ASMRs increased with deprivation in both nations and sexes. ASMRs were consistently highest in the most deprived areas. ASMRs for the most and least deprived fifths from 2001–2022 are shown in Figure 2 and Tables 2a and 2b (see Figure A2 and Tables A2a and A2b in Appendix II for all deprivation groups). Increasing rate ratios between 2010 and 2022 demonstrate a widening of inequalities for both nations and sexes. In England in 2022, ASMRs in the most deprived areas were 1.68 times higher than the least deprived for females (up from 1.53 in 2010); the equivalent rate ratios were 1.75 (1.65 in 2010) for males in England, 1.80 (1.66 in 2010) for females in Scotland, and 1.94 (1.85 in 2010) for males in Scotland.

When excess mortality was calculated relative to expected ASMRs based on austerity-era trends (2012–2019), the least deprived areas had slightly larger absolute excesses than the most deprived areas in 2022. In contrast, excesses defined relative to expected ASMRs based on pre-austerity trends (2001-2010) were substantially larger across all deprivation groups and increased with deprivation. It is important to recognise that differences in austerity-era trends by deprivation influenced the expected ASMRs used to calculate both absolute and relative excesses. In the least deprived areas, ASMRs were lower at the onset of austerity and continued to decline during the austerity period. This resulted in lower expected ASMRs in 2022, and larger relative excesses compared to the least deprived areas. In the most deprived areas, ASMRs were already high at the onset of austerity and subsequently stagnated or increased during the austerity period. This resulted in higher expected ASMRs in 2022, and smaller relative excesses despite substantially higher observed mortality rates in this deprivation group.

The Impact of Excluding Direct COVID-19 Deaths

COVID-19 was recorded on 5.7% of death certificates in England and 6.2% in Scotland in 2022. Excluding these deaths, relative excess ASMRs in England dropped from 5.6% to -0.5% and in Scotland from 2.9% to -3.5% based on austerity-era trends. These values are presented in Table 3. Across age subgroups in England, the largest remaining excess after excluding COVID-19 deaths was in the

premature mortality age subgroup (0-74 years; 2.5% for females and 4.3% for males) while all Scottish age subgroups showed mortality deficits.

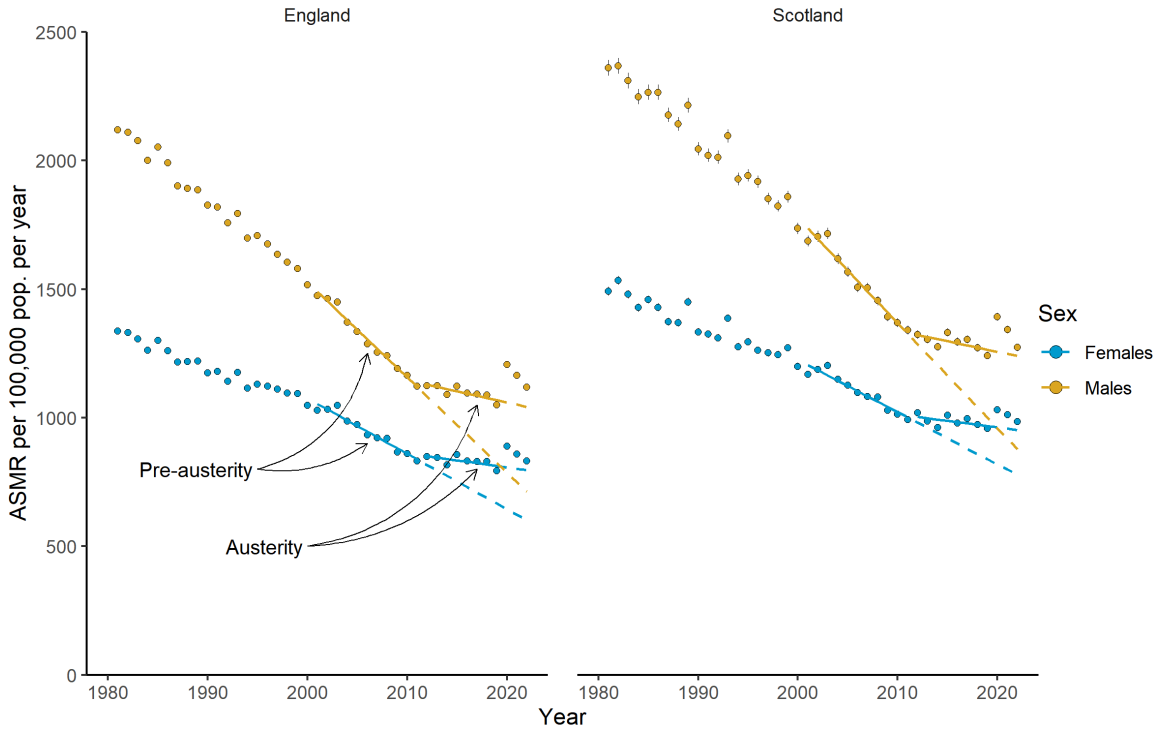

Figure 1: Age-standardised all-cause mortality rates from 1981–2022 in England and Scotland.
Notes: Points are observed rates. Confidence intervals are included for observed rates but are so narrow as to be obscured by the points in most cases. For both nations, solid lines are trends fitted through 2001–2010 (pre-austerity) and 2012–2019 (austerity). Dashed lines are trends from each of the fitted period extrapolated to 2022.

Sensitivity Analyses

Linear regression models were fitted for 60 combinations of nation, sex, age, and area deprivation level. For each, three models were run, varying the start year (2011, 2012, or 2013). Expected ASMRs using 2011 or 2013 varied from -3.2% to +5.7% relative to those based on 2012. Most expected ASMRs differed by less than 1% from the 2012 results. Figure A6 in Appendix II shows the distribution of these differences.

Estimates of Excess Deaths

In England in 2022, there were 11,290 additional female and 18,450 additional male deaths compared to expected deaths based on continuation of austerity-era trends; excluding COVID-19 deaths changed these values to 2,970 fewer deaths for females and 1,640 additional deaths for males. In Scotland, 1,020

additional female and 790 additional male deaths occurred, falling to -850 for females and -1,210 for males after excluding COVID-19 deaths.

Using pre-austerity trends (and after excluding COVID-19 deaths), England recorded 59,490 additional female and 82,480 additional male deaths in 2022, while Scotland recorded 4,670 additional female and 7,540 additional male deaths. Summing excess deaths from 2013-2022 yields 352,580 excess female and 451,700 excess male deaths in England (804,280 total) and 28,790 excess female and 46,360 excess male deaths in Scotland (75,150 total), amounting to 879,430 across both nations. Annual breakdowns are presented in Tables A4a–A4d. Excess deaths occurred across all deprivation levels (see Figures A5a and A5b in Appendix II).

Nation	Sex	Age group (years)	Obs. rate (95% CI)	Exp. rate 2012-19	Excess % 2012-19 (95% CI)	Exp. rate 2001-10	Excess % 2001-10 (95% CI)
England	Persons	All	961 (959, 964)	911	**5.6 (5.3, 5.9)**	665	**44.5 (44.1, 44.9)**
England	Females	All	831 (828, 835)	796	**4.4 (4.0, 4.8)**	602	**38.2 (37.7, 38.7)**
England	Males	All	1118 (1114, 1122)	1042	**7.2 (6.8, 7.6)**	712	**57 (56.4, 57.6)**
England	Females	0-74	269 (267, 271)	251	**7.1 (6.3, 7.9)**	183	**47 (45.9, 48.1)**
England	Males	0-74	420 (417, 422)	386	**8.8 (8.2, 9.5)**	251	**67.4 (66.3, 68.4)**
England	Females	>74	2131 (2118, 2144)	1999	**6.6 (6.0, 7.2)**	1432	**48.8 (48.0, 49.7)**
England	Males	>74	3082 (3066, 3099)	2867	**7.5 (6.9, 8.1)**	1736	**77.6 (76.6, 78.5)**
England	Females	45-64	344 (340, 348)	325	**6.0 (4.7, 7.2)**	260	**32.5 (30.9, 34.1)**
England	Males	45-64	537 (532, 542)	500	**7.4 (6.3, 8.5)**	360	**49.2 (47.7, 50.7)**
England	Females	25-44	56 (55, 58)	55	**3.2 (0.4, 6.0)**	46	**23.6 (20.3, 27.0)**
England	Males	25-44	103 (100, 105)	98	**4.6 (2.4, 6.7)**	86	**19.9 (17.5, 22.4)**
Scotland	Persons	All	1116 (1107, 1125)	1084	**2.9 (2.1, 3.7)**	839	**33.1 (32.0, 34.1)**
Scotland	Females	All	985 (974, 996)	953	**3.4 (2.2, 4.5)**	778	**26.6 (25.2, 28.0)**
Scotland	Males	All	1273 (1259, 1288)	1240	**2.6 (1.5, 3.8)**	877	**45.2 (43.6, 46.9)**

Scotland	Females	0-74	347 (340, 354)	337	**3.1 (1.0, 5.2)**	264	**31.4 (28.8, 34.1)**
Scotland	Males	0-74	514 (505, 523)	503	**2.2 (0.4, 4.0)**	318	**61.7 (58.9, 64.5)**
Scotland	Females	>74	2628 (2584, 2672)	2510	**4.7 (2.9, 6.4)**	2115	**24.2 (22.1, 26.3)**
Scotland	Males	>74	3648 (3592, 3705)	3496	**4.4 (2.7, 6.0)**	2440	**49.5 (47.2, 51.9)**
Scotland	Females	45-64	446 (431, 460)	439	1.5 (-1.8, 4.9)	332	**34.4 (30.0, 38.8)**
Scotland	Males	45-64	676 (658, 695)	665	1.6 (-1.2, 4.5)	390	**73.4 (68.6, 78.2)**
Scotland	Females	25-44	82 (76, 88)	97	**-15.6 (-21.9, -9.3)**	82	-0.6 (-8.0, 6.9)
Scotland	Males	25-44	147 (139, 155)	181	**-18.6 (-23.2, -13.9)**	149	-1.3 (-6.9, 4.4)

Table 1: Age-standardised all-cause mortality rates per 100,000 population per year by nation, sex, and age subgroup in 2022.

Notes: *Obs. rate* is the observed ASMR. *Exp. rate, 2012-19* and *Exp. rate, 2001-10* are the expected ASMRs if linear trends from the periods 2012-2019 and 2001-2010, respectively, had continued to 2022 (dashed lines in Figure 1). *Excess* percentages use expected rates as denominators. Bold excess values indicate results where the 95% CI of relative excess excludes zero.

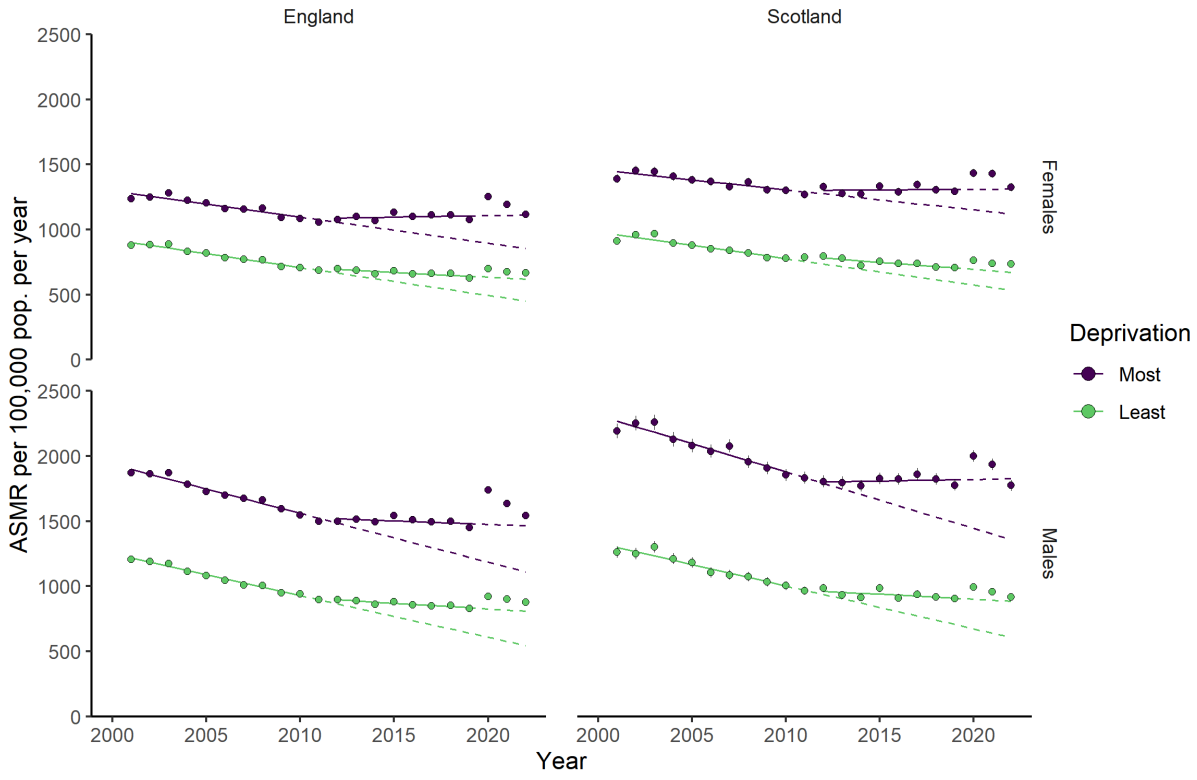

Figure 2: Age-standardised all-cause mortality (ASMR) rates from 2001–2022 in the most and least deprived fifths of the population.

Notes: Points are observed rates. Confidence intervals are included for observed rates but are so narrow as to be obscured by the points in most cases. Solid lines are trends fitted through 2001-2010 (pre-austerity) and 2012-2019 (austerity). Dashed lines are trends extrapolated to 2022.

Nation	Sex	Deprivation	Obs. Rate (95% CI)	Rate Ratio	Exp. Rate	Excess % (95% CI)
England	Females	Most	1117 (1108, 1127)	1.68	1112	0.5 (-0.4, 1.4)
England	Females	Least	667 (661, 673)		618	**7.9 (6.9, 8.8)**
England	Males	Most	1541 (1528, 1554)	1.75	1465	**5.2 (4.3, 6.1)**
England	Males	Least	878 (871, 886)		809	**8.6 (7.7, 9.5)**
Scotland	Females	Most	1324 (1294, 1356)	1.80	1311	1.0 (-1.4, 3.4)
Scotland	Females	Least	735 (715, 756)		673	**9.3 (6.3, 12.4)**
Scotland	Males	Most	1774 (1733, 1816)	1.94	1826	**-2.8 (-5.1, -0.5)**
Scotland	Males	Least	915 (888, 942)		886	**3.2 (0.2, 6.3)**

Table 2a: Age-standardised all-cause mortality rates per 100,000 population per year, rate ratios, and relative excess in ASMRs in 2022 in the most and least deprived areas, assuming continuation of austerity-era (2012-2019) trends.

Nation	Sex	Deprivation	Obs. Rate (95% CI)	Obs. Rate Ratio	Exp. Rate	Excess % (95% CI)
England	Females	Most	1117 (1108, 1127)	1.68	855	**30.7 (29.6, 31.8)**
England	Females	Least	667 (661, 673)		452	**47.5 (46.2, 48.8)**
England	Males	Most	1541 (1528, 1554)	1.75	1110	**38.8 (37.7, 40.0)**
England	Males	Least	878 (871, 886)		543	**61.8 (60.4, 63.2)**
Scotland	Females	Most	1324 (1294, 1356)	1.80	1122	**18.1 (15.3, 20.8)**
Scotland	Females	Least	735 (715, 756)		533	**37.9 (34.1, 41.8)**
Scotland	Males	Most	1774 (1733, 1816)	1.94	1359	**30.6 (27.5, 33.7)**
Scotland	Males	Least	915 (888, 942)		608	**50.5 (46.1, 54.9)**

Table 2b: Age-standardised all-cause mortality rates per 100,000 population per year, rate ratios, and relative excess in ASMRs in 2022 in the most and least deprived areas, assuming continuation of pre-austerity (2001-2010) trends.

Notes: Deprivation – *Most* = most deprived areas, *Least* = least deprived areas. *Exp. rate* is the expected ASMR in 2022 if linear trends from the period 2012-2019 had continued to 2022 (dashed lines in Figure 2). *Excess* percentages are given using the expected rate point estimate as denominators only, ignoring the confidence intervals of the expected rates due to the limited number of datapoints which contribute to the models. Bold excess values indicate results where the 95% CI of the relative excess excludes zero.

Nation	Sex	Age Group (years)	Excess % (95% CI)	Excess % excl. C19 (95% CI)	Reduction	Prop. C19 deaths (95% CI)
England	Persons	All	**5.6**	**-0.5**	6.1	5.7
			(5.3, 5.9)	**(-0.8, -0.2)**		(5.7, 5.8)
England	Females	All	**4.4**	**-1.1**	5.5	5.3
			(4.0, 4.8)	**(-1.5, -0.7)**		(5.3, 5.4)
England	Males	All	**7.2**	**0.5**	6.8	6.1
			(6.8, 7.6)	**(0.1, 0.9)**		(6.1, 6.2)
England	Females	0-74	**7.1**	**2.5**	4.6	5.3
			(6.3, 7.9)	**(1.7, 3.3)**		(5.3, 5.4)
England	Males	0-74	**8.8**	**4.3**	4.6	6.1
			(8.2, 9.5)	**(3.6, 4.9)**		(6.1, 6.2)
England	Females	>74	**6.6**	**1.1**	5.6	5.3
			(6.0, 7.2)	**(0.4, 1.7)**		(5.3, 5.4)
England	Males	>74	**7.5**	**1.2**	6.3	6.1
			(6.9, 8.1)	**(0.6, 1.7)**		(6.1, 6.2)
England	Females	45-64	**6.0**	**1.8**	4.2	5.3
			(4.7, 7.2)	**(0.5, 3.0)**		(5.3, 5.4)
England	Males	45-64	**7.4**	**3.6**	3.8	6.1
			(6.3, 8.5)	**(2.6, 4.7)**		(6.1, 6.2)
England	Females	25-44	**3.2**	-0.1	3.3	5.3
			(0.4, 6.0)	(-2.9, 2.6)		(5.3, 5.4)
England	Males	25-44	**4.6**	1.9	2.6	6.1
			(2.4, 6.7)	(-0.2, 4.0)		(6.1, 6.2)
Scotland	Persons	All	**2.9**	**-3.5**	6.5	6.2
			(2.1, 3.7)	**(-4.3, -2.7)**		(6.1, 6.4)
Scotland	Females	All	**3.4**	**-2.8**	6.1	6.0
			(2.2, 4.5)	**(-3.9, -1.6)**		(5.7, 6.3)
Scotland	Males	All	**2.6**	**-4.3**	6.9	6.5
			(1.5, 3.8)	**(-5.4, -3.2)**		(6.2, 6.8)
Scotland	Females	0-74	**3.1**	**-1.8**	4.9	6.0
			(1.0, 5.2)	**(-3.9, 0.2)**		(5.7, 6.3)
Scotland	Males	0-74	**2.2**	**-2.4**	4.5	6.5
			(0.4, 3.9)	**(-4.1, -0.6)**		(6.2, 6.8)
Scotland	Females	>74	**4.7**	**-1.8**	6.5	6.0
			(2.9, 6.4)	**(-3.5, -0.1)**		(5.7, 6.3)
Scotland	Males	>74	**4.4**	**-2.3**	6.7	6.5
			(2.7, 6.0)	**(-3.9, -0.7)**		(6.2, 6.8)
Scotland	Females	45-64	1.5	-2.2	3.8	6.0
			(-1.8, 4.9)	(-5.5, 1.1)		(5.7, 6.3)
Scotland	Males	45-64	1.6	-2.4	4.0	6.5
			(-1.2, 4.5)	(-5.1, 0.4)		(6.2, 6.8)
Scotland	Females	25-44	**-15.6**	**-18.6**	2.9	6.0
			(-21.9, -9.3)	**(-24.7, -12.3)**		(5.7, 6.3)
Scotland	Males	25-44	**-18.6**	**-20.2**	1.5	6.5
			(-23.2, -13.9)	**(-24.7, -15.5)**		(6.2, 6.8)

Table 3: Relative excesses in observed age-standardised mortality rates per 100,000 population per year before and after excluding COVID-19 (C19)-related deaths in 2022, assuming continuation of austerity-era (2012-2019) trends.

Notes: *Excess* percentages are given using the point estimates of the expected rates as denominators. Bold excess values indicate results with 95% CI excluding zero. *Reduction* is the reduction in excess in percentage points after excluding COVID-19-related deaths. *Proportion C19 deaths* is the proportion of deaths in the age-sex subgroup where COVID-19 was mentioned on the death certificate. Absolute rates underlying the excess percentages reported here are presented in Table A3.

Discussion

Our findings reinforce concerns that mortality remains elevated after the peak years of the COVID-19 pandemic in the UK, even relative to changed mortality trends due to austerity. Part of the excess is due to high COVID-19 deaths in 2022, as seen elsewhere in Europe (Burström et al. 2024, Kuhbandner & Reitzner 2023, Raknes et al. 2024, Walkowiak et al. 2023). However, trends from 2012 to 2019 should not be accepted as normal. The change in mortality trends due to austerity was associated with an estimated 879,430 excess deaths between 2013-2022, comparable to the total number of British military deaths during World War One (Thompson et al. 2012). Although the deaths discussed in this study affected all parts of society, austerity has disproportionately harmed people in the most disadvantaged areas. Reversing austerity is crucial to mitigate the dramatic worsening of mortality trends seen since 2010.

This study's findings broadly align with previous research employing different methods and time periods, while addressing limitations such as reliance on crude mortality or inappropriately short baseline periods that ignore important context around mortality trends since 2012. Pizzato and colleagues observed relative excess mortality of 5.0% in England and 5.2% in Scotland in 2022 using Poisson regression models fitted to mortality data from 2010–2019, compared to 5.6% and 2.9% in the present study (Pizzato et al. 2024). Pérez-Reche used linear regression on UK crude mortality rates from 2012–2019 to predict rates for 2022 and 2023 (Pérez-Reche 2024). In most age groups aged 30 or over, observed excesses were significant despite uncertainty in expected rates. Although methodologies differed, with this study using ASMRs, both found that the largest excesses occurred in older working age and older adults. In contrast, younger working age adults experienced more adverse trends during 2012–2019, while older groups showed modest annual improvements.

Although international comparisons should be made cautiously due to varying pandemic progressions, higher-than-expected mortality in 2022 has been reported worldwide (Hajdu et al. 2024, Kuhbandner & Reitzner 2023, Mostert et al. 2024, Raknes et al. 2024, Walkowiak et al. 2023). Walkowiak and colleagues (2023) reported post-pandemic excess mortality across Europe through 2022. They found post-pandemic excess was negatively associated with peri-pandemic excess, ranging from around -3% in Romania to 10% in Norway, with all included Western European countries showing relative excesses of 2.5-10%. Kuhbandner and Reitzner (2023) estimated a 6.6% excess mortality in Germany for 2022, comparable to that observed in England in this study. Using linear regression on 2012-2019 data, they found the 6.6% excess far exceeded predictions, even after accounting for uncertainty due to annual mortality variations. In Norway, Raknes and colleagues extrapolated all-cause ASMRs from 2010–2019 to 2022 and reported a relative excess of 13.7%, notably higher than in England and Scotland in this study (Raknes et al. 2024). The proportion of all deaths where COVID-19 was mentioned on the death certificate was, however, similar in England, Scotland, and Norway (5.7%, 6.2%, and 6.3% respectively). In line with international results, expected ASMRs based on austerity-era trends in our study indicate that COVID-19 accounts for a substantial portion of the observed excess mortality in England and Scotland in 2022. However, any excess mortality explained by COVID-19 is dwarfed by the excess related to the change in mortality trends following the imposition of austerity, which continues to accumulate even after achieving substantial control over COVID-19.

Our comparisons of recent observed ASMRs with long-term trend predictions add to and update a substantial evidence base documenting extraordinary changes in UK mortality rates since the early 2010s. These changes have been shown to have resulted in largest part from UK Government 'austerity' measures implemented from 2010 onwards (Martin et al. 2021, McCartney, McMaster et al. 2022, Prędkiewicz et al. 2022, Seaman et al. 2024, Walsh & McCartney 2024). UK Government spending was reduced by around £540 billion between 2010 and 2019, involving large cuts to social security and vital public services (via reductions in local government funding), which have profoundly harmed the health of the poorest and most vulnerable in society (Walsh & McCartney 2024). These policies were introduced in the UK and elsewhere internationally in response to the financial crisis of the mid/late 2000s and the (government-argued) need to reduce national debt accrued from the 'bailout' of banks. Although these

policies took different forms in different countries, in the UK it was principally about enormous reductions to public spending. This was initiated by the Conservative/Liberal Democrat coalition government in 2010, and expanded by subsequent administrations. The causal pathways are well established, linking increased poverty (through cuts to social security) to loss of support services, increased stress, poorer mental health, and adverse behavioural 'coping mechanisms' (Elliott 2016, Gunasekara et al. 2011, McLean 2014, Russ et al. 2012, Walsh & McCartney 2024). Many studies have shown links between the main facets of austerity (cuts to social security and vital public services) and poorer mental health (defined and measured in different ways), increased drugs harms (Friebel et al. 2022, Koltai et al. 2021), multimorbidity (Stokes et al. 2022), and ultimately reduced life expectancy and increased mortality (Cherrie et al. 2021, Katikireddi et al. 2018, Kim et al. 2022). Several of these studies used statistical methods that enabled demonstration of a causal relationship between austerity 'exposures' and mortality (see appendix of Walsh & McCartney 2024). A series of analyses have shown that changes to mortality rates (and other adverse outcomes such as poverty-driven increases in premature births; Watson et al. 2024) started within approximately two years of the implementation of the policies (Fenton et al. 2019, McCartney, McMaster et al. 2022, Walsh et al. 2022).

As described in detail elsewhere (McCartney, Walsh et al. 2022, Walsh & McCartney 2024), other hypotheses for the changed mortality trends have been proposed and assessed. Many relate to the influence of individual diseases or health conditions (for example, slowed improvement in cardiovascular disease, annual variation in influenza, increases in drug deaths and deaths from dementia) which, among other reasons, are not congruent with the evidence that changes in mortality have been observed for all major causes of death, not just these specific examples, pointing instead to a shared, underlying, cause (Bennett et al. 2018, Ramsay et al. 2020). Proposed explanations relating to demographic and methodological influences have also been discounted on the basis of flawed or weak evidence (McCartney, Walsh et al. 2022). It has been demonstrated, however, that historical increases in obesity have contributed to the mortality changes – albeit only to a relatively small degree. Analyses by Walsh et al. (2022) showed that between 10% (males) and 14% (females) of the changes to mortality rates observed in Scotland in the period 2016-19 were potentially attributable to earlier increases in obesity in the population. The equivalent figures for England were 20% (males) and 35% (females), although assessment of potential biases suggested these figures were likely to be overestimates.

Evidence also shows that the effects of austerity on mortality trends in the UK have been made worse by both the COVID-19 pandemic and the post-pandemic high rates of inflation ('cost of living crisis'). For example, Richardson et al. (2023) showed an estimated 6% increase (8% in the most deprived areas, 2% in the least) in death rates in Scotland for those aged under 75 years was attributable to high inflation. It is also important to understand the longer-term context of these trends. Even prior to the austerity-driven cuts to social security in the UK, levels of employment-replacement benefits were among the lowest of all OECD countries (OECD n.d.), falling well below levels required to pay for life's 'basic essentials' (Bannister et al. 2023). The UK has therefore been subject to what might be called a 'perfect' storm' of adversity, which has ultimately impacted on the health and mortality of its population. This has entailed: ineffective social security coverage (recently described by Amnesty International (2025) as 'social insecurity'); further cuts to levels of (and eligibility for) those same social security benefits on an arguably unprecedented scale, cuts which have markedly increased poverty rates (with increases in child poverty in the UK between 2010 and 2019 having been shown by UNICEF to have been the worst of any high-income country (UNICEF Innocenti – Global Office of Research and Foresight 2023); the COVID-19 pandemic, which also disproportionately affected the poorest; and the post-pandemic 'cost of living crisis' which has further worsened mortality rates among those living with the least.

It is important to note that the UK is not alone in seeing adverse changes to mortality rates attributable to the implementation of austerity-related policies. Notable effects have been observed in the USA and several European countries including Greece, Spain and Iceland (Walsh & McCartney 2024). Analyses by McCartney et al. demonstrated that across all high-income countries, implementation of austerity measures had a negative impact on mortality, life expectancy and inequalities in life expectancy

(McCartney, McMaster et al. 2022). In contrast, mortality trends in Japan – a country which did not introduce austerity measures – continued to improve (Walsh & McCartney 2024).

Strengths and Limitations

One strength of this study is its use of population-wide data for England and Scotland over two decades. Standardising ASMRs to the 2013 European Standard Population overcomes the shortcomings of raw death counts, which do not account for population changes or varying deprivation group structures. ASMRs also address the limitations of crude mortality rates that fail to adjust for changes in age and sex structure over time or between countries. By projecting ASMRs from longer pre-pandemic (2001-2010) and austerity-era (2012-2019) linear trends rather than using a five-year average, this study captures longer-term mortality shifts and provides a more accurate counterfactual than recent methods, including those published by the ONS.

This study also has limitations. We were unable to obtain mortality data (stratified by deprivation) beyond 2022; updating the analyses to include further years of data is therefore a key recommendation. ASMRs vary year-to-year, and this study did not account for that variability when defining excess mortality. Fitting linear regression models to only 11 years of data introduces uncertainty, especially when extrapolating 12 years beyond the fitting period, as it assumes a stable long-term trend that may not capture underlying fluctuations or structural changes. Using area-level deprivation measures yields smaller inequality gradients than individual measures due to misclassification (McCartney et al. 2023b). These indices include health outcomes, which potentially introduces endogeneity, though its impact on summary measures is minimal (Bradford et al. 2023, McCartney et al. 2023a). Defining COVID-19 deaths as any death mentioning COVID-19 rather than as the underlying cause may distort estimates of excess mortality from other causes. For example, in Scotland fewer than 60% of what we considered COVID-19 deaths in 2022 listed it as the underlying cause. However, many direct COVID-19 deaths are also attributable to austerity as highlighted in the ongoing public enquiry, making their exclusion from austerity-era excess mortality estimates highly conservative (Bambra & Marmot 2023).

Conclusions

This study has shown that mortality in 2022 remained higher than expected in England and Scotland, exceeding predictions based on both pre-pandemic austerity-era and pre-austerity trends. Our work overcomes key methodological limitations of earlier research and reveals that austerity has disproportionately impacted on the most socioeconomically disadvantaged groups. The findings suggest 879,430 excess deaths occurred between 2013 and 2022 in these nations due to changes in mortality trends linked to austerity. Although some excess mortality in 2022 is attributable to direct COVID-19 deaths, the dramatic ASMR changes since the early 2010s account for far more excess deaths; yet these changes receive far less attention. Improving UK mortality rates requires reversing the austerity-driven policies that underpin these trends, especially for those experiencing the most severe socioeconomic disadvantages.

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Conflicts of interest

The authors declare they have no conflicts of interest.

Data availability statement

Data are available upon request from the Office of National Statistics and National Records of Scotland.

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Ethics statement

This study used publicly available data and required no ethical approval.

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Appendix I – The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1a) Title page 1b) Abstract	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1.1 – Abstract 1.2 – Title and abstract 1.3 – N/A

Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction		
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction		
Methods					
Study Design	4	Present key elements of study design early in the paper	Introduction and Methods		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods		

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 b) Cohort study - For matched studies, give matching criteria and number of exposed and unexposed Case-control study - For matched studies, give matching criteria	N/A – Population-wide data used.	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage	N/A – Population-wide data used.

		and the number of controls per case		process, including the number of individuals with linked data at each stage.	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	N/A	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	N/A
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	Methods - Data		

Bias	9	Describe any efforts to address potential sources of bias	Methods – Sensitivity Analysis		
Study size	10	Explain how the study size was arrived at	N/A – Population-wide data used.		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			
Statistical methods	12	a) Describe all statistical methods, including those used to control for confounding b) Describe any methods used to examine subgroups and interactions c)Explain how missing data were addressed d) C*ohort study* - If applicable, explain how loss	a) Methods – Analysis b) Methods – Analysis c) Methods – Analysis describes where some missing population denominators were estimated and the methods used for doing so. d) N/A – Population-wide data used. e) Methods – Sensitivity Analysis		

		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 e) Describe any sensitivity analyses			
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	12.1 - N/A – Population -wide data used.

				RECORD 12.2: Authors should provide	N/A – Mortality and

				information on the data cleaning methods used in the study.	deprivation data were complete and no cleaning was necessary.
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	N/A – No linkage
Results					
Participants	13	a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing	N/A – Population-wide data used.	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of	N/A – Population-wide data used.

		follow-up, and analysed) b) Give reasons for nonparticipation at each stage. c) Consider use of a flow diagram		included persons can be described in the text and/or by means of the study flow diagram.	
Descriptive data	14	a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders b) Indicate the number of participants with missing data for each variable of interest c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	N/A – Population-wide data used.		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary	Results		

		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			

Main results	16	a) Give unadjusted estimates and, if applicable, confounder adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included b) Report category boundaries when continuous variables were categorized c) If relevant, consider translating estimates of relative	a) N/A b) Methods (for age group definitions) c) N/A		

		risk into absolute risk for a meaningful time period			
Other analyses	17	Report other analyses done— e.g., analyses of subgroups and interactions, and sensitivity analyses	Results and Appendix		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Discussion		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion – Strengths Limitations	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they	Results – Limitations

				pertain to the study being reported.	
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Discussion		
		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion		
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Author information		
Accessibility of protocol, raw data, and programming code				RECORD 22.1: Authors should provide information on how to access any supplemental information such	N/A – No protocol, data not permissible for public release, code

				as the study protocol, raw data, or programming code.	irrelevant without data.

Appendix II

Index of Multiple Deprivation versions

Table A1a – Alignment of mortality data years with the corresponding versions of the England (and Wales) Index of Multiple Deprivation (IMD)

Mortality data	***IMD version***
2001-05	2004
2006-08	2007
2009-12	2010
2013-17	2015
2018-22	2019

Table A1b – Alignment of mortality data years with the corresponding versions of the Scottish Index of Multiple Deprivation (SIMD)

Mortality data	***SIMD version***
2001-04	2004
2005-07	2006
2008-10	2009
2011-13	2012
2014-17	2016
2018-22	2020v2

Excess mortality by age subgroup

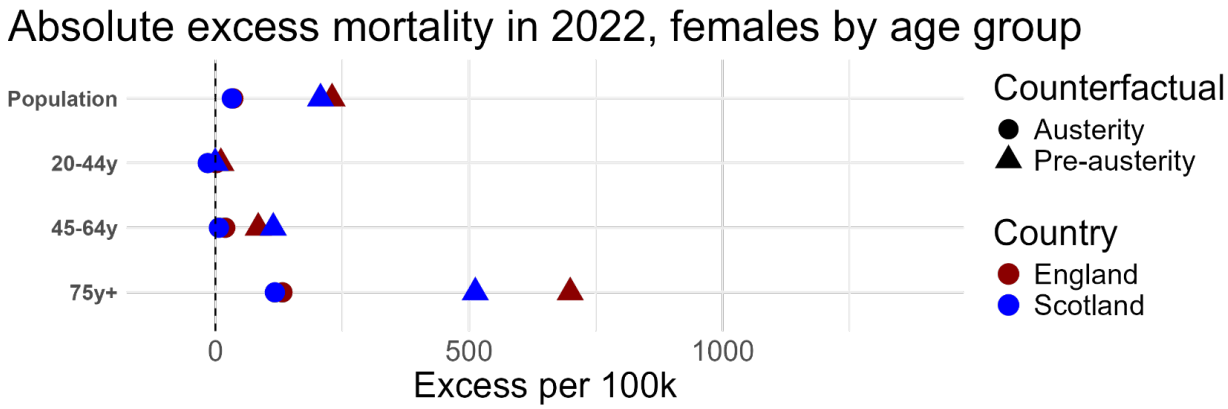

Figure A1a – Excess mortality across age subgroups in females based on expected ASMRs predicted by trends from austerity (2012-2019) and pre-austerity (2001-2010) eras.

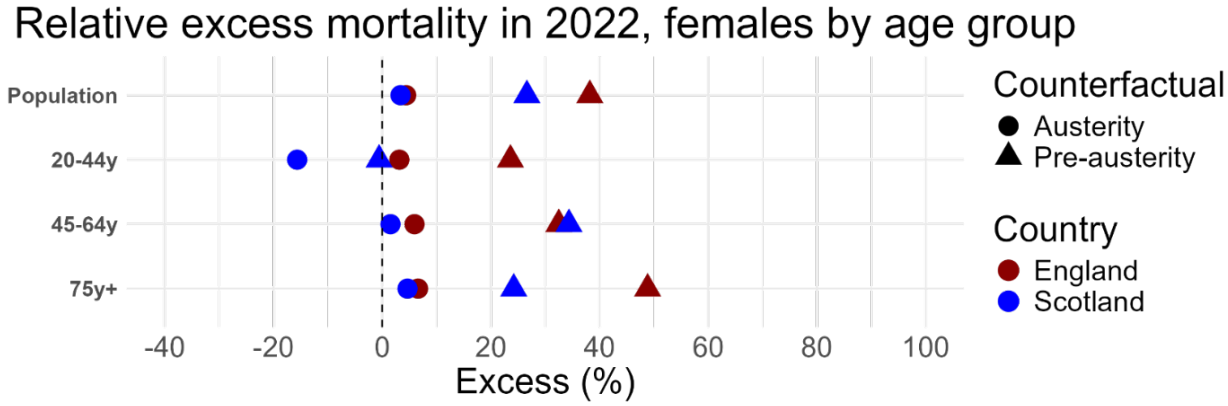

Figure A1b – Relative excess mortality across age subgroups in females based on expected ASMRs predicted by trends from austerity (2012-2019) and pre-austerity (2001-2010) eras.

Figure A1c – Excess mortality across age subgroups in males based on expected ASMRs predicted by trends from austerity (2012-2019) and pre-austerity (2001-2010) eras.

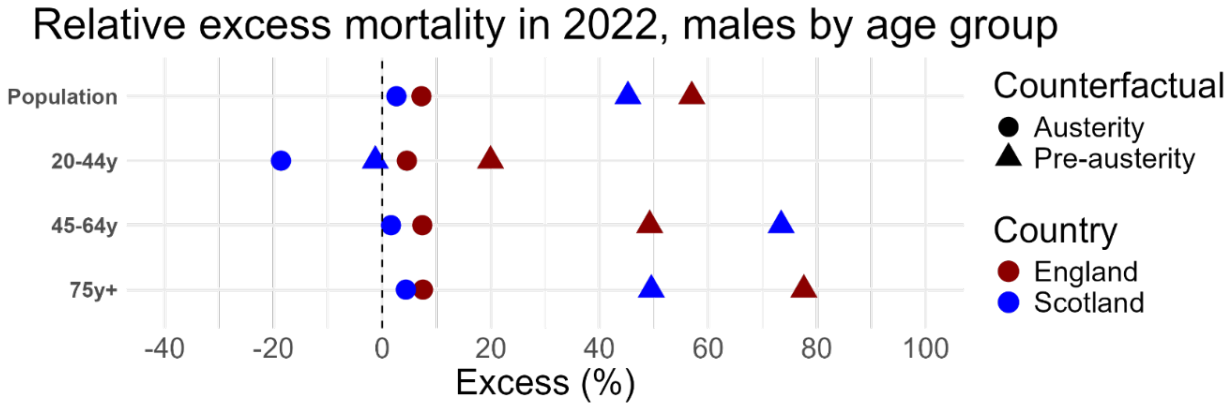

Figure A1d – Relative excess mortality across age subgroups in males based on expected ASMRs predicted by trends from austerity (2012-2019) and pre-austerity (2001-2010) eras.

Mortality by deprivation level

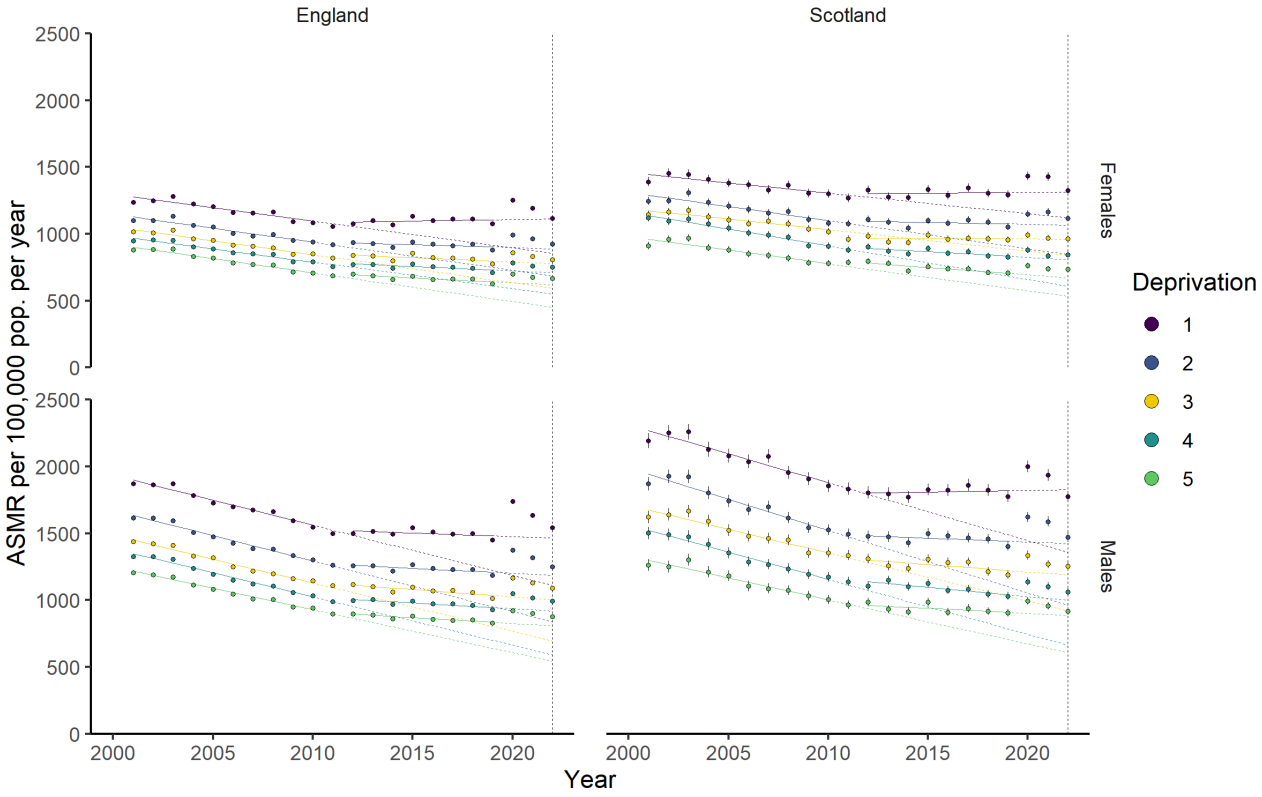

Figure A2 - Age-standardised mortality rates from 2001–2022 by deprivation level. 1 = most deprived, 5 = least deprived. Points are observed rates. Solid lines are trends fitted through 2001–2010 (pre-austerity) and 2012–2019 (austerity imposed). Dashed lines are trends projected to 2022. Confidence intervals are included for observed rates but are so narrow as to be obscured by the points in most cases.

Table A2a – Age-standardised all-cause mortality rates, rate ratios, absolute excess in ASMRs, and relative excess in ASMRs in 2022 by fifths of deprivation, assuming continuation of austerity era (2012-2019) trends.

Nation	*Sex*	*Deprivation*	*Obs. Rate (95% CI)*	*Rate Ratio*	*Exp. Rate*	*Excess % (95% CI)*
England	Females	1 – Most	1117 (1108, 1127)	1.68	1112	0.5 (-0.4, 1.4)
England	Females	2	924 (916, 932)	1.39	889	4.0 (3.1, 4.8)
England	Females	3	808 (801, 815)	1.21	778	3.9 (3.1, 4.8)
England	Females	4	749 (743, 756)	1.12	710	5.6 (4.7, 6.4)
England	Females	5 – Least	667 (661, 673)		618	7.9 (6.9, 8.8)
England	Males	1 – Most	1541 (1528, 1554)	1.75	1465	5.2 (4.3, 6.1)
England	Males	2	1249 (1238, 1259)	1.42	1184	5.4 (4.5, 6.3)
England	Males	3	1088 (1079, 1097)	1.24	1002	8.6 (7.7, 9.5)
England	Males	4	992 (984, 1000)	1.13	919	8.0 (7.1, 8.9)
England	Males	5 – Least	878 (871, 886)		809	8.6 (7.7, 9.5)
Scotland	Females	1 – Most	1324 (1294, 1356)	1.80	1311	1.0 (-1.4, 3.4)
Scotland	Females	2	1118 (1091, 1144)	1.52	1066	4.8 (2.4, 7.3)

Scotland	Females	3	965 (942, 989)	1.31	962	0.4 (-2.0, 2.9)
Scotland	Females	4	845 (823, 868)	1.15	809	4.5 (1.8, 7.3)
Scotland	Females	5 – Least	735 (715, 756)		673	9.3 (6.3, 12.4)
Scotland	Males	1 – Most	1774 (1733, 1816)	1.94	1826	-2.8 (-5.1, -0.5)
Scotland	Males	2	1470 (1435, 1506)	1.61	1423	3.4 (0.9, 5.9)
Scotland	Males	3	1255 (1224, 1286)	1.37	1189	5.6 (3.0, 8.2)
Scotland	Males	4	1062 (1034, 1091)	1.16	999	6.3 (3.5, 9.2)
Scotland	Males	5 – Least	915 (888, 942)		886	3.2 (0.2, 6.3)

Notes: *Depr.* 1 = most deprived areas, 5 = least deprived areas. Rates are per 100,000 population. *Rate ratio* is the ratio of observed ASMR compared to the appropriate least deprived fifth of areas. *Exp. rate* is the expected ASMRs if linear trends from the period 2012-2019 had continued to 2022 (exemplified by dashed lines in Figures 1, 2, and A2). *Excess* percentages are given using the expected rates as denominators. Bold excess values indicate results where the 95% CI of the relative excess excludes zero.

Table A2b – Age-standardised all-cause mortality rates, rate ratios, absolute excess in ASMRs, and relative excess in ASMRs in 2022 by fifths of deprivation, assuming continuation of austerity era (2001-2010) trends.

Nation	*Sex*	*Deprivation*	*Obs. Rate (95% CI)*	*Rate Ratio*	*Exp. Rate*	*Excess % (95% CI)*
England	Females	1 – Most	1117 (1108, 1127)	1.68	855	30.7 (29.6, 31.8)
England	Females	2	924 (916, 932)	1.39	687	34.6 (33.4, 35.7)
England	Females	3	808 (801, 815)	1.21	593	36.2 (35.1, 37.4)
England	Females	4	749 (743, 756)	1.12	551	36.1 (35.0, 37.3)
England	Females	5 – Least	667 (661, 673)		452	47.5 (46.2, 48.8)
England	Males	1 – Most	1541 (1528, 1554)	1.75	1110	38.8 (37.7, 40.0)
England	Males	2	1249 (1238, 1259)	1.42	839	48.7 (47.5, 50.0)
England	Males	3	1088 (1079, 1097)	1.24	697	56.0 (54.7, 57.3)
England	Males	4	992 (984, 1000)	1.13	593	67.4 (66.0, 68.8)
England	Males	5 – Least	878 (871, 886)		543	61.8 (60.4, 63.2)
Scotland	Females	1 – Most	1324 (1294, 1356)	1.80	1122	18.1 (15.3, 20.8)
Scotland	Females	2	1118 (1091, 1144)	1.52	847	32.0 (28.9, 35.2)

Scotland	Females	3	965 (942, 989)	1.31	838	15.2 (12.4, 18.0)
Scotland	Females	4	845 (823, 868)	1.15	609	38.9 (35.2, 42.5)
Scotland	Females	5 – Least	735 (715, 756)		533	37.9 (34.1, 41.8)
Scotland	Males	1 – Most	1774 (1733, 1816)	1.94	1359	30.6 (27.5, 33.7)
Scotland	Males	2	1470 (1435, 1506)	1.61	961	53.0 (49.4, 56.8)
Scotland	Males	3	1255 (1224, 1286)	1.37	922	36.1 (32.8, 39.5)
Scotland	Males	4	1062 (1034, 1091)	1.16	663	60.3 (56.0, 64.7)
Scotland	Males	5 – Least	915 (888, 942)		608	50.5 (46.1, 54.9)

Excluding COVID-19-related deaths

Table A3 - Age-standardised mortality rates before and after excluding COVID-19-related deaths in 2022, supporting Table 3.

Nation	***Sex***	***Age group***	***Exp. rate (95% CI)***	***Obs. rate (95% CI)***	***Obs. rate exc. C19 (95% CI)***
England	Persons	All	911	961 (959, 964)	**906 (904, 909)**
England	Females	All	796	831 (828, 835)	**787 (784, 791)**
England	Males	All	1042	1118 (1114, 1122)	**1047 (1043, 1051)**
England	Females	0-74y	251	269 (267, 271)	**258 (256, 260)**
England	Males	0-74y	386	420 (417, 422)	**402 (400, 405)**
England	Females	>74y	1999	2131 (2118, 2144)	**2020 (2008, 2032)**
England	Males	>74y	2867	3082 (3066, 3099)	**2901 (2885, 2917)**
England	Females	45-64y	325	344 (340, 348)	**330 (326, 334)**
England	Males	45-64y	500	537 (532, 542)	**518 (513, 523)**
England	Females	24-44y	55	56 (55, 58)	**55 (53, 56)**
England	Males	24-44y	98	103 (100, 105)	**100 (98, 102)**
Scotland	Persons	All	1084	1116 (1107, 1125)	**1046 (1038, 1055)**
Scotland	Females	All	953	985 (974, 996)	**926 (916, 937)**

Scotland	Males	All	1240	1273 (1259, 1288)	**1187 (1173, 1201)**
Scotland	Females	0-74y	337	347 (340, 354)	**331 (324, 337)**
Scotland	Males	0-74y	503	514 (505, 523)	**491 (483, 500)**
Scotland	Females	>74y	2510	2628 (2584, 2672)	**2465 (2423, 2508)**
Scotland	Males	>74y	3496	3648 (3592, 3705)	**3415 (3360, 3470)**
Scotland	Females	45-64y	439	446 (431, 460)	**429 (415, 444)**
Scotland	Males	45-64y	665	676 (658, 695)	**650 (631, 668)**
Scotland	Females	24-44y	97	82 (76, 88)	79 (73, 85)
Scotland	Males	24-44y	181	147 (139, 155)	144 (136, 152)

Notes: *Exp. rate* is the expected ASMR per 100,000 population assuming the continuation of linear trends from the period 2012-2019 to 2022 (exemplified by dashed lines in Figures 1, 2, and A2). *Obs. rate* is the observed ASMR per 100,000 population and *Obs. rate exc. C19* is the ASMR per 100,000 population where deaths were removed from the numerator if COVID-19 was mentioned on the death certificate. Bold figures in the *Obs. rate exc. C19* column indicate this rate is significantly lower than the observed all-cause ASMR (*Obs. rate*).

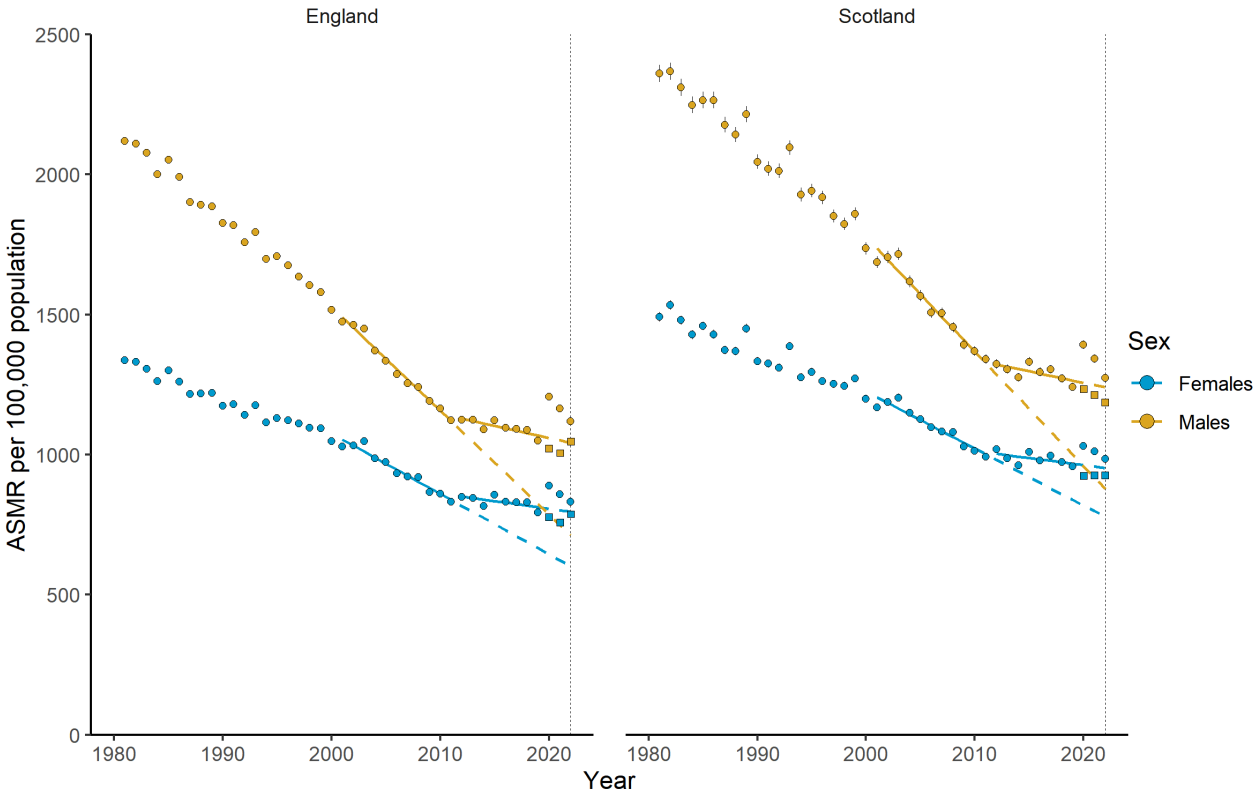

Figure A3 - Age-standardised mortality rates from 2010–2022 for all-cause mortality and all-cause excluding cases where COVID-19 was mentioned on the death certificate. Points are observed rates. Square points are observed rates excluding COVID-19 deaths. Solid lines are trends fitted through 2001–2010 (pre-austerity). Dashed lines are trends projected to 2022. Confidence intervals are included for observed rates but are so narrow as to be obscured by the points in most cases.

Estimating absolute excess death counts

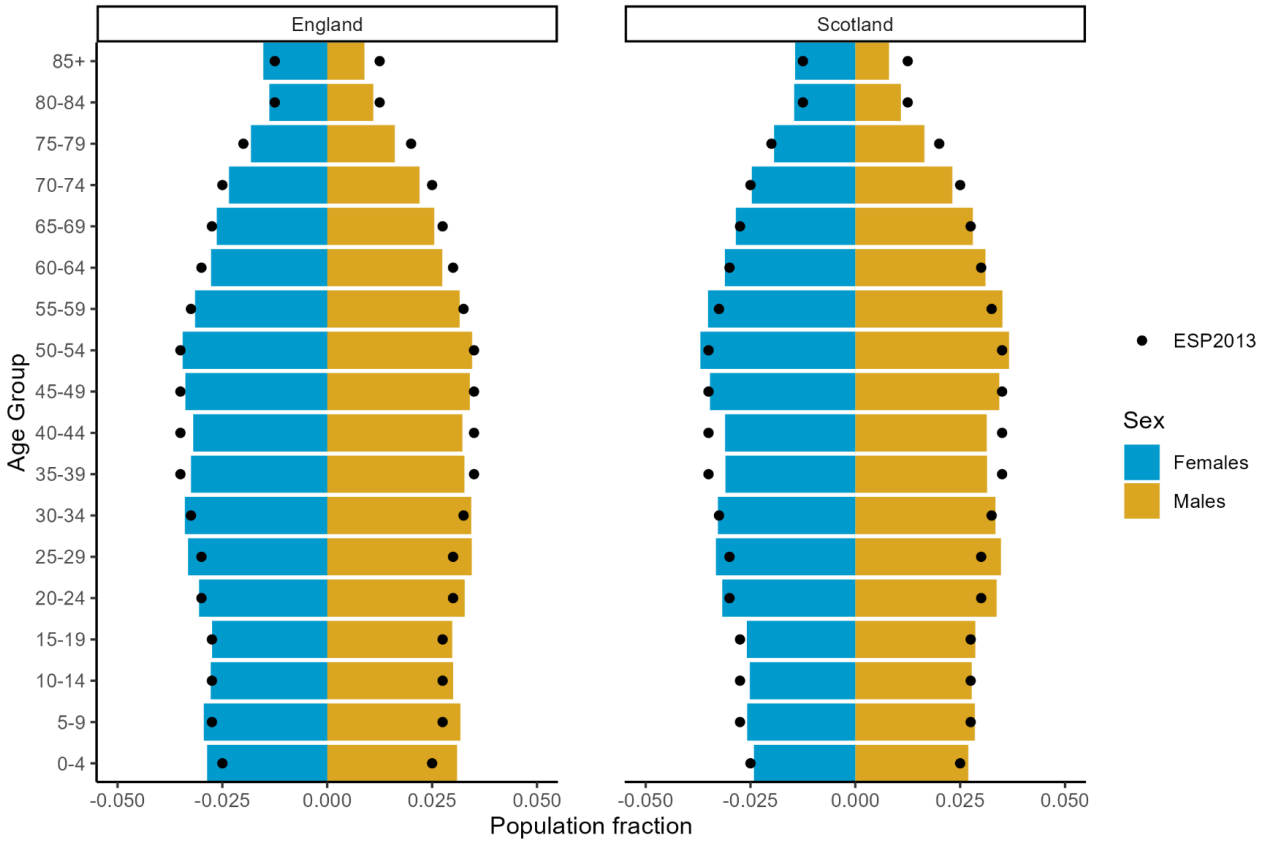

Figure A4 – Mean fractional population distribution by five-year age group for 2013-2022 (inclusive) in England and Scotland compared to the European Standard Population 2013. Shows face validity of multiplying national population by mortality rates standardised to the European Standard Population to estimate absolute deaths.

Numerical example of excess deaths counts – Females in England in 2020

- Observed deaths = 280,958 (presented in column *Deaths* in the tables below)
- Observed ESP2013-standardised rate * population = (888.357 /100,000 * 28,567,320) = 253,779.8 (presented in column *Obs. rate * pop*)
- ESP2013 correction factor = 280,958 / 253,779.8 = 1.107094 (presented in column *Ratio*)
- Expected deaths in 2020 based on 2001-2010 trend continuing = Expected rate * population * ESP2013 correction factor
  = 644.6 * 28,567,320 * 1.107094 = 203,858 (presented in column *Exp. deaths (scaled)*)
- Excess deaths = observed deaths – COVID19 deaths – expected deaths
  = 280,958 – 35,483 – 203,857.7 = 41,618 (allowing for rounding in the ESP2013 correction factor and expected deaths; presented in column *Excess deaths*)

Table A4a - Estimates of absolute excess female deaths in England in 2013-2022 had 2001-2010 trends had continued.

Year	***Deaths***	***Obs. rate * pop.***	***Ratio***	***C19 deaths***	***Deaths exc. C19***	***Exp. deaths (unscaled)***	***Exp. deaths (scaled)***	***Excess deaths***
2013	244261	231129	1.06	0	244261	217360	229710	14551
2014	239759	224933	1.07	0	239759	213113	227160	12599
2015	254892	237901	1.07	0	254892	208791	223703	31189
2016	250070	232651	1.07	0	250070	204351	219651	30419
2017	253418	233629	1.08	0	253418	199545	216447	36971
2018	255847	234846	1.09	0	255847	194662	212070	43777
2019	248476	225493	1.10	0	248476	189567	208888	39588

2020	280958	253780	1.11	35483	245475	184138	203858	41618
2021	270176	247738	1.09	31736	238440	179775	196057	42383
2022	266754	242120	1.10	14260	252494	175182	193005	59489
Totals	*2564611*	-	-	*81479*	-	*1966484*	*2130549*	*352584*

Deaths = observed deaths, *Obs. rate * pop.* = observed ESP2013-standardised * population, *Ratio* = correction factor used to adjust for differences in age distribution between population under observation and ESP2013 notional population, *C19 deaths* = observed deaths where COVID-19 was mentioned on the death certificate, *Deaths exc. C19* = observed deaths excluding deaths where COVID-19 was noted on the death certificate, *Exp. deaths (unscaled)* = expected ESP2013-standardised rate multiplied by population, *Exp. deaths (scaled)* = expected ESP2013-standardised rate multiplied by population multiplied by ESP2013 correction factor (Ratio), *Excess deaths* = observed deaths – C19 deaths – Exp. deaths (scale)

Table A4b – Estimates of absolute excess male deaths in England in 2013-2022 had 2001-2010 trends had continued.

Year	***Deaths***	***Obs. * pop.***	***Ratio***	***C19 deaths***	***Deaths exc. C19***	***Exp. deaths (unscaled)***	***Exp. deaths (scaled)***	***Excess deaths***
2013	229291	298127	0.77	0	229291	277399	213349	15942
2014	229118	291933	0.78	0	229118	269983	211891	17227
2015	240417	303484	0.79	0	240417	262554	207992	32425
2016	240721	299171	0.80	0	240721	255080	205244	35477
2017	245465	299987	0.82	0	245465	246584	201768	43697
2018	250012	300954	0.83	0	250012	238013	197725	52287
2019	247894	292306	0.85	0	247894	229081	194275	53619
2020	288742	337880	0.85	43793	244949	219992	187998	56950
2021	279173	322263	0.87	37926	241247	207376	179648	61599

2022	273579	312776	0.87	16808	256771	199265	174293	82477
-	*2524412*	-	-	*98527*	-	*2405327*	*1974183*	*451700*

Table A4c - Estimates of absolute excess female deaths in Scotland in 2013-2022 had 2001-2010 trends had continued.

Year	***Deaths***	***Obs. * pop.***	***Ratio***	***C19 deaths***	***Deaths exc. C19***	***Exp. deaths (unscaled)***	***Exp. deaths (scaled)***	***Excess deaths***
2013	28127	27061	1.04	0	28127	26341	27378	749
2014	27869	26437	1.05	0	27869	25876	27278	591
2015	29485	27861	1.06	0	29485	25422	26904	2581
2016	28938	27184	1.06	0	28938	24992	26605	2333
2017	29896	27755	1.08	0	29896	24491	26381	3515
2018	29452	27149	1.08	0	29452	23967	26000	3452
2019	29508	26834	1.10	0	29508	23491	25832	3676
2020	31947	28843	1.11	3344	28603	22926	25392	3211
2021	31719	28399	1.12	2686	29033	22408	25028	4005
2022	31085	27590	1.13	1863	29222	21788	24548	4674
-	*298026*	-	-	*7893*	-	*241702*	*261346*	*28787*

Table A4d - Estimates of absolute excess male deaths in Scotland in 2013-2022 had 2001-2010 trends had continued.

Year	***Deaths***	***Obs. * pop.***	***Ratio***	***C19 deaths***	***Deaths exc. C19***	***Exp. deaths (unscaled)***	***Exp. deaths (scaled)***	***Excess deaths***
2013	26033	33732	0.77	0	26033	32202	24852	1181
2014	26094	33120	0.79	0	26094	31264	24632	1462
2015	27639	34749	0.80	0	27639	30363	24151	3488
2016	27659	34034	0.81	0	27659	29486	23963	3696
2017	28342	34448	0.82	0	28342	28549	23488	4854
2018	28253	33674	0.84	0	28253	27556	23120	5133
2019	28259	33063	0.85	0	28259	26615	22748	5511
2020	32105	37088	0.87	3496	28609	25546	22114	6495
2021	31617	35879	0.88	3006	28611	24523	21610	7001
2022	30599	33695	0.91	1989	28610	23202	21070	7540
-	*286600*	-	-	*8491*	-	*279306*	*231748*	*46361*

Distribution of excess deaths by deprivation level

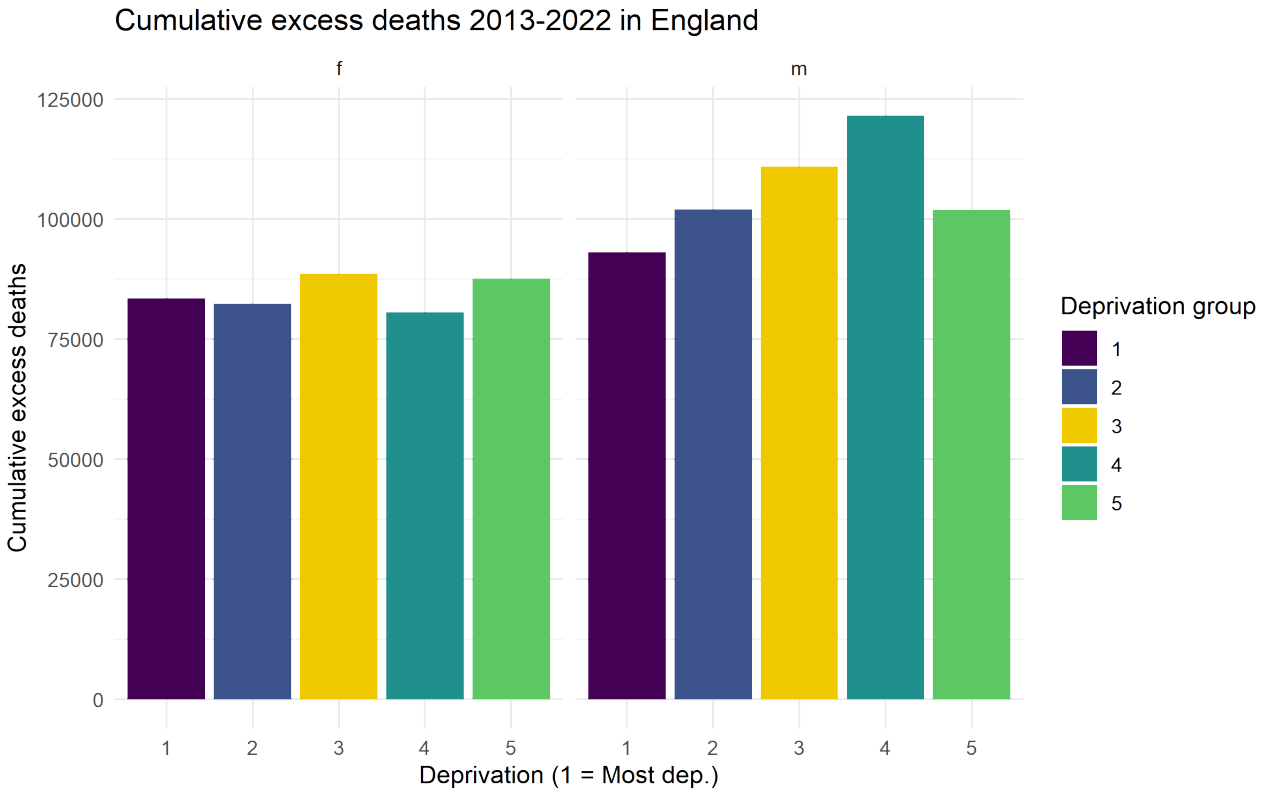

Figure A5a – Distribution of total estimated excess deaths by deprivation and sex in England. Cumulative totals over 2013—2022 inclusive.

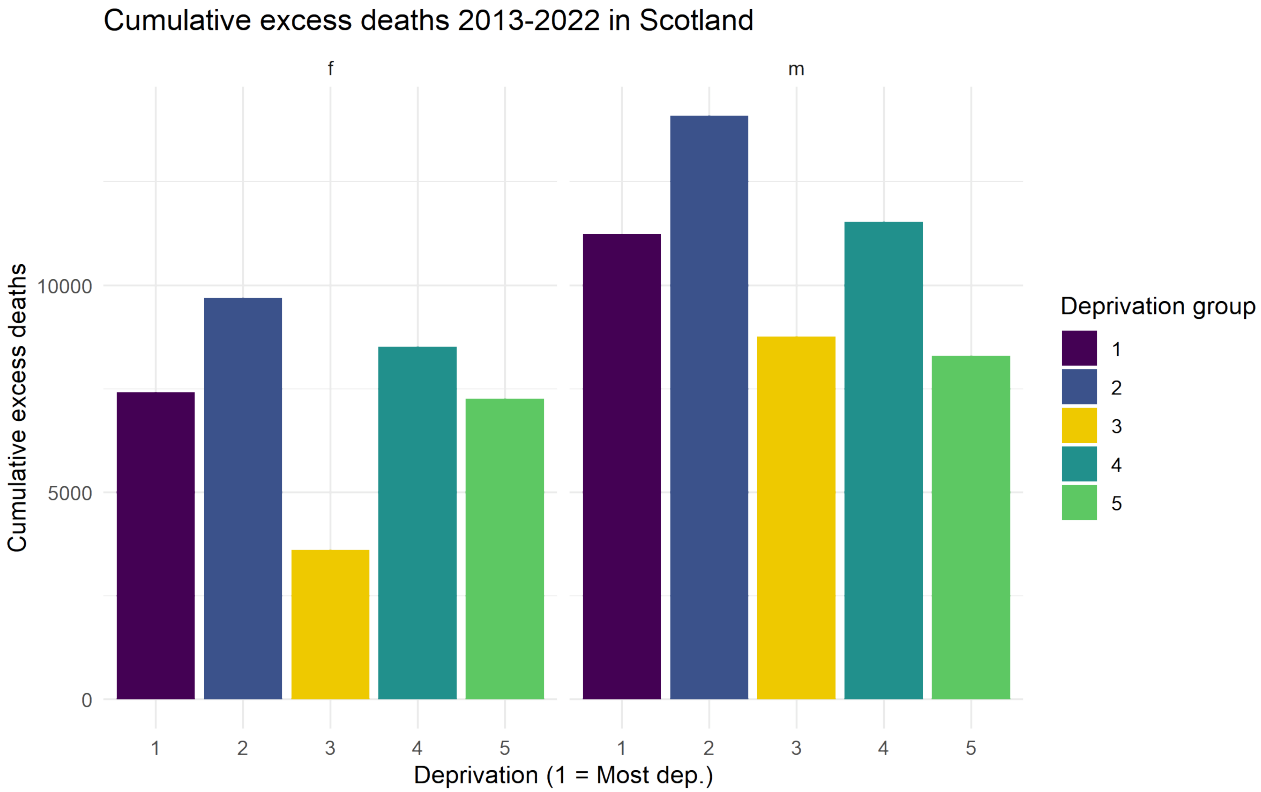

Figure A5b – Distribution of total estimated excess deaths by deprivation and sex in Scotland. Cumulative totals over 2013—2022 inclusive.

Sensitivity analysis – Start year

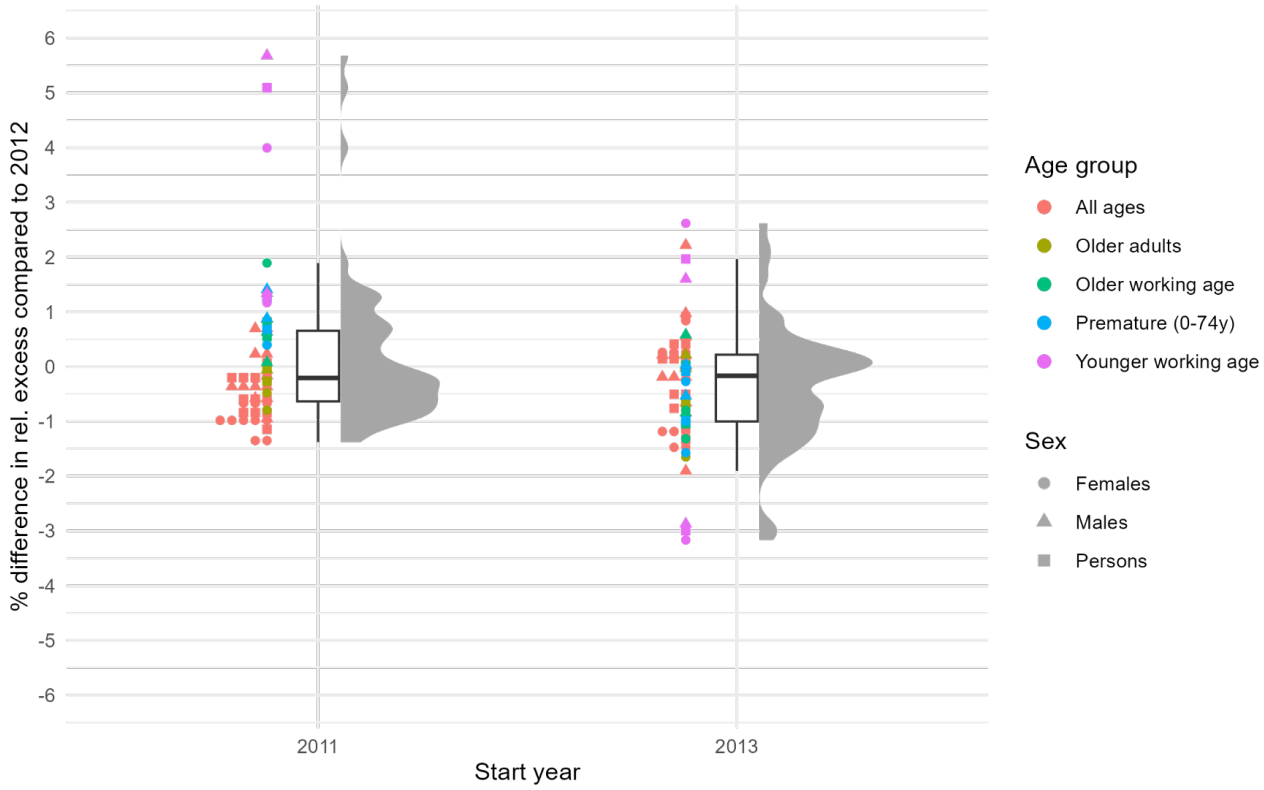

Figure A6 – Differences in relative excess mortality values across combinations of age group and sex when using 2011 or 2013 as the start year for linear regression models compared to using 2012.