The changing contribution of socioeconomic deprivation to variance in age at death

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Abstract

Mortality inequalities demonstrate a double burden: the most deprived socioeconomic groups experience the lowest average age of death and the highest variation in age at death. Two processes generate variation in age at death: individual stochasticity (within-group variance) and heterogeneity (between-group inequality). Limited research has evaluated how these two components have changed over time. We address this research gap by using population and mortality data for the entire population of Scotland stratified by area-level deprivation for 1981-2011. The most deprived areas have experienced stagnating or slight increasing variance in age at death and the least deprived areas have experienced decreasing variance. This is consistent with the literature demonstrating that there is not simply a social gradient for variation in age at death but that socioeconomic groups have experienced diverging trends. The relative contributions from between-group inequality increased faster than than the relative inequalities from within-group inequality, indicating that area-level deprivation may be increasingly important for total variation in age at death.

1 Background

The relationship between socioeconomic inequality and mortality is traditionally based on life expectancy comparisons. The most deprived populations experience the lowest average age of death, and the least deprived populations experience the highest. Studies have further demonstrated that the most deprived populations also demonstrate the highest level of variation in age at death when measuring socioeconomic inequality by income, education, or occupation (Broennum-Hansen 2017, van Raalte et al. 2011, Sasson 2016, van Raalte et al. 2014). Higher variation in age at death means greater uncertainty leading to the notion that the social patterning of these two distinct dimensions of mortality is a double burden of inequality.

Homogeneity in age at death is desirable for both individuals and societies in terms of forecasting pensions, comparing savings and investments, and estimating health care and

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social security needs (van Raalte et al. 2011). Relatively low and decreasing variation also means that the risk of premature death is being reduced for the population[1]. Greater reductions in the risk of premature death may be a feature of population mortality associated with more efficient social security systems and higher welfare redistribution (van Raalte et al. 2012, Bambra 2011, Popham et al. 2013). Despite the growing body of evidence documenting the double burden of mortality inequality variation in age at death is not yet routinely measured alongside life expectancy. This is important for evaluating the extent to which public health policies are simultaneously improving average mortality and reducing inequalities (Németh 2017, Smits and Monden 2009).

Two processes underly the total variance in age at death: individual stochasticity (within-group variance) and heterogeneity (between-group inequality). Within-group variance tends to arise from differences due to random demographic processes. The lifetable assumes that every individual, at the same age, is subject to the same schedule of mortality rates, such that any variance in age of death can be interpreted as individual stochasticity. Within-group variance can also be due to unaccounted for subgroup heterogeneity. For example males and females have different mortality schedules. Aggregating a lifetable over both sexes increases within-group variance due to induced between-group heterogeneity, even if males and females have identical within-group variance. It is also possible that a lifetable could be produced for populations that are heterogeneous but without knowing the reasons why the mortality of the populations are disparate and being unable to produce stratified lifetables. Therefore, within-group variance is theoretically always inflated due to heterogeneity on unmeasured characteristics of the population. For example, we cannot always stratify our lifetables on all characteristics that are hypothesized to be important for mortality such as marital, employment, or diabetes status: characteristics of a population that are likely to account for a non-trivial fraction of within-group variance.

Between-group lifespan inequality arises when individuals at the same age are subject to different mortality rates, which may be due to exposures to different social, economic, or environmental contexts (Hartemink et al. 2017). van Raalte et al. (2012) estimated the contribution of educational inequalities (the between-group component) to the total variance in age at death for 11 individual European countries. For males in Sweden the between-group component accounted for 1.7% of the total variance in age at death but for males in the Czech Republic it accounted for 10.9% of total variance in age at death. The between-group component was higher in the Czech Republic because the age distributions of death, stratified by education, are more disparate than in Sweden. van Raalte et al. (2012) used data aggregated over 1990 to 2000, such that time trends for the between-group and within-group components could not be assessed. In addition, it recognised that education may be a problematic socioeconomic measure for studying trends in between-group components due to changes in educational composition and the meanining of education attainment (van Raalte et al. 2012, Hendi 2015). A further limitation when stratifying data by education is that researchers may need to left-truncate data at some age, that may not be consistent across time or across comparison countries, because education is acquired over the life course. Area-level measures of relative deprivation have tended to be used as simple proxy measures for individual or household level socioeconomic indicators. They are able to overcome the limitations of education

[1]increasing variation comes from both premature deaths and deaths at very old ages, and theoretically the latter could drive increasing variance, but this is not the case for Scotland or any of its deprivation quantiles

and social class indicators which are poorly recorded, or even absent, for large groups of the population (Morgan and Baker 2006). However, it is now recognized that area-level deprivation can have an influence on risk of death independent of individual level socioeconomic circumstance (Carstairs and Morris 1989, Macintyre et al. 2002, Tunstall et al. 2011). Empirical results are somewhat mixed but it remains valuable to understand that mortality outcomes are not only driven by characteristics of individuals but also by the collective and contextual characteristics of areas (Macintyre et al. 2002).

It is important to recognize that choice of area-level measure will be driven by conceptual and pragmatic factors. However, most aim to capture the notion of relative deprivation in order to understand its impact on health (Kearns et al. 2000, Morgan and Baker 2006). Relative deprivation is the concept that not having enough material cultural or social resources to participate in the socially accepted way of life is as important for health as absolute poverty (Townsend 1987, Carstairs and Morris 1989, ?, ?). This hypothesis is supported by studies showing that more equal societies have better health outcomes, even if the material standards of living are worse in absolute terms (Wilkinson 1997, Marmot and Wilkinson 2001, Wilkinson and Pickett 2007). In pragmatic terms, area-level measures of relative deprivation tend to weight equal sized population groups into quantiles. This gives a consistent interpretation over time; although absolute levels of poverty in a country will have changed there is a notional most deprived fraction of the population being compared with a notional least deprived fraction of the same size. Area-level measures constructed from administrative data have a practical advantage over area-level measures constructed from survey data because they can be updated more frequently. Assigning individuals to an area-level measure deprivation based on their post-code is also advantageous. Left age truncation is not required because home address is routinely collected across all stages of the life course and passively by a range services, while measures of income, occupation, or education again tend to be derived from survey data and are age dependent characteristics.

We contribute to the mortality inequalities literature by measuring the changing contributions from within and between-group components to variance in age at death. Data are centered on Census years, ensuring the most robust population estimates available. Populations in each postal code are aggregated base on population-weighted quintiles of the Carstairs score distribution. Death counts are matched to postal codes based on place of usual residence and then aggregated on Carstairs quintiles. The data include the whole population of Scotland (ca 5 million persons) and cover the time period between 1981 and 2011.

2 Data and methods

2.1 Area-level deprivation

Census population estimates and mortality data[2] by single year of age and sex for each part-postcode (zip-code) sector in Scotland were obtained via a commissioned request to National Records of Scotland. There are around 1,012 part-postcode sectors in Scotland

[2]Mortality data used came from 1980-1982, 1990-1991, 2000-2002 and 2010-2012 to increase the number of events centered around each census. 1990-1991 is just a two-year numerator sample due to geographical boundary changes occurring in 1990. Corresponding Census population estimates are adjusted accordingly.

at each Census year each with an average population size of 5,000 individuals. Table ?? shows the number of postcode sectors and the population sizes for each Census year.

Table 1: Number of postcode sectors and population size

Year	Number	Mean pop.	sd
1981	1010	4982.47	1178.53
1991	1001	4993.02	1653.67
2001	1010	5011.89	1542.42
2011	1012	5232.61	1568.05

Population-weighted quintiles (each 20% of the population) were created by aggregating the 1,012 part-postcode sectors ordered on Carstairs score of deprivation. The Carstairs score is a z-score for each part-postcode sector that is derived from four individual-level census variables: overcrowding, male unemployment, low social class, and car ownership. The Carstairs Score (z-score) reflects the material resources that provide the means to access the goods, services, amenities, and physical environment seen as expected in society (Carstairs and Morris 1989). This means the Carstairs score is a method of capturing relative deprivation at the contextual level (cite). In 2011 for example, scores ranged from -7.53 to 13.24 and were centered on zero, with higher scores indicating relatively higher deprivation than the national level.

2.2 Lifetables and variance decomposition

Deaths[3] and Census population denominators were used to construct complete lifetables for each deprivation quintile, centered on each Census year, for males and females separately. The Human Mortality Database Methods Protocol was used to extrapolate age specific mortality rates from ages 85 to 110 (Wilmoth et al. 2017).[4]

From the complete lifetables we compute remaining life expectancy and the conditional variance and standard deviation of the remaining lifespan distribution. A number of highly correlated indices measure variation in age at death (van Raalte and Caswell 2013). We use lifetable variance for two reasons. firtst, there is a well-known analytic method (appendix 1 for full description) to decompose variance into within and between-group components (Caswell 2001, 2009, 2014). Second, we can transform variance into standard deviations, a common measure of the variability applied to the distribution of age at death (van Raalte and Caswell 2013), which allows for results to be interpreted intuitively in year units.

3 Results

Table 2 and Table 3 show the life expectancy and variation in age at death for males and females, respectively, in each deprivation quintile at each Census year. The same tables

[3]NRS policy for assigning geography to each death - deaths of Scottish residents that occur in Scotland are assigned to their place of normal residence, deaths of non-Scottish residents that occur in Scotland are assigned a geography based on their place of death, deaths of Scottish residents that occur outside of Scotland are not included(General Register Office for Scotland 2016)

[4]Specifically, we apply equations (53) and (54) from the HMD protocol v6, modified to use information from ages 75+ rather than 80+.

reporting life expectancy and variation in age at death conditional upon survival to age 35 are included in the appendices.

Table 2: Life expectancy and standard deviation for males, age 0.

	1981		1991		2001		2011	
quintile	ex	sd	ex	sd	ex	sd	ex	sd
1 (least dep.)	71.6	15.4	74.5	14.4	77.6	13.7	80.2	13.6
2	69.9	16.1	72.9	14.9	75.3	15.1	78.5	14.6
3	69.1	16.2	72.1	15.4	73.9	15.4	77.0	15.1
4	68.2	16.2	70.4	16.1	72.2	16.1	75.3	15.6
5 (most dep.)	66.4	16.4	68.3	16.5	69.0	17.2	72.4	16.5
Total pop.	69.0	16.1	71.6	15.6	73.5	15.8	76.7	15.4

Table 3: Life expectancy and standard deviation for females, age 0.

	1981		1991		2001		2011	
quintile	ex	sd	ex	sd	ex	sd	ex	sd
1 (least dep.)	77.1	14.9	79.1	14.1	81.3	13.0	83.4	12.8
2	75.8	15.3	78.6	13.9	80.4	13.6	82.1	13.5
3	75.1	15.6	77.7	14.7	78.9	14.5	80.9	13.9
4	74.4	15.7	76.6	14.8	78.1	14.6	80.0	14.0
5 (most dep.)	72.8	16.3	74.9	15.9	76.3	15.7	77.9	15.1
Total pop.	75.0	15.6	77.3	14.8	78.9	14.4	80.9	14.0

The most deprived quintile experiences the lowest life expectancy and the highest variation in age at death (highest standard deviation) at each year. For males there was an increase in variation in age at death between 1991 and 2001. Although there was some improvement between 2001 and 2011, variation in age at death was very similar to the level experienced 30 years earlier. Females from the most deprived quintile have experienced decreasing variation in age at death (decreasing standard deviation) but the decrease was greater for the least deprived.

The change in variance over time, across all ages is shown in Figure 1. Male total variation has increased somewhat, and female total variation has changed very little over the time period studied. Variance was transformed into the standard deviation to give the y axis a more meaningful interpretation in years. This is shown in Figure 2.

Figure 3 compares the proportion of the total difference in variation in age at death that is due to between-group inequality with the proportion that is due to within-group variance. Figure 4 shows the same for females. For males the proportion of variation explained by between-group inequality was lowest in 1981 and highest in 2001. By 2011 the proportion of between-group inequality had decreased slightly but was still greater than in 1981. The proportion of total variation in age at death explained by within-group variance was highest in 1981 and lowest in 2001. The proportion of variation explained by the within-group component increased slightly for males in 2011, which is mirrored in the decrease in the between-group component. This cross over between 2001 and 2011 was not found for females. For females the proportion explained by between-group inequality

Figure 1: Variance for total population by age, Census years 1981 until 2011.

(a) Males

(b) Females

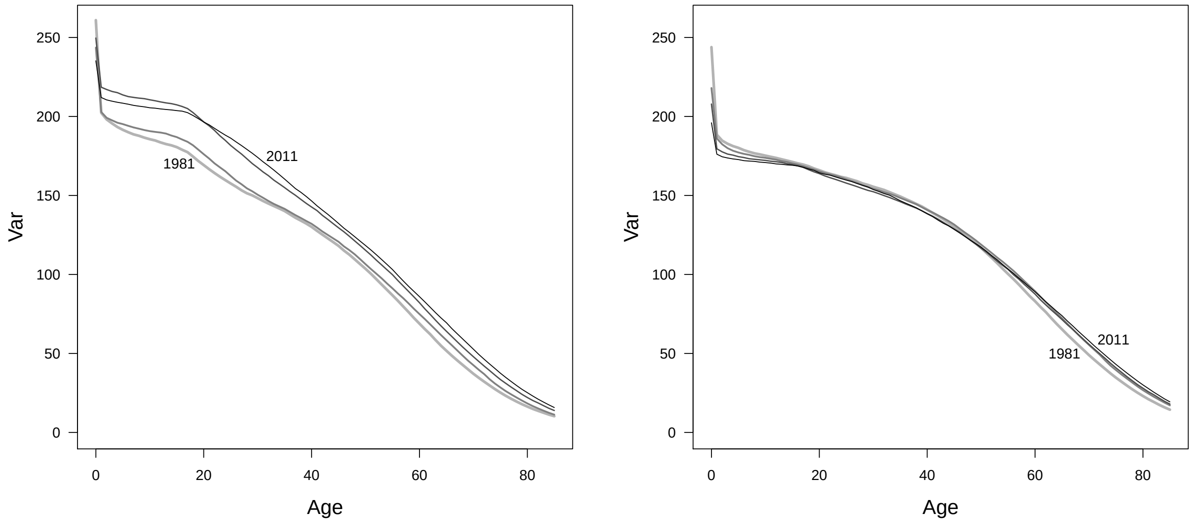
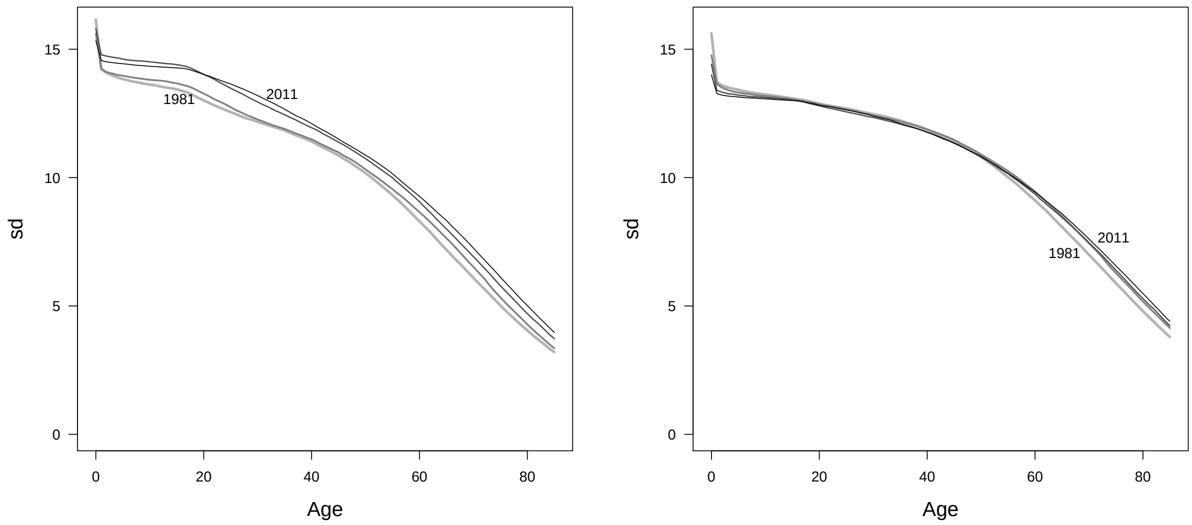


Figure 2: Standard deviation of remaining lifespan for total population by age, Census years 1981 until 2011.

(a) Males

(b) Females



consistently increased between 1981 and was mirrored by a consistent decrease in the within-group component. Changes to the two components over time do not appear to have occurred across older ages for males or females.

Figure 3: Proportion of variance due to differences within and between deprivation quintiles by age, Census years 1981 until 2011, males.

(a) Between (b) Within

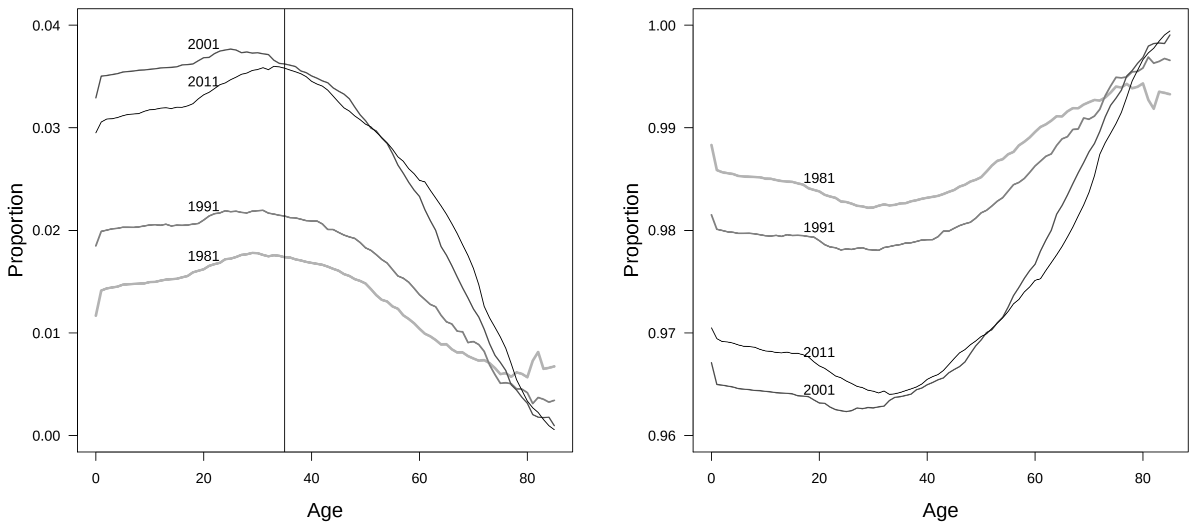
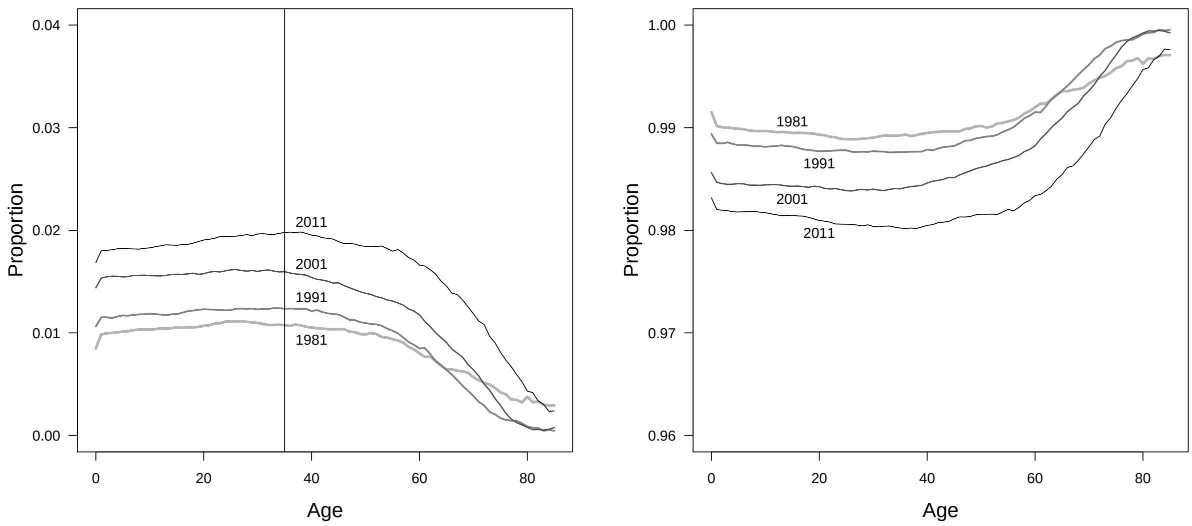


Figure 4: Proportion of variance due to differences between deprivation quintiles by age, Census years 1981 until 2011, females.

(a) Between (b) Within



3.1 Sensitivity analysis

We tested the sensitivity of our results to the size of deprivation group by replicating the analysis using deciles of deprivation, each representing 10% of the population. The conclusions were the same for males and for females. However, the increase in the between-group component over time was greater in magnitude when using deciles. We chose to report results for quintiles of deprivation as they are the preferred analytical grouping for routine reporting of health measures in Scotland (NHS PublicHealth&Intelligence 2017).

4 Discussion and conclusion

4.1 Summary of main findings

Deprivation differences in age at death were evident at all Census years when measuring socioeconomic inequality by area-level. Those living in the most deprived areas can expect to live the shortest lives and experience the greatest variation in age at death: a double burden of mortality inequality. The difference between deprivation groups was larger for males than for females. Males from the most deprived quintile experienced increasing variation in age at death between 1991 and 2001 so that the level of variation in 2011 was the same as that experienced 30 years earlier. The proportion of variation in age at death explained by the between-group component of inequality was higher in 2011 than in 1981 for males and females.

4.2 Strengths and limitations

Our results are unable to determine the exact reason why the between-group proportion has increased. The timing of the increasing between-group component may be associated with the well documented 'polarization' of deprivation, health and mortality that increased in the UK following the 1980s (Shaw et al. 2000, Mitchell et al. 2000) and they may provide support for existing theories which emphasizes the negative impact relative deprivation can have on population level health and mortality (Wilkinson and Pickett 2007, Marmot and Wilkinson 2001). Therefore our results are important for governments to consider when deciding how best to tackle mortality inequalities: whether to allocate resources to social policies that intervene at the contextual and area-level versus social policies that intervene at the individual level (Allik et al. 2016, Diez Roux 2001, Robert 1999, The Scottish Government 2016). In addition to these theoretical contributions, our study demonstrates a number of empirical strengths.

The data used for this study includes the most robust population estimates and mortality data for the entire population of Scotland. Using a validated area-level measure of socioeconomic inequality meant that complete lifetables could be constructed and no ages were truncated from the analysis. However, it is important to acknowledge the reasons why studies interested in the social distribution mechanisms of adult mortality may consider restricting analysis to older ages. Smits and Monden (2009) suggest only looking at ages 15+ because these are the ages where 80% of deaths in developed countries now occur. Looking only at adult mortality may better reflect the causes of death driving mortality change in more recent time periods: infectious disease and effective medical intervention historically reduced infant and childhood deaths rapidly but reductions in adult mortality are influenced by more complex mechanisms that change slowly (Smits and Monden 2009, Vallin and Mesl 2004). Our results indicate that the age at which the difference in variation in age at death is greatest is around 35 years old. This provides some reassurance for studies that are forced to truncate out younger age groups: the peak of variation in age at death (at least in developed countries) is likely to be captured.

The Carstairs score as an empirical measure has been critiqued. For example, the meaning of car ownership is fundamentally different for individuals in rural contexts compared to urban contexts. It is also acknowledged that overcrowding may occur out of choice and for cultural reasons rather than simply being a marker of deprivation (Fischbacher 2014). Therefore it has been suggested that the Carstairs score may be an out of date measure of socioeconomic deprivation (Schofield et al. 2016, Tunstall et al. 2011) because the relevance of the variables used for capturing the meaning of deprivation varies across contexts and over time (Norman 2010). In response, it was demonstrated that the scores for each postcode sector at each Census year are highly correlated despite changes to the formal definitions of the variables. This is interpreted as evidence that the underlying information the variables aim to capture is similar or that deprivation has remained stable over time (Leyland et al. 2007b). Alternative measures of area-level deprivation are available, for example the Scottish index of multiple deprivation (SIMD). The SIMD includes 38 indicators from 7 domains (employment,income,health,education,access to services, crime and housing). The SIMD was not suitable for the trend focus of this research as it is only recommended for analysis using data beginning in 1996 (NHS PublicHealth&Intelligence 2017). A further limitation is that it includes indicators of health and mortality meaning that the full SIMD can not be used for health inequalities research. Instead health inequalities research tends to use the income domain only (Leyland et al. 2007a). The income domain is highly correlated with the full SIMD and is one of the most heavily weighted domains (NHS PublicHealth&Intelligence 2017, The Scottish Government 2016).

5 Conclusion

Monitoring variance in age at death is complimentary to the routine monitoring of life expectancy: monitoring both allows us to establish if average population mortality and mortality inequalities have been improved simultaneously. This study has demonstrated increasing relative contributions from area-level deprivation differences to total variance in age at death using population level data for Scotland. This type of trend analysis is important for understanding the changing nature of the social determinants of mortality inequalities in developed countries. More countries should begin to measure the between-group and within-group contributions to variance in age at death and monitor trends in order to understand the extent to which mortality is dependent upon, and amenable to, relative area-level deprivation.

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6 Appendices

6.1 Appendix 1

see supplementary pdf

6.2 Appendix 2

Table 4: Life expectancy and standard deviation for males, age 35.

	1981		1991		2001		2011	
quintile	ex	sd	ex	sd	ex	sd	ex	sd
1 (least dep.)	38.4	11.4	40.9	11.2	43.7	11.3	46.3	11.1
2	37.1	11.6	39.5	11.6	41.9	11.8	44.7	12.0
3	36.4	11.8	38.8	11.8	40.5	12.2	43.4	12.4
4	35.5	11.8	37.6	11.9	39.1	12.5	41.7	13.0
5 (most dep.)	33.8	12.1	35.8	12.3	36.6	13.2	39.2	13.5
Total pop.	36.2	11.8	38.5	11.8	40.3	12.4	43.1	12.6

6.3 Appendix 3

Table 5: Life expectancy and standard deviation for females, age 35.

	1981		1991		2001		2011	
quintile	ex	sd	ex	sd	ex	sd	ex	sd
1 (least dep.)	43.4	11.7	45.1	11.5	47.0	11.1	49.0	49.0
2	42.2	12.0	44.4	11.7	46.1	11.5	47.9	47.9
3	41.6	12.2	43.8	12.1	45.0	12.0	46.7	46.7
4	41.0	12.1	42.7	12.3	44.1	12.2	45.7	45.7
5 (most dep.)	39.6	12.7	41.4	12.8	42.6	13.1	43.9	43.9
Total pop.	41.5	12.2	43.4	12.2	44.9	12.1	46.7	46.7