# Introduction

Population health is a marker of the stability and, at times, fragility of a nation. Health outcome measures such as life expectancy, age-standardised mortality rates (ASMR), and infant mortality rates (IMR) are often used as indicators to compare trends both within a nation and between nations. Increasingly, the utility of measuring a less reported outcome, lifespan variation, for comparing populations is being recognised. This indicates the variation in age of death, rather than just the average age of death, providing rich information that is lost in a single figure like life expectancy at birth.

Lifespan variation shows the range of ages at death for populations. For example, an increasing lifespan variation reflects heterogeneity of a population, with wide, more unpredictable ages of death, whereas decreasing lifespan variation, that is ages of death clustered around a similar age, reflects homogeneity, and thus greater predictability. Historically, the association between life expectancy and lifespan variation is a negative correlation—as life expectancy increases, lifespan variation decreases. Indeed, this has been shown to be true across both primate species and humans ‘separated by millions of years of evolution and over hundreds of years of human social progress’.1 Furthermore, research in 2011 using the Human Mortality Database (HMD) found that those countries with the highest life expectancy also had the lowest lifespan variation, associated with decreasing premature deaths.2 Conversely, a reduction in deaths at older ages increased lifespan variation.2 As a result, lifespan variation should not be expected to increase markedly if a key assumption of demographic forecasting models is correct: the assumption that age-specific mortality trends should be similar at different ages, such that trends at most ages should be highly correlated—that a ‘rising tide raises all ships’.

Researchers have argued that lifespan variation is an important supplemental measure when examining mortality, without which information is lost.3 For example, life expectancy in the USA increased by approximately 10% for men and 5% for women between 1980 and 2014. However, when lifespan variation is examined over the same period, it fluctuates markedly and ultimately increases as life expectancy increases—the inverse to its historical association. As such, the authors argue that had lifespan variation been monitored more closely, the rise in it noted and investigated, the mid-life mortality crisis in the USA could have perhaps been uncovered earlier.3 Life expectancy in the USA has subsequently declined every year since 2015,4 with a rise in mid-life mortality due to so-called ‘deaths of despair’.5 6

Disparities in life expectancy have long been recognised as a marker of inequality between populations, but there is a ‘double burden of mortality inequality’, with those in the most deprived areas experiencing both lower life expectancy and increased lifespan variation.7 Increased lifespan variation impact at both an individual and a population level. Firstly, as an individual, a higher lifespan variation means greater uncertainty in the timing of death, impacting personal plans such as pensions, retirement, and resulting in precarity.3 7 As a result, a social inequality exists: that those who are more advantaged can plan their lifecourse, where those in more deprived areas live with uncertainty due to higher lifespan variation.7 Secondly, at a population level, decreased lifespan variation, that is deaths occurring around a common age with homogeneity, allows for public service planning that increased lifespan variation does not. These aspects are not captured in life expectancy measures.

Life expectancy is expected to steadily increase in high-income countries (HICs), though global disparities are evident.8 9 This is largely in-keeping with demographic assumption forecasting methods. Specifically, Lee-Carter proposed linear projections of logged age-specific death rates result in straight line projections in HICs.10 In addition, mortality convergence among HICs is expected, and has occurred historically, due to changes such as globalisation, for example increasingly similar diet internationally, resulting in Japan increased red meat consumption.11

However, recent data have shown this may no longer be the case, with improvements in life expectancy varying widely between HICs when data was analysed by the Office for National Statistics (ONS).12 Figures 1 and 2 show the differences between the most recent six years and preceding six years in life expectancy improvements. For both males and females, Japan leads the way in improvements, with the UK and USA doing the least well.

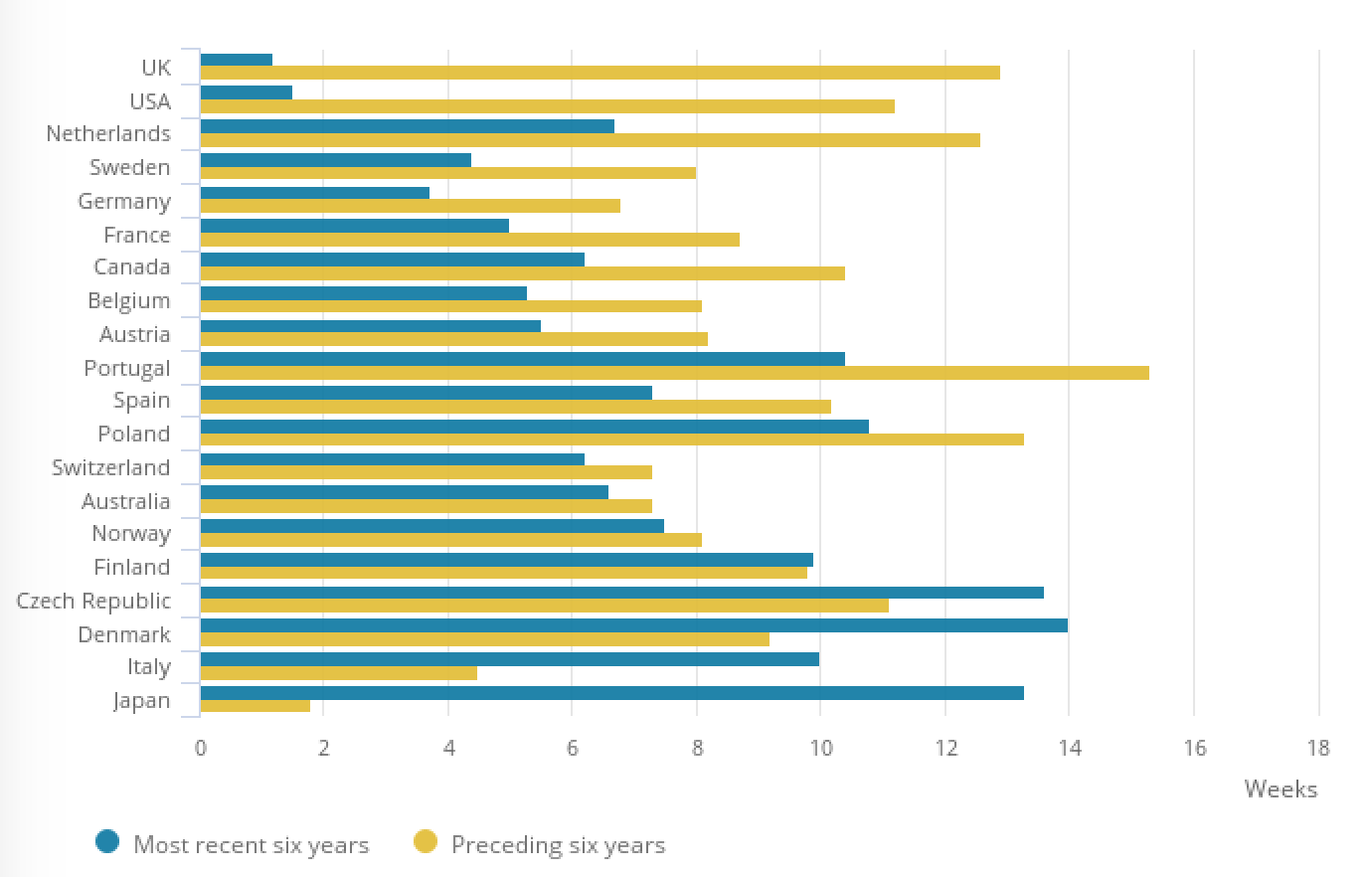


Figure : Average annual increase in period life expectancy at birth, selected countries, females. Source: Office for National statistics analysis of Human Mortality Database data

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Figure : Average annual increase in period life expectancy at birth, selected countries, males. Source: Office for National Statistics analysis of Human Mortality Database data

The UK has seen unprecedented changes in health outcomes in the past decade. Since peaking in 2014, IMR has increased for 3 years in a row,13 life expectancy has stalled,14 and for some groups declined.15 16 Inequalities have widened, with studies finding one in three premature deaths is attributable to socioeconomic inequality,17 and one third of the increase in infant mortality attributable to child poverty.18 No longer unique to the USA, there has been a rise in ‘deaths of despair’ in the UK.19 The term was first used by researchers in the USA regarding deaths due to due to drug and alcohol overdoses, suicides, and alcohol-related liver disease.6 In England, deaths from these causes increased between 1993 and 2017, contributing to a rise in all-cause mortality in those aged 45-54 years.19 If and how these deteriorating health outcomes have impacted the lifespan variation is not yet known.

The USA has been similarly impacted by poor health outcomes. Life expectancy at birth stalled between 2010 and 2014, and has declined since 2015,4 with rising rates of mortality from ‘deaths of despair’20 in particular among the poor in states that had experienced the greatest economic and social decline.21 These ‘deaths of despair’ were concentrated among non-Hispanic whites, linked to the opioid epidemic, but recent evidence has suggested this focus is misleading—it occurs alongside higher mortality rates for all Americans and is accompanied by a decline in measures of general well-being.22

While the USA and UK have experienced reversals in decades of improvement, Japan has not. There are many possible explanations for such changes, but arguments of life expectancy reaching a ‘natural plateau’ seem implausible when other countries continue to thrive. Christensen et al reviewed the challenges of ageing populations, examining probability of dying within the next 12 months at ages 80 and 90 years, for males and females.23 They found life expectancy is lengthening linearly in most developed countries, but that these improvements are not due to uniform decreases at all ages. For example, in the first part of the 20th century, improvements were due to reductions in infant and child mortality, with better diagnosis, management and prevention of infectious diseases. Following that, reduction in old age mortality has driven some improvements.

The link between politics and health is a difficult one to unravel however it is notable that two countries that had political ‘shocks’ in 2016, the UK and USA, are faring the least well in international comparisons. In the USA analysts have attributed, in part, Trump’s success to targeting those who felt ‘left behind’, and racial and ethnic disputes.24. Indeed, in US counties with economic distress and poor health, Trump performed better.25 Indeed, researchers found mortality had a strong correlation with voting patterns: counties experiencing wider health inequalities in life expectancy and worsening premature mortality were more likely to vote Republican;26 counties experiencing less of an increase in age-adjusted death rates correlated with increasing likelihood of voting Republican;27 and counties where life expectancy had stagnated or declined saw a 10% point increase in Republican vote share between 2008 and 2016.28 The same has been seen in analyses of Brexit voting and health outcomes (GET REF/PAPER FROM MARTIN). Furthermore, in the UK, a growing body of evidence demonstrates a link between deteriorating health outcomes and cuts to health and social care in the guise of austerity since 2010.

When comparing the impact of changes to the political landscape on health, the evidence is contradictory. Research has shown democracy is positively related to health,29 and countries with proportional electoral rules tend to have better population health,30 but why the link is there is far from clear. Some researchers have demonstrated that democratisation can have immediate impacts on population health,31 citing changes in Germany at reunification as an example, while others found cumulative years of good government have positively impacted infant mortality and life expectancy at birth.32 A study using extent of freedom as a proxy for democracy, found an independent positive association with health for life expectancy and infant mortality, apparently being more than inequality, government expenditure, and gross national product per capita.33

In this paper we investigate whether correlations between trends at different ages remain highly correlated in a number of HICs: UK, USA, Japan as these countries are faring the least and most well with life expectancy improvements, and France and Canada as geographical neighbours to the UK and USA respectively.

# Methods

Data from the Human Mortality Database will be used to complete the analysis.

Country selection:

Based on the ONS analysis of HMD data, Japan, UK and USA for females and males will be explored and compared.

g. Replicating Christensen et al and White’s methods, comparison was made of probability of dying at 80, 90, 0-1yrs and 40yrs in the next 12 months. The correlation was strongest between the extremes of age, with divergence in working age…

* 1980s changes unravelled continued improvements in childhood and older ages mortality from trends in working life.
* We extract sex- and age-specific mortality rates from the Human Mortality Database (HMD) for the following countries: the USA, Japan, the UK, France, and Canada. The USA and Japan were selected as they have been consistently ranked as the high-income countries with the lowest and highest life expectancies, respectively, and the UK was selected as there has been adverse trends and evidence of a stalling in life expectancy in recent years. France and Canada were selected as geographic neighbours of the UK and USA, respectively.
* For each population, we calculated the average annual percentage change in age-specific mortality rates between 1975 and the latest available year. We then calculated the correlations between these age-specific trends for all ages in single years, and presented and compared these large matrices of correlations as heatmaps, allowing intuitive visual comparison within and between populations. We also performed the same analyses splitting the time period in two: 1975-1990, and 1990 onwards

# Results

6 figures: UK/USA/Japan tartans for males and females

# Discussion

*Increasing life- span variation signals uneven age patterns of mortality decline, with faster declines at older rather than at younger ages, or even rising early and midlife mortality. There- fore, monitoring life-span variation may fa- cilitate early detection of adverse mortality developments and warrant social interven- tions at younger ages. Van raalte)(*

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