Changing life expectancy in European countries 1990–2021: a subanalysis of causes and risk factors from the Global Burden of Disease Study 2021

*GBD 2021 Europe Life Expectancy Collaborators**

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Summary

Background Decades of steady improvements in life expectancy in Europe slowed down from around 2011, well before the COVID-19 pandemic, for reasons which remain disputed. We aimed to assess how changes in risk factors and cause-specific death rates in different European countries related to changes in life expectancy in those countries before and during the COVID-19 pandemic.

Methods We used data and methods from the Global Burden of Diseases, Injuries, and Risk Factors Study 2021 to compare changes in life expectancy at birth, causes of death, and population exposure to risk factors in 16 European Economic Area countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, and Sweden) and the four UK nations (England, Northern Ireland, Scotland, and Wales) for three time periods: 1990–2011, 2011–19, and 2019–21. Changes in life expectancy and causes of death were estimated with an established life expectancy cause-specific decomposition method, and compared with summary exposure values of risk factors for the major causes of death influencing life expectancy.

Findings All countries showed mean annual improvements in life expectancy in both 1990–2011 (overall mean 0·23 years [95% uncertainty interval [UI] 0·23 to 0·24]) and 2011–19 (overall mean 0·15 years [0·13 to 0·16]). The rate of improvement was lower in 2011–19 than in 1990–2011 in all countries except for Norway, where the mean annual increase in life expectancy rose from 0·21 years (95% UI 0·20 to 0·22) in 1990–2011 to 0·23 years (0·21 to 0·26) in 2011–19 (difference of 0·03 years). In other countries, the difference in mean annual improvement between these periods ranged from –0·01 years in Iceland (0·19 years [95% UI 0·16 to 0·21] *vs* 0·18 years [0·09 to 0·26]), to –0·18 years in England (0·25 years [0·24 to 0·25] *vs* 0·07 years [0·06 to 0·08]). In 2019–21, there was an overall decrease in mean annual life expectancy across all countries (overall mean –0·18 years [95% UI –0·22 to –0·13]), with all countries having an absolute fall in life expectancy except for Ireland, Iceland, Sweden, Norway, and Denmark, which showed marginal improvement in life expectancy, and Belgium, which showed no change in life expectancy. Across countries, the causes of death responsible for the largest improvements in life expectancy from 1990 to 2011 were cardiovascular diseases and neoplasms. Deaths from cardiovascular diseases were the primary driver of reductions in life expectancy improvements during 2011–19, and deaths from respiratory infections and other COVID-19 pandemic-related outcomes were responsible for the decreases in life expectancy during 2019–21. Deaths from cardiovascular diseases and neoplasms in 2019 were attributable to high systolic blood pressure, dietary risks, tobacco smoke, high LDL cholesterol, high BMI, occupational risks, high alcohol use, and other risks including low physical activity. Exposure to these major risk factors differed by country, with trends of increasing exposure to high BMI and decreasing exposure to tobacco smoke observed in all countries during 1990–2021.

Interpretation The countries that best maintained improvements in life expectancy after 2011 (Norway, Iceland, Belgium, Denmark, and Sweden) did so through better maintenance of reductions in mortality from cardiovascular diseases and neoplasms, underpinned by decreased exposures to major risks, possibly mitigated by government policies. The continued improvements in life expectancy in five countries during 2019–21 indicate that these countries were better prepared to withstand the COVID-19 pandemic. By contrast, countries with the greatest slowdown in life expectancy improvements after 2011 went on to have some of the largest decreases in life expectancy in 2019–21. These findings suggest that government policies that improve population health also build resilience to future shocks. Such policies include reducing population exposure to major upstream risks for cardiovascular diseases and neoplasms, such as harmful diets and low physical activity, tackling the commercial determinants of poor health, and ensuring access to affordable health services.

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Research in context

Evidence before this study

In 2018, the Organisation for Economic Co-operation and Development reported on the slowdown in improvements in life expectancy in many European countries since 2011, and called for further analysis to better understand the relative contributions of different factors. Since then, the high mortality during the COVID-19 pandemic led to decreases in life expectancy in many, but not all, European countries. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 estimated life expectancy, causes of death, and associated risk factors from 1990 to 2021. GBD methods facilitate international comparisons and analysis of the relative contributions of different risk exposure levels to changes in life expectancy before and during the COVID-19 pandemic. In Europe, the 16 founding European Economic Area (EEA) countries and the four nations of the UK are reasonably similar in terms of their economies and geographical locations, yet have different government policies that influence population exposure to major risk factors that likely have a knock-on effect on life expectancy.

Added value of this study

This study compared changes in life expectancy, disaggregated by causes of death, and changes in population exposure to attributable risk factors for the major causes of death, in the 16 founding EEA countries and four UK nations over three time periods: 1990 to 2011 (pre-slowdown in life expectancy), 2011 to 2019 (slowdown in life expectancy to pre-COVID-19 pandemic), and 2019 to 2021 (COVID-19 pandemic). We found that from 1990 to 2011, reductions in deaths from cardiovascular diseases and cancers led to substantial improvements in life expectancy in all the studied countries. From 2011 to 2019, life expectancy improvement slowed with marked international differences. The countries that best maintained improvements in life expectancy after 2011 (Norway, Iceland, Sweden, Denmark, and Belgium) had no decrease in life expectancy from 2019 to 2021, despite the COVID-19 pandemic. Exposure to some of the major attributable risks for cardiovascular diseases and cancers, such as high BMI, high systolic blood pressure, and high LDL cholesterol, increased or stopped improving in many or all countries after 2011.

Implications of all the available evidence

The extent to which life expectancy slowed during 2011–19 was largely determined by changes in mortality from cardiovascular diseases and cancers. Countries with maintained improvements in mortality from these conditions went on to maintain increases in life expectancy during the COVID-19 pandemic. The slowdown in life expectancy in other countries suggests that improved treatment for individuals with raised lipids or blood pressure is not sufficient to offset the effect of adverse population changes, for example in BMI, or sustained high exposure to dietary risks. Different national policies were potentially associated with the changes in risk factors and mortality patterns that were observed. Our findings suggest that stronger government policies are needed to reduce population levels of major attributable risks including high BMI, dietary risks, and upstream factors such as low physical activity and the wider commercial and social determinants of health, to improve population health over the long term and build resilience to future shocks.

Introduction

Life expectancy is an important summary measure of the health of populations and has been increasing in high-income countries since at least 1900, interrupted only by periods of high mortality during both world wars and the 1918 influenza pandemic.[1] The increase has been due to sustained and progressive improvements in infant mortality, nutrition, living standards, and the control of major infectious diseases such as tuberculosis and cholera.[2,3] In recent decades, increases in life expectancy among high-income countries have been due to reducing death rates from non-communicable diseases, especially cardiovascular diseases and some cancers, with reductions in risk factors such as smoking and raised blood pressure.[3] The rise in life expectancy has slowed down since 2011,[3,4] and further slowed in many countries when the COVID-19 pandemic occurred in 2020. The COVID-19 pandemic itself led to exceptionally high mortality rates and corresponding decreases in life expectancy due to COVID-19 in many countries. These falls in life expectancy are not yet recovering as consistently as they did in 2014–15 after a severe influenza season, and there remains substantial heterogeneity across countries with some locations continuing to have substantial excess mortality post-2021.[5,6] There could still be a continuing impact on life expectancy due to the COVID-19 pandemic, for example from continued disruption to health services as a result of work postponed during the pandemic, and from post-COVID-19 condition and effects on multiple organ systems.[7]

Recovery from the sustained slowdown in improvements in life expectancy from around 2011 could be especially difficult if the underlying causes remain poorly understood. The Organisation for Economic Co-operation and Development (OECD) has reported on potential explanations for the slowdown in life expectancy. The OECD highlighted changes in direct causes of death, including smaller reductions in deaths from cardiovascular diseases and some cancers, and increased respiratory deaths in older people in some winters, since 2011.[3] Meanwhile, a rise in age-specific death rates due to dementia is at least partly due to changes in coding practices over time.[8] The OECD report considered potential effects of changes in underlying risk factors, including

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the well established links between the rise in obesity and diabetes and raised mortality from cardiovascular diseases, widening socioeconomic inequalities in mortality, and economic downturns and austerity.

Multiple causes are likely to be responsible for the observed trends in life expectancy and researchers have previously called for further analysis to improve understanding of the relative contributions of different factors.[3,9] One difficulty with such international research is that nationally produced mortality statistics are often not comparable between countries due to methodological differences. The long-standing Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) has provided comprehensive assessments of global health for three decades and goes to great lengths to achieve internationally comparable estimates of mortality, life expectancy, morbidity, and associated risk factors, and is therefore well suited to analysis of the causes of international trends in life expectancy.[10–12]

In this analysis, we compared trends in life expectancy, causes of death, and risk factors estimated by GBD 2021 for the 16 founding European Economic Area (EEA) countries and the four nations of the UK from 1990 to 2021. We built on the published GBD 2021 capstone papers on global causes of death, life expectancy, risk factors, and disease forecasting.[10–13] We aimed to identify trends in specific causes of death and risk factors associated with changing life expectancy in specific countries and for the EEA and the UK. This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Overview

Life expectancy at birth, overall and with decomposition by cause of death, summary exposure values (SEVs) for risk factors, and deaths attributable to specific risk factors were estimated from 1990 to 2021 for the 16 EEA countries and the four UK nations that were part of the EEA at its inception. These countries were chosen because they are reasonably similar in terms of their economies and geographical locations. The countries were Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, and the UK nations of England, Northern Ireland, Scotland, and Wales. We compared three time periods: 1990 to 2011, 2011 to 2019 and 2019 to 2021. 2011 and 2019 were included at both the start and end of the time periods so as not to exclude changes from 2010 to 2011 and from 2019 to 2020. 2021 is the most recent GBD data year, 2019 was the last year before the COVID-19 pandemic was declared in 2020, and 2011 was when we identified a statistically significant change in the slope of life expectancy improvement for the region from 1990 to 2019 (see next section). The mean annual changes in life expectancy during these intervals were estimated, with 95% uncertainty intervals (UIs) for each year's individual life expectancy. Life expectancy at birth is the mean number of years that a newborn infant could expect to live, if he or she were to pass through life exposed to the sex-specific and age-specific death rates prevailing at the time of his or her birth, in a given country. Countries are presented according to 2019 life expectancy as 2019 was the last year before the COVID-19 pandemic. Population sizes in 2021 are also presented, sourced from the GBD Results tool.

For the **GBD Results tool** see https://vizhub.healthdata.org/gbd-results/

Change in life expectancy improvement

The year when there was an overall slowdown in life expectancy improvement was estimated by joinpoint regression modelling, described in detail previously.[14] A multisegmented line was fitted with use of the population-weighted means of all selected countries' life expectancy at birth from 1990 to 2019, in order to find an approximate point where a change in trend occurred (pooled life expectancy values for the combined group of countries were not available). Joinpoint regression identifies a statistically significant change in trend for time-series data. It assumes that a single linear model does not fully capture a trend but rather that data can be sectioned, with each section having a unique trend. To identify one predominant joinpoint, and avoid capturing small fluctuations in trend, the number of joinpoints was restricted to one. Joinpoint regression was implemented in the National Cancer Institute Joinpoint Regression Program (version 4.9.0.0).[15]

Life expectancy decomposition

Life expectancy was calculated using age-specific mortality rates with data from vital statistics registers, surveys and censuses, and standard demographic methods as described previously.[10] The method for estimation of 95% UIs is presented in appendix 1 (p 6). Cause-specific death rates for 288 causes of death, organised in hierarchical levels (levels 1–4) of increasing granularity for causes of death, were estimated with the Cause of Death Ensemble model, a modelling tool developed for GBD to produce stable estimates of mortality across age, location, year, and sex, adjusted to match the total number of all-cause deaths, as previously described.[12] Imprecise causes of deaths were redistributed to the most likely alternative causes of death.[12]

See **Online** for appendix 1

For more on this **organisational structure and causes of death** see https://www.healthdata.org/research-analysis/diseases-injuries/factsheets-overview

Changes in life expectancy were attributed to changes in causes of death (at GBD level 2, in which causes are grouped into 22 clusters) for each period, in order to identify the contribution of changes in specific causes of death to the slowdown of improvement in life expectancy. Life expectancy decomposition by cause was used to quantify contributions from specific causes of death by country with an established decomposition method.[12] Firstly, age-specific life expectancy was calculated, and secondly, the top 20 GBD causes of death that contributed to the variation in life expectancy within each age group

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were identified. Finally, these cause-age-specific contributions were aggregated across age groups to produce cause-specific contributions to the overall change in life expectancy over a given period. Life expectancy decomposition data for the total years within each period were explored as well as annualised data (estimates divided by the total number of years in each period) to facilitate comparisons between intervals with differing lengths of time. One of the causes identified was other COVID-19 pandemic-related outcomes; the process for estimating mortality from other COVID-19 pandemic-related outcomes has been described previously.[6,10] Briefly, this mortality estimate is the difference between excess mortality due to the COVID-19 pandemic and the sum of deaths due directly to COVID-19 infection and indirect deaths due to lower respiratory infections, measles, and pertussis. The top five causes were presented, with remaining causes grouped into "other" causes. Respiratory infections and tuberculosis were included as a cause across all time periods regardless of whether a top five cause to allow for comparisons before and during the COVID-19 pandemic.

Risk factor estimation

GBD 2021 produced epidemiological estimates for 88 risk factors (organised into four hierarchical levels of increasing granularity, with 20 risks at level 2) and their associated health outcomes for a total of 631 risk–outcome pairs.[11] The methods used to synthesise large amounts of heterogeneous data for risk–outcome pairs have been described previously.[11] The relative risks of each outcome occurring as a result of exposure to each risk were estimated for each risk–outcome pair. A new method in GBD 2021 is the burden of proof approach to evaluating the strength of evidence of risk–outcome relationships by combining effect size and consistency of evidence.[11,16] SEVs and theoretical minimum risk exposure levels were estimated for each risk factor, as previously described.[11] SEV is the GBD measure of risk-weighted exposure prevalence, which indicates a population's exposure to a risk factor accounting for the extent of exposure by risk level and the severity of that risk's contribution to disease burden. The SEV is on a 0–100 scale where 100 means the entire population is at maximum risk and 0 means the population is at

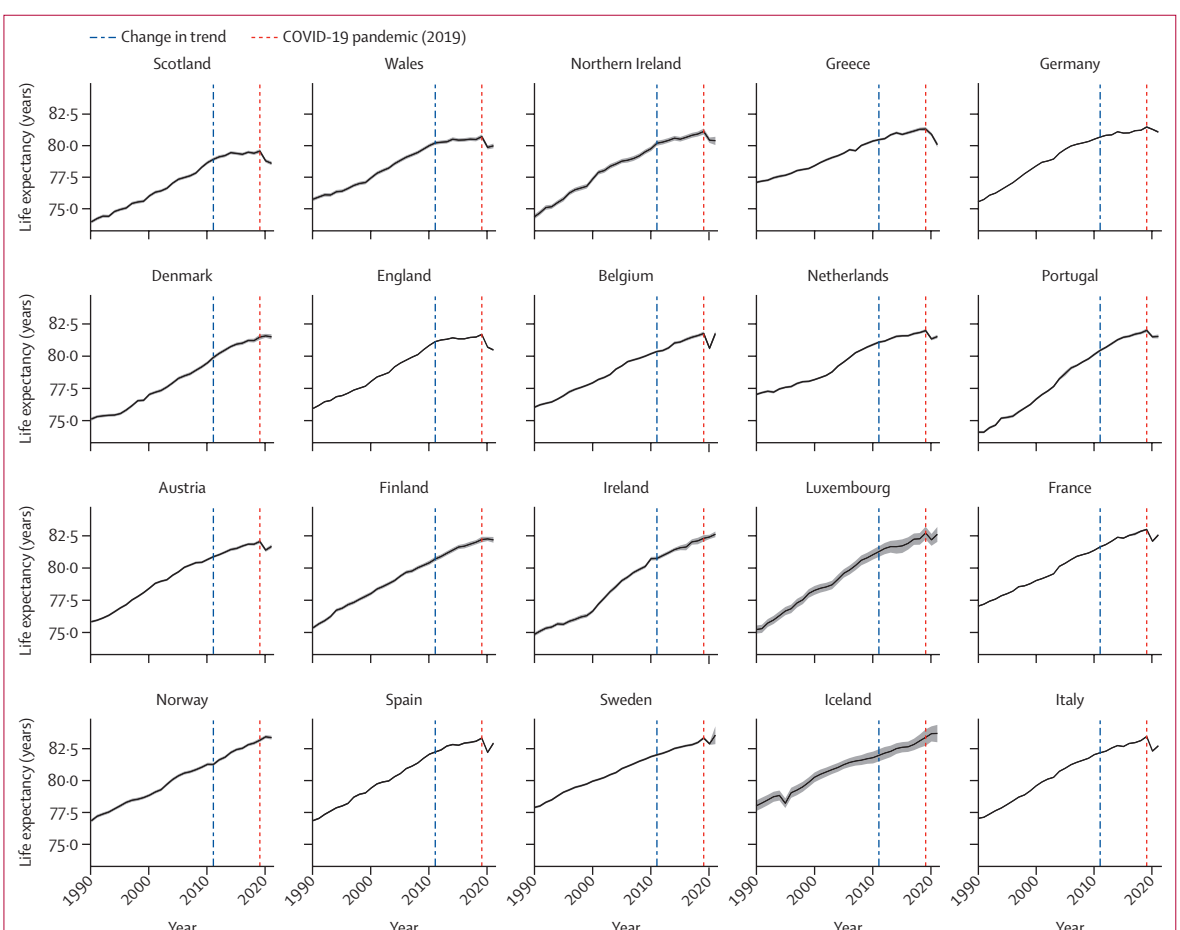


Figure 1: **Life expectancy at birth for both sexes combined, from 1990 to 2021 by country, ordered by 2019 life expectancy**
95% uncertainty intervals are shown as grey shading around the central lines.

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minimum risk. The theoretical minimum risk exposure level is the minimum theoretically possible level of risk in the exposed population.

The crude mean age-standardised death rates attributable to major risk factors for all countries combined in 2019 were estimated for each of cardiovascular diseases and neoplasms, as the causes of death responsible for the largest improvements in life expectancy up to 2019, as a prespecified part of the analysis. The top 10 level 2 risk factors, plus low physical activity if not included in the top 10 as an upstream risk factor for both cardiovascular diseases and neoplasms (within the top 11 risk factors for both causes), were presented. Changes in SEVs for risk factors for cardiovascular diseases and neoplasms over time from 1990 to 2021 were plotted by country. Additionally, the crude mean annual rates of change in SEVs for risk factors for cardiovascular diseases and neoplasms for each country were plotted against the crude mean annual rates of change for life expectancy for 1990–2011 and 2011–19, to show any associations. The visual display of information on multiple risk factors was limited to the top five risk factors (based on death rates attributable to the risk factors) for each of cardiovascular diseases and neoplasms to manage the number of datapoints and lines. Collectively, these risk factors were high systolic blood pressure, dietary risks, tobacco smoke, high LDL cholesterol, high BMI, occupational risks, and high alcohol use, plus low physical activity as an upstream risk factor for both cardiovascular diseases and neoplasms. GBD definitions for risk factors were used, presented in appendix 1 (pp 4–5). The mean annual rate of change was calculated as the change between the start year and end year of a period divided by the number of years in that period. Analyses of changes over time and estimation of standard errors were done in R (version 4.2.1), with use of ggplot2 for visualisations.[17,18]

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the manuscript for publication.

Results

Life expectancy steadily improved for at least two decades in all the included countries until around 2011, estimated by joinpoint regression modelling as the year when there was a statistically significant change in the slope of life expectancy improvement for the mean of all countries. Countries had different life expectancies and improvements over time (figure 1). All countries showed mean annual improvements in life expectancy in both 1990–2011 (overall mean 0·23 years [95% UI 0·23 to 0·24]) and 2011–19 (0·15 years [0·13 to 0·16]) but the rate of

	2019 life expectancy, years	1990 to 2011 change, years	2011 to 2019 change, years	2019 to 2021 change, years	Difference between 1990–2011 and 2011–19 changes, years	Difference between 2011–19 and 2019–21 changes, years	Population size in 2021, n
Overall	NA	0·23 (0·23 to 0·24)	0·15 (0·13 to 0·16)	−0·18 (−0·22 to −0·13)	−0·08 (−0·10 to −0·07)	−0·32 (−0·37 to −0·28)	NA
Scotland	79·48 (79·32 to 79·62)	0·23 (0·22 to 0·24)	0·08 (0·05 to 0·10)	−0·48 (−0·57 to −0·36)	−0·15 (−0·18 to −0·12)	−0·56 (−0·67 to −0·43)	5 515 838
Wales	80·60 (80·43 to 80·76)	0·21 (0·20 to 0·22)	0·06 (0·03 to 0·09)	−0·35 (−0·48 to −0·23)	−0·15 (−0·18 to −0·11)	−0·42 (−0·56 to −0·27)	3 152 120
Northern Ireland	81·00 (80·76 to 81·22)	0·27 (0·26 to 0·29)	0·11 (0·08 to 0·15)	−0·35 (−0·55 to −0·16)	−0·16 (−0·20 to −0·11)	−0·46 (−0·68 to −0·25)	1 930 081
Greece	81·19 (81·04 to 81·34)	0·16 (0·15 to 0·16)	0·10 (0·08 to 0·12)	−0·61 (−0·70 to −0·51)	−0·05 (−0·08 to −0·03)	−0·71 (−0·81 to −0·61)	10 174 910
Germany	81·35 (81·28 to 81·41)	0·24 (0·24 to 0·24)	0·10 (0·09 to 0·11)	−0·20 (−0·23 to −0·15)	−0·14 (−0·15 to −0·13)	−0·29 (−0·34 to −0·25)	85 371 848
Denmark	81·49 (81·28 to 81·68)	0·23 (0·22 to 0·24)	0·20 (0·17 to 0·23)	0·01 (−0·10 to 0·11)	−0·03 (−0·06 to 0·01)	−0·19 (−0·31 to −0·07)	5 851 783
England	81·69 (81·63 to 81·74)	0·25 (0·24 to 0·25)	0·07 (0·06 to 0·08)	−0·60 (−0·65 to −0·56)	−0·18 (−0·19 to −0·17)	−0·67 (−0·72 to −0·62)	57 250 352
Belgium	81·76 (81·61 to 81·91)	0·21 (0·20 to 0·21)	0·18 (0·15 to 0·20)	0·00 (−0·08 to 0·07)	−0·03 (−0·06 to −0·01)	−0·17 (−0·26 to −0·09)	11 469 272
Netherlands	81·99 (81·86 to 82·11)	0·19 (0·19 to 0·20)	0·11 (0·09 to 0·13)	−0·23 (−0·29 to −0·17)	−0·08 (−0·10 to −0·06)	−0·34 (−0·42 to −0·27)	17 210 662
Portugal	82·01 (81·86 to 82·15)	0·30 (0·30 to 0·31)	0·19 (0·17 to 0·22)	−0·24 (−0·31 to −0·16)	−0·11 (−0·13 to −0·08)	−0·43 (−0·52 to −0·35)	10 607 849
Austria	82·07 (81·91 to 82·21)	0·24 (0·23 to 0·25)	0·15 (0·13 to 0·17)	−0·19 (−0·27 to −0·11)	−0·09 (−0·12 to −0·07)	−0·34 (−0·43 to −0·25)	8 982 312
Finland	82·22 (82·00 to 82·43)	0·25 (0·24 to 0·26)	0·19 (0·15 to 0·22)	−0·02 (−0·12 to 0·10)	−0·06 (−0·11 to −0·03)	−0·21 (−0·33 to −0·07)	5 535 925
Ireland	82·31 (82·07 to 82·56)	0·28 (0·27 to 0·29)	0·20 (0·16 to 0·23)	0·16 (0·03 to 0·28)	−0·09 (−0·13 to −0·05)	−0·04 (−0·18 to 0·11)	4 941 374
Luxembourg	82·72 (82·22 to 83·21)	0·29 (0·26 to 0·31)	0·18 (0·10 to 0·26)	−0·05 (−0·23 to 0·14)	−0·11 (−0·20 to −0·02)	−0·23 (−0·42 to −0·02)	644 266
France	82·99 (82·92 to 83·06)	0·22 (0·22 to 0·22)	0·17 (0·16 to 0·18)	−0·21 (−0·26 to −0·16)	−0·05 (−0·06 to −0·04)	−0·38 (−0·43 to −0·33)	66 389 877
Norway	83·08 (82·95 to 83·22)	0·21 (0·20 to 0·22)	0·23 (0·21 to 0·26)	0·10 (0·00 to 0·20)	0·03 (0·00 to 0·06)	−0·13 (−0·24 to −0·02)	5 418 070
Spain	83·24 (83·16 to 83·32)	0·25 (0·25 to 0·26)	0·13 (0·12 to 0·15)	−0·19 (−0·24 to −0·15)	−0·12 (−0·13 to −0·10)	−0·33 (−0·38 to −0·27)	45 549 328
Sweden	83·26 (83·15 to 83·36)	0·19 (0·19 to 0·20)	0·16 (0·15 to 0·18)	0·11 (−0·24 to 0·45)	−0·03 (−0·05 to −0·01)	−0·06 (−0·41 to 0·29)	10 373 513
Iceland	83·31 (82·66 to 83·92)	0·19 (0·16 to 0·21)	0·18 (0·09 to 0·26)	0·15 (−0·01 to 0·31)	−0·01 (−0·11 to 0·08)	−0·02 (−0·21 to 0·16)	350 386
Italy	83·37 (83·32 to 83·42)	0·24 (0·24 to 0·24)	0·16 (0·15 to 0·17)	−0·36 (−0·40 to −0·32)	−0·08 (−0·09 to −0·08)	−0·52 (−0·56 to −0·47)	59 811 452

Numbers in parentheses are 95% uncertainty intervals. Values are rounded to two and three decimal places. Population sizes in 2021 were sourced from the GBD Results tool. NA=not applicable.

Table 1: **Mean annual changes in life expectancy at birth in years by time periods, ordered by 2019 life expectancy**

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improvement varied substantially between countries. The rate of improvement was lower in 2011–19 than in 1990–2011 for all countries expect Norway, where the mean annual increase in life expectancy rose from 0·21 years (95% UI 0·20 to 0·22) in 1990–2011 to 0·23 years (0·21 to 0·26) in 2011–19 (difference of 0·03 years [95% UI 0·00 to 0·06]). Conversely, England showed the biggest decrease in the rate of improvement between these two periods, going from a mean annual increase in life expectancy of 0·25 (0·24 to 0·25) to 0·07 (0·06 to 0·08; difference of –0·18 years [–0·19 to –0·17]; table 1). Iceland had the smallest decrease (0·19 [0·16 to 0·21] *vs* 0·18 [0·09 to 0·26]; difference of –0·01 [–0·11 to 0·08]). Between 2019 and 2021, there was an overall decrease in mean annual life expectancy across all countries (overall mean –0·18 years [–0·22 to –0·13]), with all countries having an absolute fall in life expectancy except for Ireland, Iceland, Sweden, Norway, Denmark, and Belgium. The improvement was very marginal for Denmark, and marginal for Norway, Sweden, Iceland, and Ireland, due to the small improvements and relatively wide 95% UIs for this short period. Belgium showed no change in life expectancy during this period. The greatest decreases in 2019–21 were observed in Greece (mean annual change –0·61 [–0·70 to –0·51]) and England (–0·60 [–0·65 to –0·56]).

The causes of death responsible for the largest improvements in life expectancy from 1990 to 2011 were cardiovascular diseases and neoplasms, shown by the decomposition analysis (figure 2). The countries where gains in life expectancy attributed to these causes of death were similar going from 1990–2011 to 2011–19 were also countries that best maintained improvements in life expectancy between 1990–2011 and 2011–19: Norway, Iceland, Belgium, Denmark, and Sweden (figure 3, table 1, appendix 1 p 1). Although Denmark was one of the best at maintaining improvements in life expectancy post-2011, the contribution of cardiovascular disease-related deaths to life expectancy gains was reduced in Denmark after 2011 while the contribution of neoplasm-related deaths was increased. These countries also maintained or marginally improved life expectancy from 2019 to 2021 during the COVID-19 pandemic, when life expectancy decreased in all other countries except Ireland. During 2019–21, in countries where life expectancy decreased, the decreases were entirely attributable to deaths from respiratory infections and other COVID-19-related outcomes apart from

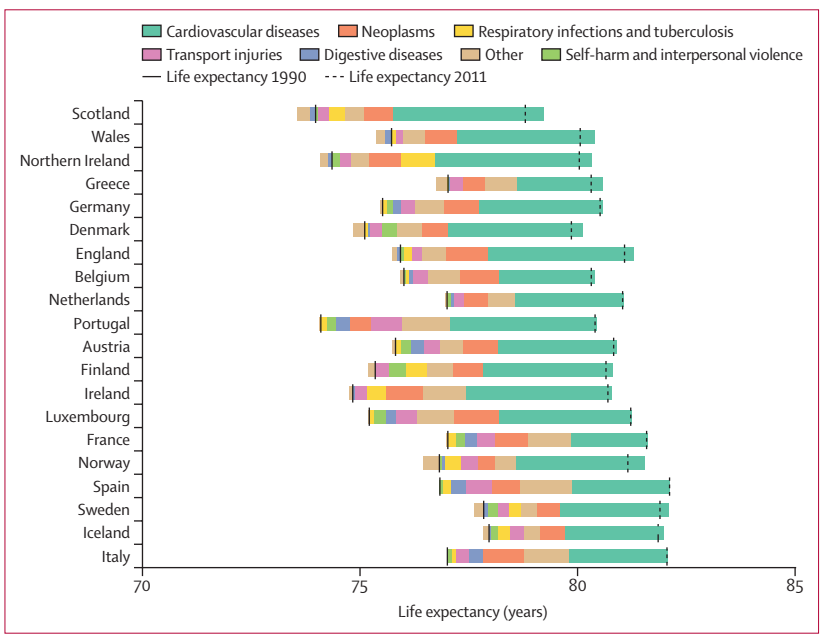


Figure 2: **Changes in life expectancy at birth for both sexes combined, by country and cause of death from 1990 to 2011, ordered by 2019 life expectancy**

The solid vertical black bars show life expectancy in 1990 for each country, and the dashed vertical black bars show life expectancy in 2011. The coloured bars to the right of the 1990 life expectancy line represent the number of years of improvement that were attributed to specific causes of death. Any coloured bars to the left of the 1990 line represent years of worsening of life expectancy attributed to specific causes of death between 1990 and 2011. Coloured bars to the right of the 2011 life expectancy line represent years of improvement attributed to specific causes of death, which are equal to the number of years to the left of the 1990 line. Further details on the methodology for the figure are provided in appendix 1 (p 6). Small proportions visible in appendix 1 (p 1) might not be visible in this figure due to the difference in scale.

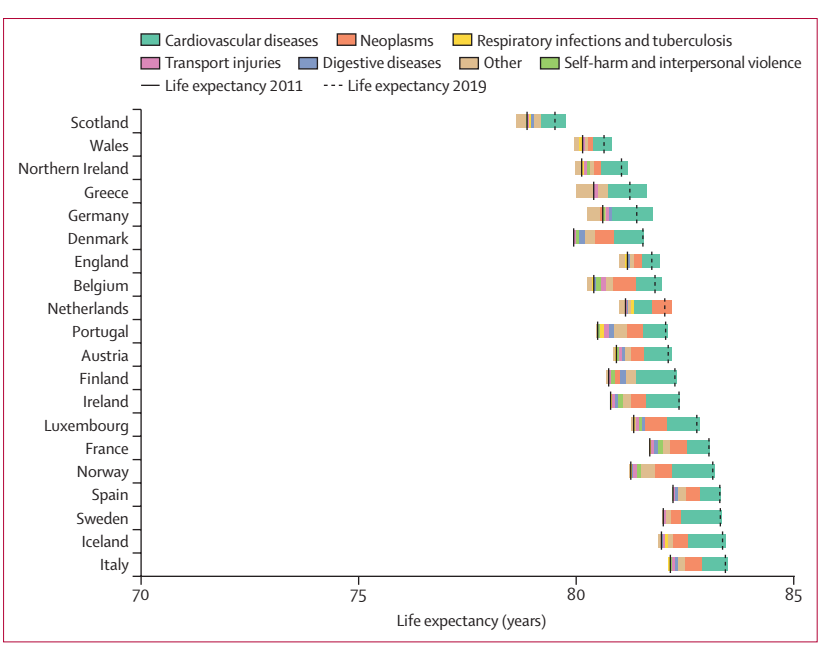


Figure 3: **Changes in life expectancy at birth for both sexes combined, by country and cause of death from 2011 to 2019, ordered by 2019 life expectancy**

The solid vertical black bars show life expectancy in 2011 for each country, and the dashed vertical black bars show life expectancy in 2019. The coloured bars to the right of the 2011 life expectancy line represent the number of years of improvement that were attributed to specific causes of death. Any coloured bars to the left of the 2011 line represent years of worsening of life expectancy attributed to specific causes of death between 2011 and 2019. Coloured bars to the right of the 2019 life expectancy line represent years of improvement attributed to specific causes of death, which are equal to the number of years to the left of the 2011 line. Further details on the methodology for the figure are provided in appendix 1 (p 6). Small proportions visible in appendix 1 (p 1) might not be visible in this figure due to the difference in scale.

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in Greece (where a very small portion of the decrease was also attributable to deaths from neoplasms; figure 4, table 1).

Up until the COVID-19 pandemic, deaths from cardiovascular diseases were the primary driver of reductions in life expectancy improvement from pre-2011 to post-2011, with reductions in the amount that deaths from cardiovascular diseases contributed to improvements going from 1990–2011 to 2011–19 in all countries except Greece (appendix 1 p 1). Countries varied in how well they maintained progress with neoplasm-related mortality during 2011–19. Norway, Denmark, Belgium, the Netherlands, Iceland, Portugal, Sweden, Luxembourg, France, and Spain had larger gains in life expectancy attributed to deaths from neoplasms in 2011–19 versus 1990–2011, whereas England, Wales, Northern Ireland, and Finland had smaller gains in life expectancy attributed to deaths from neoplasms in the post-2011 period (appendix 1 p 1). Germany, Scotland, and Greece had decreases in life expectancy attributable to neoplasms in 2011–19. Austria, Ireland, and Italy had little change in the gains in life expectancy attributable to deaths from neoplasms between 1990–2011 and 2011–19.

Among the studied countries, those with the greatest slowdown in life expectancy improvements before the COVID-19 pandemic were generally most severely affected by COVID-19 and had some of the largest decreases in life expectancy in 2019–21 (figures 3, 4, table 1). Greece, the four UK nations, and Italy had the largest decreases in life expectancy (mean annual change ranging from –0·35 years [95% UI –0·55 to –0·16] in Northern Ireland and –0·35 years [–0·48 to –0·23] in Wales, to –0·61 years [–0·70 to –0·51] in Greece) between 2019 and 2021. As aforementioned, Ireland, Iceland, Sweden, Norway, and Denmark maintained marginal improvements (mean annual change ranging from 0·01 years [–0·10 to 0·11) in Denmark to 0·16 years [0·03 to 0·28] in Ireland). Sweden and Ireland both had a high number of deaths from respiratory infections during 2019–21, but maintained an overall improvement in life expectancy due to decreased deaths from cardiovascular diseases and neoplasms. By comparison, the UK nations (Scotland in particular), Greece, and Italy showed decreases in life expectancy because these countries had high death rates due to respiratory infections and other COVID-19-related outcomes, while making little or no progress with cardiovascular diseases and neoplasms.

The specific risk factors with the three highest mean age-standardised death rates (per 100 000 of the population) attributable to cardiovascular diseases in 2019, for both sexes in all countries combined, were high systolic blood pressure (54·25 per 100 000), dietary risks (27·74 per 100 000), and high LDL cholesterol (23·02 per 100 000). The top three risk factors for neoplasms were tobacco smoke (27·30 per 100 000), dietary risks (9·83 per 100 000), and occupational risks (8·89 per 100 000). The major risk factors observed for both cardiovascular diseases and neoplasms were dietary risks, tobacco smoke, high BMI, high fasting plasma glucose, air pollution, other environmental risks, and low physical activity. Death rates for the top 10 risk factors plus physical activity for both causes are provided in table 2.

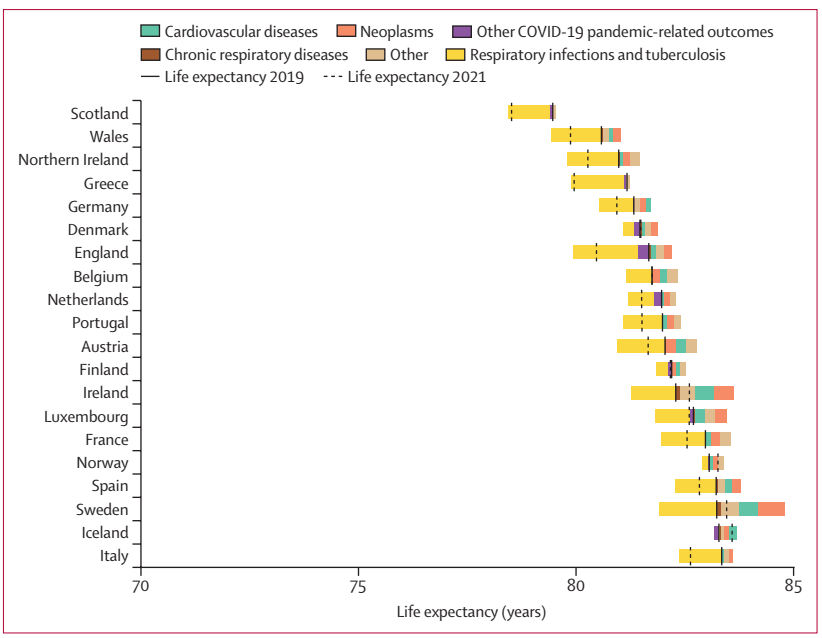


Figure 4: **Changes in life expectancy at birth for both sexes combined, by country and cause of death from 2019 to 2021, ordered by 2019 life expectancy**

The solid vertical black bars show life expectancy in 2019 for each country, and the dashed vertical black bars show life expectancy in 2021. The coloured bars to the right of the 2019 life expectancy line represent the number of years of improvement that were attributed to specific causes of death. Any coloured bars to the left of the 2019 line represent years of worsening of life expectancy attributed to specific causes of death between 2019 and 2021. Bars on the outsides of the solid and dashed lines represent equal numbers of years. Further details on the methodology for the figure are provided in appendix 1 (p 6).

The SEVs for the top five attributable risk factors for each of cardiovascular diseases and neoplasms changed over time from 1990 to 2021, with some consistent patterns (appendix 1 p 2). Exposure to tobacco smoke remained a high population risk but exposure decreased steadily in all countries from 1990 to 2021, in contrast to the SEV for high BMI, which steadily increased in all countries. Reductions in the SEVs for high LDL cholesterol slowed or began to reverse in most countries around 2011, and reductions in the SEVs for high systolic blood pressure slowed or began to reverse in many countries. Exposure to other risk factors including dietary risks, high alcohol use, and low physical activity remained elevated or slightly increased in most countries over the three decades. There were some examples where countries that maintained improvements in life expectancy up to 2021 tended to have favourable risk factor trends, although the patterns were complex. For example, comparing England and Sweden, Sweden had a continued reduction in SEV for high systolic blood pressure after 2011, whereas improvements stalled in

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	Deaths per 100 000 of the population
Cardiovascular diseases	
High systolic blood pressure	54·25
Dietary risks	27·74
High LDL cholesterol	23·02
Tobacco smoke	13·95
High BMI	12·80
Kidney dysfunction	11·74
High fasting plasma glucose	11·54
Non-optimal temperature	6·99
Air pollution	5·56
Other environmental risks	4·60
Low physical activity	2·34
Neoplasms	
Tobacco smoke	27·30
Dietary risks	9·83
Occupational risks	8·89
High BMI	6·48
High alcohol use	5·96
High fasting plasma glucose	4·88
Low physical activity	1·78
Other environmental risks	1·76
Air pollution	1·60
Unsafe sex	1·30

Global Burden of Disease Study risk factor definitions are provided in appendix 1 (pp 4–5).

Table 2: **Mean age-standardised death rates (per 100 000 of the population) attributable to specific risk factors for cardiovascular diseases and neoplasms for both sexes for all countries combined in 2019**

England, and Sweden had substantially lower SEVs than England for low physical activity over the three decades.

A scatter graph of change in life expectancy against change in SEVs for the top five attributable risk factors for each of cardiovascular diseases and neoplasms by country was used to identify associations and compare the two periods of 1990–2011 and 2011–19 (appendix 1 p 3). This graph complemented the timelines for SEVs (appendix 1 p 2) and showed that SEVs for high systolic blood pressure and high LDL cholesterol were reducing in many countries before 2011 but increasing after 2011. These increasing SEVs after 2011 generally coincided with decreasing annual improvements in life expectancy. SEVs for high BMI were increasing in all countries in both periods, and SEVs for dietary risks and low physical activity remained reasonably constant with minor increases for several countries in each period. Tobacco smoke exposure continued to improve after 2011. These steady or increasing exposures to high BMI, dietary risks, and low physical activity were associated with slowing improvements in life expectancy over time, despite the benefits to be expected from reduced exposure to tobacco smoke over the same time period.

Discussion

Main findings

All countries in this study except Norway had a slowing in life expectancy improvements after 2011, but the slowdown was greater in some countries than others. Improvements in mortality from cardiovascular diseases and neoplasms slowed substantially in many countries after 2011, as did improvements in high LDL cholesterol and high systolic blood pressure. High BMI steadily increased over the three decades and other risks including dietary risks, high alcohol use, and low physical activity remained high in most countries. Exposure to tobacco smoke decreased steadily in all countries, but remains important. There were notable international differences in life expectancy improvement, with Norway, Iceland, Sweden, Denmark, and Belgium continuing to make progress after 2011. These countries (except Belgium) also maintained improvements in life expectancy in 2019–21 during the COVID-19 pandemic, when life expectancy decreased in all other countries except Ireland.

Various underlying factors are likely to explain the observed patterns in cause-specific death rates and trends in risk factors observed in this study. These include structural, economic, commercial, and environmental determinants of health and illness, access to high quality preventive health care and treatment, and individual behavioural factors. The relative contribution of each factor is difficult to ascertain from statistical analyses such as ours and remains the subject of considerable debate. The findings reported in this paper do not support the hypothesis that the slowing of life expectancy improvements is because a natural longevity ceiling has been reached at around 110 years of age.[19] The GBD 2019 life tables estimate age-specific mortality rates above 110 years, reflecting the continued rise in life expectancy for older people in many countries.[20] Even if some countries were approaching a longevity ceiling, life expectancy is driven by changes in mortality below age 100 years, where there remains considerable scope for reduced mortality and key risks.

Health services

Reductions in cardiovascular risk factors, particularly high blood pressure and tobacco smoking, explained 30–40% of the reduction in cardiovascular mortality in England in 2000–07, and improvements in medical treatments (including antihypertensives and cholesterol-lowering medication) explained approximately half of the decrease in cardiovascular mortality between 1995 and 2008 in Turkey.[21,22] It is possible that a limit is being reached on the reductions that can be achieved through current medical treatments, although surveys suggest that there are still many individuals who would benefit from preventive treatments who are not yet receiving them, particularly among socioeconomically deprived subgroups.[23]

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In this study, the worsening trend in population exposure to high LDL cholesterol and high systolic blood pressure after 2011 in many countries suggests that improved treatment for individuals with raised lipid concentrations or blood pressure is not sufficient to offset the effect of adverse population changes, for example in BMI, or continued high exposure to dietary risks. Italy has one of the highest life expectancies in the world, which has been attributed to the quality of the universal health system and healthy behaviours.[24] However, life expectancy in Italy decreased substantially in 2019–21 with a downturn in life expectancy gains due to neoplasms and cardiovascular diseases from pre-2019 to post-2019 for uncertain reasons, but possibly associated with reduced spending on public health and preventive measures rather than a specific policy. National policies that address diagnosis, treatment, and prevention of neoplasms through reduction in risks have been implemented to different degrees in different countries. Belgium, France, and Norway all increased their cancer diagnosis and treatment activity in recent years through national policies[25–27] and have maintained progress in improving life expectancy linked to neoplasms between 1990–2011 and 2011–19 (appendix 1 p 1). Belgium's National Cancer Plan for 2008–10 emphasised prevention (screening and action on smoking, alcohol, and food) as well as treatment.[26] In Norway, national guidance to standardise prevention, diagnosis, and monitoring for breast, lung, colon, and prostate cancer was issued in 2013 as one of an ongoing series of National Cancer Strategies.[27] Similar approaches to the prevention and treatment of cardiovascular diseases have been shown to be effective, for example the National Service Framework approach adopted in England in 2000.[28]

Risk factors for cardiovascular diseases and neoplasms

Four industry sectors (tobacco, ultra-processed food, fossil fuel, and alcohol) are responsible for at least a third of global deaths, and the power of the commercial sector tends to prevent the implementation of effective policies to mitigate risks.[29] A partial exception is tobacco, for which sustained action over decades has reduced exposure, although tobacco smoke remains the biggest risk factor for cancer by some margin (table 2), and a continued policy focus on tobacco smoking is essential to maintain the current gains. Successful actions to reduce the harm from tobacco offer a template for reducing alcohol and dietary risks. Effective national policies on minimum unit pricing to reduce the consumption of alcohol exist, but are not being widely implemented.[30,31] Risks related to alcohol consumption are increased in people with low economic status due to the coexistence of other risk factors such as smoking and heavy episodic drinking.[32]

The effects of upstream risk factors, such as diet and low physical activity, are particularly important as they have a wide range of beneficial effects, some of which are mediated through high systolic blood pressure, high LDL cholesterol, and high plasma glucose, and some through other mechanisms which are less well understood.[33] Dietary risk in GBD is an aggregate risk factor for a diet low in wholegrains, fruit, fibre, legumes, nuts and seeds, omega-3 fatty acids, polyunsaturated fats, vegetables, milk, and calcium; and a diet high in sodium, trans fats, red or processed meat, and sugar-sweetened beverages (appendix 1 p 4).[34] There is strong evidence that improving diet offers scope for large population health gains: in a meta-analysis of studies comparing a Mediterranean diet with unrestricted fat intake with other diets, the Mediterranean diet reduced major cardiovascular events by around 30% and cancer mortality by 25%.[35,36] The EAT–*Lancet* Commission defines a healthy diet as one that provides plenty of fruit, vegetables, wholegrains, and healthy proteins, with minimal saturated fats, highly processed foods, and added sugar.[37]

Variation in diet between countries reflects a combination of cultural, social, economic, and policy factors, but can still be influenced by sustained policy intervention. For example, Norway has a long history of fiscal intervention to reduce sugar consumption and protect domestic food production, as well as strong social security and policies aiming for regional balance in economic growth, sustainability, travel, and access to education and health services.[38] A tax on sugar has been in place since 1922 and the Norwegian Government consulted with industry as early as the 1980s to reduce the amount of salt in food products. A cross-sectoral national plan also led to improvements in the national diet.[39] This approach has been more successful than voluntary and educational approaches, such as the Scottish Government policy since 2001 to make healthy foods more widely available, primarily through voluntary reformulation of foods and improving consumer knowledge. This approach led to little change in the proportion of people in Scotland who consumed the recommended amount of five or more portions per day of fruit and vegetables.[40]

Levels of physical activity are assessed in GBD based on the frequency, duration, and intensity of activity. The wide-ranging effects of physical activity are reflected in the benefits seen in large observational studies of regular physical activity, which consistently report a 20–30% risk reduction in premature mortality and the incidence of several chronic health conditions.[41] Individuals who are sedentary experience substantial health benefits from even a small increase in their physical activity and there is no minimum threshold for benefit.[41] However, at a population level in the current analysis, there had been little change in exposures to low physical activity across the studied countries despite the strengthening evidence for its benefits. Again, coordinated systematic strategies are required to achieve improvement in levels of physical activity at the population level. A further incentive to do so is the clear additional benefit of an active travel policy in reducing climate risk.

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Fiscal policies

The links between poverty and health and life expectancy are well established and are partly mediated through the biomedical risk factors considered in this paper. The biomedical risk factors are prioritised when quantifying the effect of poverty on health by the GBD selection of risk–outcome pairs, which depends on robust quantitative estimates of effect size. The broader determinants of health, such as fiscal policies, also influence population health more widely than can be captured by changes in measurable biomedical risk factors.[11,42–44] A worsening economic position could increase short-term mortality in the most socioeconomically deprived individuals as well as increasing longer term exposure to risks such as poverty, poor diet, food insecurity, low pay and employment levels, and poor housing.[42] Among 28 EU countries between 1991 and 2013, austerity regimes were associated with an overall 0·7% increase in all-cause mortality, and similar findings have been observed in England and Wales.[45,46]

Most countries had some degree of reduced spending on public services and benefits following the economic recession of 2007–08, and although deficit reduction policies varied considerably by country, health expenditure plateaued in nearly all countries.[47] The 2007–08 recession was followed by adverse impacts on health and social wellbeing across Europe (for example, through unemployment and poverty) in addition to health service cuts.[48] In the UK, a National Health Inequalities Strategy between 1997 and 2010 coincided with a reduction in health inequalities in England, overall and for cardiovascular diseases and some cancers.[49] Subsequent large funding cuts to health, social care, and welfare since 2010, particularly in areas of socioeconomic deprivation, affected the social determinants of health and therefore contributed to the slowdown in mortality improvement.[50,51]

Cohort effects

National and international cohort effects might be contributing to the slowdown in life expectancy improvements. Populations born around the same time and sharing specific life experiences might have increased or decreased mortality compared with other groups born before or after that period. For example, in Scotland in the early 1980s, there was widespread deindustrialisation and unemployment, which might have led to negative future health effects for those children whose parents were unemployed or for unemployed young adults.[52] These people will have had increased exposure to risk factors such as high BMI, tobacco smoke, dietary risks, and alcohol use. In Scotland, there is evidence of a cohort effect on drug-related deaths and suicide, but weaker evidence for a cohort effect on ischaemic heart disease and stroke.[52–56] Another example of a cohort effect is the increased mortality in the USA in individuals who were born during the Great Depression of 1929 compared to those born before or after this period.[57] The long latency of these cohort effects needs to be considered in any analysis of future scenarios.

Strengths and limitations

A major strength of the GBD method is that it goes to great lengths to produce comparable and consistent estimates of mortality, causes of death, and risk factors. GBD methods for estimating life expectancy differ slightly from those used by Eurostat which inform OECD estimates of life expectancy. Eurostat uses data from national statistical offices and Farr's method, which calculates life expectancy with use of life tables presenting age-specific mortality rates.[58] GBD adds additional steps, evaluating the completeness of vital registration data via death distribution methods.[59] Life expectancy estimates produced by individual nations might also differ from both GBD and OECD estimates because of methodological inconsistencies, but the overall trends are similar. We did not present results for healthy life expectancy as well as life expectancy due to space limitations and because the two measures give similar results, except that there were slightly smaller gaps between male and female individuals with respect to healthy life expectancy (with female individuals having higher life expectancy; data not shown).

In this paper, we chose fixed periods to evaluate differences and combined findings for both sexes. Although this allows for a consistent approach, changes in life expectancy trends occurred at different times for different countries. Any differences would be exacerbated or underestimated if different periods were chosen, or if estimates for male and female individuals were analysed separately. For example, the increase in life expectancy in Denmark, Finland, and Portugal appeared to slow down in 2015 or 2016, compared with 2010 in England. Trends in life expectancy and both risk exposure and mortality vary between male and female individuals, such as in Finland and the UK.[60] Differences in male and female individuals might, for example, reflect broader inequalities in society. In Sweden and Norway, the gender gaps in labour market participation and employment are among the smallest of the OECD countries, and this might be a contributor to the continued rise in life expectancy that we observed up to 2021.[61]

The production of cause-specific estimates of mortality relies on accurately coded death certificates that correctly consider comorbidities at the time of death. Where necessary, GBD redistributes inaccurate causes of deaths to more accurate plausible causes of death.[12] Attributable risk estimates within GBD need to be interpreted with caution because of modelling assumptions. The lag time between exposure and harm varies for different risk factors, and some major risks such as tobacco smoking and obesity can have an effect over decades. Exposure before our start date of 1990 has not been considered in the analyses. GBD does not have data to explore the effect

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on life expectancy of immigration, including asylum seekers, into Europe between 1990 and 2021.

The evidence-based focus on single proximal determinants of health does not capture the effect of risk factors acting in combination, where the evidence is scant. In general, the quality and extent of the evidence base correlates poorly with the public health importance of many risks. This explains why GBD includes few risk factors associated with wider determinants of health, such as poverty, employment, and housing, for which the non-observational evidence base is scarce due to the unfeasibility of conducting trials of interventions.

Implications for policy and research

The present results can guide action by policy makers seeking to reverse the slowdown in life expectancy improvements in the studied European nations. The immediate signal was changing mortality patterns, and the underlying population risk factors are clear. Improvements in upstream risk factors such as dietary risks and physical inactivity offer the potential for substantial improvements in mortality across multiple conditions.[13]

Country-specific public health and health-care policies can have a positive impact. Policy responses should build on the experience of those countries who have implemented successful health-care and public health strategies. Multiple factors have contributed to the slowdown in life expectancy, and coordinated action across multiple sectors will be needed to reverse it. The wider economic, social, and commercial determinants of health are particularly important as they affect multiple conditions, and a Health in All Policies approach is needed to address these determinants and to reduce health inequalities.[62,63] The growing evidence of an association between fiscal austerity and changes in life expectancy implies that addressing the continuing shortfall in services, especially for the most socioeconomically deprived and for marginalised groups, will be an essential component of any recovery plan.[64,65]

The link between pre-existing general health and mortality during the COVID-19 pandemic period shows the need to build resilience in a population by addressing non-communicable diseases as well as reducing the risk of infection. An unequal society with limited social welfare will see early spreading of infectious disease among populations who live in crowded multiple occupancy households, those who have a high prevalence of multimorbidity, exacerbating poor outcomes from infection, and those who cannot afford to isolate and take time off work. The public health control measures implemented during the COVID-19 pandemic (including closures to schools and the hospitality sector) disproportionately affected deprived communities, exacerbating existing inequalities.[66] A life course approach is likely to be needed to minimise the long-term impact of future major adverse events such as the financial crash of 2007–08 or the COVID-19 pandemic, and to reduce risks to future health.[67]

Conclusions

Gains in life expectancy have slowed and in most cases life expectancy has decreased across the included European countries between 1990 and 2021. These findings show that the stalled progress in reducing deaths from the major causes of cardiovascular diseases and cancer is attributable to changes in population exposure to common risk factors, including high BMI, and continued high exposure to dietary risks. Trends in life expectancy at the national level are associated with major long-term policy interventions, implying that governments can substantially influence the longevity of their population through policy choices that should include addressing the commercial determinants of health, reducing dietary risks, improving physical activity levels, and ensuring access to effective health care for prevention and treatment. Further development of long-term national and international cross-sectoral strategies, involving governments, communities, schools, and employers, is urgently needed to reverse the slowdown in life expectancy improvements and worsening life expectancy over the past 15 years in European nations.

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Data sharing

Citations and metadata for all input data used in this analysis are available for download from the GBD 2021 Sources Tool (https://ghdx.healthdata.org/gbd-2021/sources). To visualise or download the estimates produced in this analysis, please visit the GBD Compare tool (https://vizhub.healthdata.org/gbd-compare/) and GBD Results tool (https://vizhub.healthdata.org/gbd-results/). A Global Health Data Exchange record with the life expectancy decomposition estimates is available from: https://ghdx.healthdata.org/record/ihme-data/gbd-2021-europe-le-change-cause-1990-2021.

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