International Health 2025; **17**: 517–526
https://doi.org/10.1093/inthealth/ihae091 Advance Access publication 14 January 2025

ORIGINAL ARTICLE

The effect of addressing the top 10 global causes of death on life expectancy in 2019: a global and regional analysis

Fatemeh Shahbazi [a,b,c], Samad Moslehi[d], Zahra Mirzaei[e] and Younes Mohammadi[a,f,*]

[a]*Department of Epidemiology, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran;* [b]*Occupational Health and Safety Research Center, Health Sciences and Technology Research Institute, Hamadan University of Medical Sciences, Hamadan, Iran;* [c]*Modeling of Noncommunicable Diseases Research Center, Health Sciences and Technology Research Institute, Hamadan University of Medical Sciences, Hamadan, Iran;* [d]*Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran;* [e]*Department of Public Health, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran;* [f]*Social Determinants of Health Research Center, Hamadan University of Medical Sciences, Hamadan, Iran*

*Corresponding author: Tel: +98 81 38380090; E-mail: younesmohamadi@gmail.com

Received 24 July 2024; revised 20 September 2024; editorial decision 12 December 2024; accepted 18 December 2024

Background: The life expectancy (LE) index reflects health changes in society, highlighting trends in health quality and quantity. This study focused on analysing the impact of the top 10 causes of death on the global increase in LE in 2019.

Methods: Data on the top 10 causes of death in 2019 were obtained from the Global Burden of Disease website and a period life table was used to assess how eliminating these causes would impact LE.

Results: At the global level, eliminating deaths from ischaemic heart disease, stroke, chronic obstructive pulmonary disease, lower respiratory infections, neonatal conditions, lung cancers, Alzheimer's disease, diarrheal diseases, diabetes mellitus and kidney diseases resulted in an increase in LE at birth of 2.44, 1.64, 0.75, 0.80, 4.06, 0.48, 0.36, 0.52, 0.36 and 0.35 y, respectively.

Conclusions: The analysis reveals a gender gap in LE influenced by specific causes of death and regional differences. Therefore, public health policies should be customized for each area to target reductions in deaths that significantly improve LE.

Keywords: life expectancy, cause of death, mortality, global health, public health.

Introduction

Life expectancy (LE) is the estimated average lifespan of an individual, taking into account advancements in living standards and societal conditions. The LE index serves as a direct indicator of changes in both the quantity and quality of health within a society, providing a concise overview of health trends. This measure plays a pivotal role in shaping health policies.[1] LE is indicative of the conditions in a specific area. In countries with lower levels of development, the average LE at birth tends to be lower than that in more developed nations.[2] Globally, in the third epidemiological transition, LE increased in many regions and countries of the world due to the control of infectious diseases, reduction of maternal and child mortality and improvement of health conditions and living standards.[1,2]

The overall progress in LE is mostly due to postponement of the main cause of death at older ages.[3] According to the latest World Health Organization (WHO) report on 9 December 2020, the top 10 causes of death worldwide are ischaemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), lower respiratory infections, neonatal conditions, lung cancers, Alzheimer's disease, diarrheal diseases, diabetes mellitus and kidney diseases, respectively. These causes accounted for 55% of deaths worldwide in 2019, which is equivalent to 55.4 million deaths.[4] By implementing appropriate health and medical measures, we can reduce the mortality rates associated with these causes and increase LE.

Most of the studies on the increase in LE have been conducted in Western societies, specific age subgroups or limited health outcomes.[1,5–7] Yet we still do not know completely about the

increase in LE due to the complete elimination of the main causes of death globally and by different geographic regions, sexes and age groups. Examination of cause deletion is crucial for both researchers and policymakers for several key reasons.[8] First, by examining the elimination of specific causes of death, healthcare policymakers gain insight about the impacts of various outcomes on health for evidence-based decision-making.[9] Second, analysis by geographic areas provides the basis for reducing inequalities, as it determines which regions will benefit by eliminating each cause of death and require more attention from health policymakers.[8] Third, focusing on high-impact causes ensures efficient allocation of resources and targeted strategies.[10] Fourth, estimating increases in LE offers policymakers a way to assess the potential health improvements within a population and determine which policies are most likely to be effective. Thus identifying which causes significantly affect health outcomes allows policymakers to prioritize interventions.[7,8] In this article we aimed to investigate how much LE at birth will increase if we eliminate each of the top 10 causes of death by sex, age group, WHO region and sociodemographic index.

Methods

Data sources

In this study we utilized two data sources. The first source was the Global Burden of Disease (GBD; 2019), from which we extracted data on the total number of deaths from the top 10 causes of death: ischaemic heart disease, stroke, COPD, lower respiratory infections, neonatal conditions, lung cancer, Alzheimer's disease, diarrheal diseases, diabetes mellitus and kidney diseases. The GBD data are openly available at https://vizhub.healthdata.org/gbd-results/.[11] This source includes censuses, insurance data, disease registries, birth and death registry data, surveys and population studies and scientific literature. The neonatal conditions in the GBD dataset include neonatal preterm birth, neonatal encephalopathy due to birth asphyxia and trauma, neonatal sepsis and other neonatal infections and haemolytic disease and other neonatal jaundice. Lung cancers were also a general name for cancers of the trachea, bronchi and lungs. The second data source was the United Nations Department of Economic and Social Affairs, Population Division, from which we extracted the corresponding population data, stratified by sex, age (19 age groups, from <1 to ≥ 85 y), WHO region (Africa, Americas, Eastern Mediterranean, South-East Asia, Europe and West Pacific) and grouping countries based on the sociodemographic index (SDI) (low, low-middle, middle, high-middle and high). The data from this source can be downloaded freely from https://population.un.org/wpp/downloads.

Data analysis

We utilized the period life table to determine the increase in LE. Demographers created life tables long ago to analyse overall mortality rates. Later, these tables were adapted to compute LE by excluding a particular cause of death. Essentially, this table assesses how much LE will increase if deaths from a specific cause are eliminated while mortality rates from other causes stay unchanged. In the calculations for increased LE, it is assumed that there are n different causes of death at a given time t. The probability of surviving from birth to age z at time t, assuming the only cause of death is cause i, is:

$$p_i(z,t) = e^{-\int_0^z \mu_i(s,t)ds},$$

where $\mu_i(s,t)$ is the age-specific mortality rate from cause i in the age interval s to s+ss. Next, in the life table, the survival function is written as follows:

$$p(z,t) = e^{-\int_0^z \mu(s,t)ds} \quad where \quad (\mu(s,t) = \sum_{i=1}^{n} \mu_i(s,t)).$$

If we assume that all causes of death are independent, LE at birth will be calculated as follows:

$$e(0) = \int_0^\omega e^{-\int_0^z \mu(s)ds} \quad that \quad (dz = \int_0^\omega p(z)dz).$$

But if we assume that there are specific and comprehensive causes for death in a society, then the LE at birth is calculated as follows:

$$e(0) = \int_0^\omega p1(z)p2(z)....pn(z)dz$$

If $D_i(0)$ is the gain in LE at birth by elimination of the cause of death i, then it is calculated as follows:

$$D_i(0) = \int_0^\omega p - i(z)dz - \int_0^\omega p - i(z)p_i(z)dz.$$

We analysed by sex, age group, WHO region and SDI. All analyses were performed using R version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria). Data visualization was performed using the Geofacet and ggplot2 packages in R.

Results

Globally, LE at birth in 2019 was 73.60 y for both sexes and 70.92 and 76.38 y for men and women, respectively (women's LE was 5.46 y higher than men's). LE at birth in the regions of the Americas, Africa, Eastern Mediterranean, Europe, South-East Asia and Western Pacific was 77.34, 65.03, 69.90, 77.88, 71.59 and 78.00 y, respectively. The lowest and highest LE at birth was in the African and Western Pacific regions, respectively (the difference between these two areas in LE at birth was about 13 y). In terms of grouping countries based on the SDI, high SDI countries had the highest LE at birth (81.30 y) and low-income countries had the lowest LE at birth (65.55 y).

Our analysis showed that worldwide LE at birth in 2019 was 73.60 y and would increase to 76.04 y if death from ischaemic heart disease was completely removed (gain in LE for this cause of death is 2.44 y) (Table 1, Figure 1). Also, if we remove death from stroke, COPD and lower respiratory infections, the worldwide LE will increase to 75.24, 74.35 and 74.40 y, respectively. The greatest increase in LE in both sexes will be achieved by eliminating neonatal conditions (increase in LE for this health outcome is 4.06 y) (Table 1, Figure 1).

Table 1. LE at birth and change in the LE due to mortality from the top 10 causes of death by sex, SDI and WHO region

Characteristics	LE at birth (years)	Change in LE by elimination of each of the top 10 causes of death									
		IHC	Stroke	COPD	Lower respiratory infections	Neonatal conditions	Lung cancers	Alzheimer	Diarrhoea	Diabetes mellitus	Kidney diseases
Sex											
Both	73.60 (73.58 to 73.62)	76.04 (76.02 to 76.06)	75.24 (75.22 to 75.26)	74.35 (74.33 to 74.37)	74.40 (74.38 to 74.42)	77.66 (77.64 to 77.68)	74.08 (74.06 to 74.10)	73.96 (73.94 to 73.98)	74.12 (74.10 to 74.14)	73.96 (73.94 to 73.98)	73.95 (73.93 to 73.97)
Male	70.92 (70.90 to 70.94)	73.29 (73.27 to 73.31)	72.40 (72.38 to 72.42)	71.69 (71.67 to 71.71)	71.67 (71.65 to 71.69)	74.88 (74.86 to 74.90)	71.50 (71.48 to 71.52)	71.13 (71.11 to 71.15)	71.24 (71.22 to 71.26)	71.24 (71.22 to 71.26)	71.24 (71.22 to 71.26)
Female	76.38 (76.36 to 76.40)	78.81 (78.79 to 78.83)	78.14 (78.12 to 78.16)	77.07 (77.05 to 77.09)	77.21 (77.19 to 77.23)	80.51 (80.49 to 80.53)	77.17 (77.15 to 77.19)	76.91 (76.89 to 76.93)	76.96 (76.94 to 76.98)	76.78 (76.76 to 76.80)	76.73 (76.71 to 76.75)
SDI											
Low	65.55 (65.53 to 65.57)	67.12 (67.10 to 67.14)	66.75 (66.73 to 66.77)	66.22 (66.20 to 66.24)	66.91 (66.89 to 66.93)	74.79 (74.77 to 74.81)	65.67 (65.65 to 65.69)	65.71 (65.69 to 65.73)	67.02 (67.00 to 67.04)	65.94 (65.92 to 65.96)	65.87 (65.85 to 65.89)
Low-middle	69.74 (69.72 to 69.76)	71.81 (71.79 to 71.83)	71.26 (71.24 to 71.28)	70.85 (70.83 to 70.87)	70.63 (70.61 to 70.65)	75.09 (75.07 to 75.11)	69.94 (69.92 to 69.96)	69.94 (69.92 to 69.96)	70.54 (70.52 to 70.56)	70.17 (70.15 to 70.19)	70.09 (70.07 to 70.11)
Middle	74.71 (74.69 to 74.73)	77.19 (77.17 to 77.21)	76.66 (76.64 to 76.68)	75.51 (75.49 to 75.51)	75.23 (75.21 to 75.25)	77.03 (77.01 to 77.05)	74.84 (74.82 to 74.86)	75.00 (74.98 to 75.02)	74.92 (74.90 to 74.94)	75.14 (75.12 to 75.16)	75.15 (75.13 to 75.17)
High-middle	77.58 (77.56 to 77.60)	80.78 (80.76 to 80.80)	79.54 (79.52 to 79.56)	78.14 (78.12 to 78.16)	77.96 (77.94 to 77.98)	78.63 (78.61 to 78.65)	78.23 (78.21 to 78.25)	77.98 (77.96 to 78.00)	77.63 (77.61 to 77.65)	77.85 (77.83 to 77.87)	77.82 (77.80 to 77.84)
High	81.30 (81.28 to 81.32)	83.49 (83.47 to 83.51)	82.29 (82.27 to 82.31)	81.87 (81.85 to 81.89)	81.80 (81.78 to 81.82)	82.13 (82.11 to 82.15)	82.12 (82.10 to 82.14)	82.03 (82.01 to 82.05)	81.33 (81.31 to 81.35)	81.57 (81.55 to 81.59)	81.66 (81.64 to 81.68)
WHO regions											
Americas	77.34 (77.32 to 77.36)	79.70 (79.68 to 79.72)	78.32 (78.30 to 78.34)	78.01 (77.99 to 78.03)	78.00 (77.98 to 78.02)	79.04 (79.02 to 79.06)	79.13 (79.11 to 79.15)	77.88 (77.86 to 77.90)	77.44 (77.42 to 77.46)	77.89 (77.87 to 77.91)	77.93 (77.91 to 77.95)
African	65.03 (65.01 to 65.05)	66.28 (66.26 to 66.30)	66.22 (66.20 to 66.24)	65.31 (65.29 to 65.33)	66.52 (66.50 to 66.54)	75.61 (75.59 to 75.63)	65.16 (65.14 to 65.18)	65.20 (65.18 to 65.22)	66.26 (66.24 to 66.28)	65.49 (65.47 to 65.51)	65.36 (65.34 to 65.38)
Eastern Mediterranean	69.90 (69.88 to 69.92)	73.70 (73.68 to 73.72)	71.29 (71.27 to 71.31)	70.35 (70.33 to 70.37)	70.58 (70.56 to 70.60)	73.93 (73.91 to 73.95)	70.11 (70.09 to 70.13)	70.11 (70.09 to 70.13)	70.38 (70.36 to 70.40)	70.37 (70.35 to 70.39)	70.38 (70.36 to 70.40)
European	77.88 (77.86 to 77.90)	81.27 (81.25 to 81.29)	79.39 (79.37 to 79.41)	78.29 (78.27 to 78.31)	78.32 (78.30 to 78.34)	78.84 (78.82 to 78.86)	78.54 (78.52 to 78.56)	78.31 (78.29 to 78.33)	77.91 (77.89 to 77.93)	78.11 (78.09 to 78.13)	78.09 (78.07 to 78.11)
South-East Asia	71.59 (71.57 to 71.61)	73.88 (73.86 to 73.90)	73.08 (73.06 to 73.10)	72.76 (72.74 to 72.78)	72.37 (72.35 to 72.39)	76.16 (76.14 to 76.18)	71.78 (71.76 to 71.80)	71.80 (71.78 to 71.82)	72.45 (72.43 to 72.47)	72.06 (72.04 to 72.08)	71.93 (71.91 to 71.95)
Western Pacific	78.00 (77.98 to 78.02)	80.09 (80.07 to 80.11)	80.36 (80.34 to 80.38)	78.93 (78.91 to 78.95)	78.47 (78.45 to 78.49)	79.18 (79.16 to 79.20)	78.45 (78.43 to 78.47)	78.44 (78.42 to 78.46)	78.04 (78.02 to 78.06)	78.22 (78.20 to 78.24)	78.22 (78.20 to 78.24)

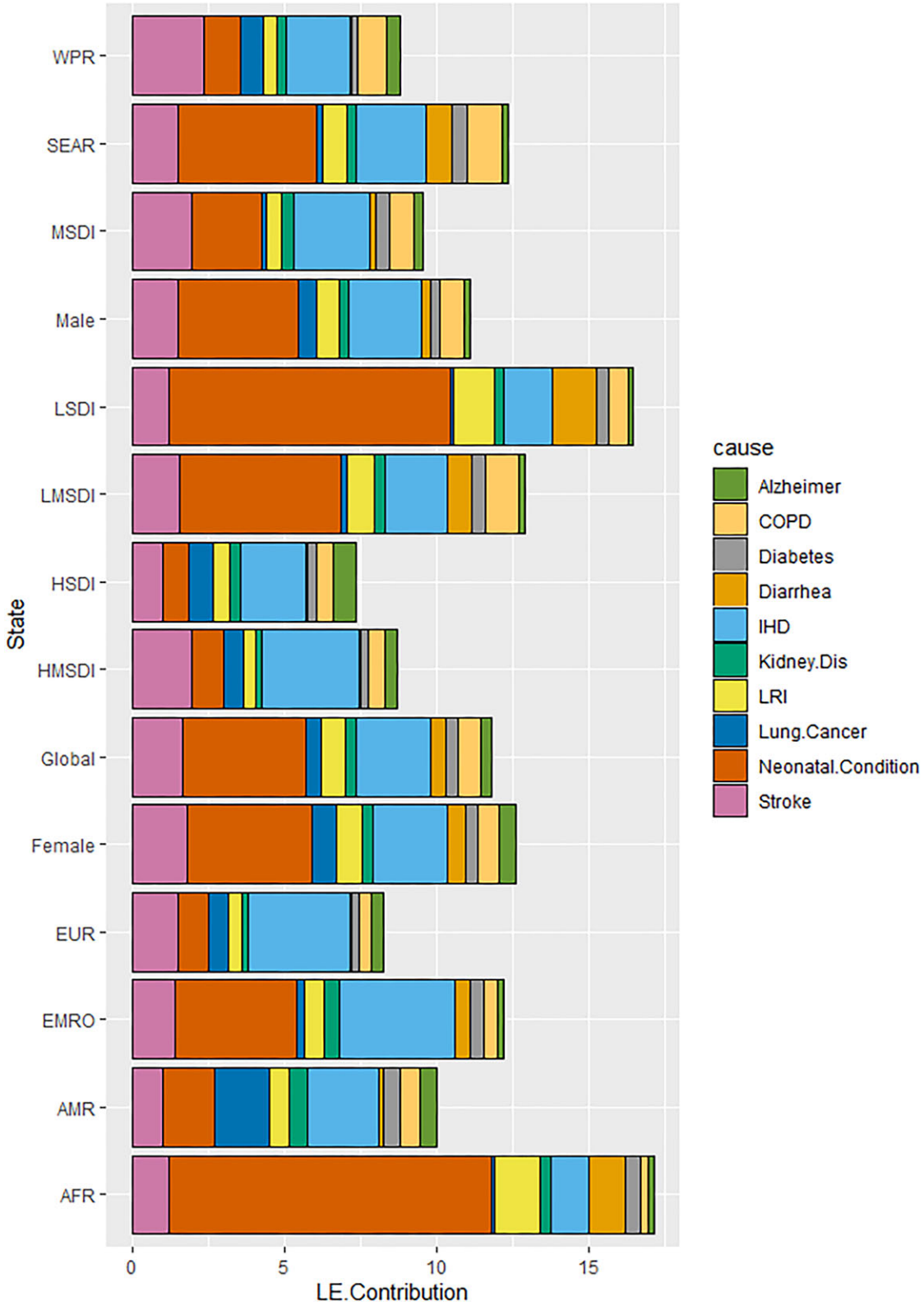

Figure 1. Top 10 cause of death contribution to LE increase in 2019 in the world and country groups based on the sex, SDI and the six WHO regions. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

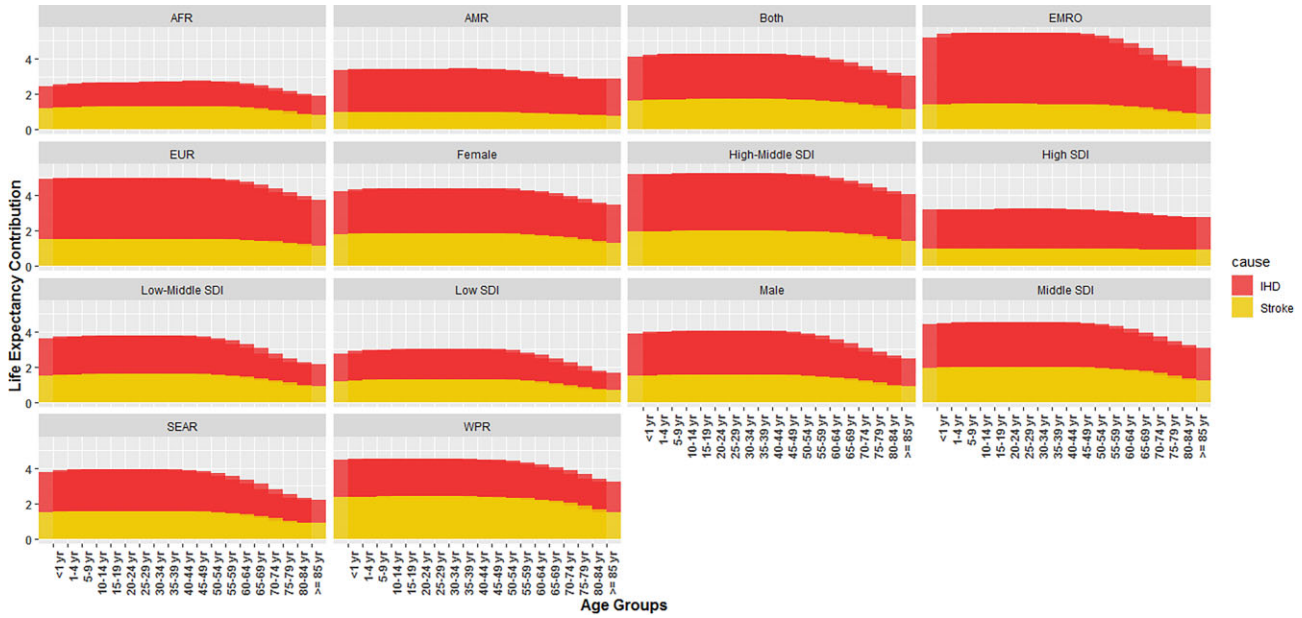

Figure 2. The map of the contribution of ischaemic heart disease (IHD) and stroke in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

In general, the LE in women was higher than in men (76.38 vs 70.92 y). We estimated that by removing deaths from ischaemic heart disease, LE in men and women will increase to 73.29 and 78.81 y, respectively (the at-birth LE increase for this cause of death in men and women was 2.37 and 2.43 y, respectively) (Table 1, Figure 1). Among men and women, the largest increase in LE will be obtained by elimination of deaths from neonatal conditions, ischaemic heart disease and stroke (increase in LE for these three causes was 3.96, 2.37 and 1.48 y in men, respectively, and 4.13, 2.43 and 1.76 y in women, respectively) (Table 1, Figure 1).

High SDI countries had the highest LE at birth (81.30 y) and low SDI countries had the lowest LE at birth (65.55 y) in 2019. It is estimated that with a 100% reduction in deaths from the first three causes of death, LE in low SDI countries will increase to 67.12, 66.75 and 66.22 y and in high SDI countries it will reach 83.49, 82.29 and 81.87 y, respectively (Table 1). Further details about changes in LE by elimination of each of the top 10 causes of death by grouping countries and territories according to SDI are presented in Table 1 and Figure 1.

The Western Pacific region (78.00 y), European region (77.88 y) and the Americas (77.34 y) had the highest LE at birth in 2019. It is estimated that the LE at birth in these three regions with the elimination of death from ischaemic heart disease will increase to 80.09, 81.27 and 79.70 y, respectively. In contrast, the African (65.03 y), Eastern Mediterranean (69.90 y) and South-East Asia (71.59 y) regions had the lowest LE at birth in 2019. It is worth considering that by eliminating deaths caused by neonatal conditions in the African region, LE at birth can be increased by 10.58 y. Generally, in the Western Pacific, European and Americas regions, the largest increase in at-birth LE will be achieved by eliminating deaths from ischaemic heart disease and the smallest increase will be achieved by eliminating deaths from diarrheal diseases. At the same time, in the African, Eastern Mediterranean and South-East Asia regions, the largest increase in at-birth LE is seen by eliminating neonatal conditions. In the African region, the lowest at-birth LE increase was related to lung cancer (0.13 y), and in the Eastern Mediterranean and South-East Asia regions it was related to Alzheimer's disease (0.21 y for both regions) (Table 1, Figure 1).

Figure 2 shows the age-specific increase in LE for ischaemic heart disease and stroke at the global level and by sex, grouping countries based on the SDI and WHO regions (Supplementary Tables S1–S14, Supplementary Figures S1–S14). The largest LE increases at the global level in all age subgroups, both sexes and different geographic areas are mainly due to ischaemic heart disease. In other words, eliminating deaths due to ischaemic heart disease mainly in women; the Eastern Mediterranean, Western Pacific and European regionsand high-middle SDI and middle SDI countries produces the largest increase LE.

COPD has a greater contribution to increase LE than lower respiratory infections (Figure 3, Supplementary Tables S1–S14, Supplementary Figures S1–S14). Except for the age groups younger than 4 y, the rest of the age subgroups had almost the same values of LE gain with complete removal of these causes.

Based on the information presented in Table 1 (Supplementary Tables S1–S14, Supplementary Figures S1–S14), the elimination of neonatal conditions brings the greatest gain in LE at the global level; in men; in the African, Eastern Mediterranean and South-East Asia regions; and in low, low-middle and middle SDI countries. In these areas, lung cancer contributes less to increasing LE at all ages compared with neonatal conditions. In contrast, eliminating lung cancer deaths

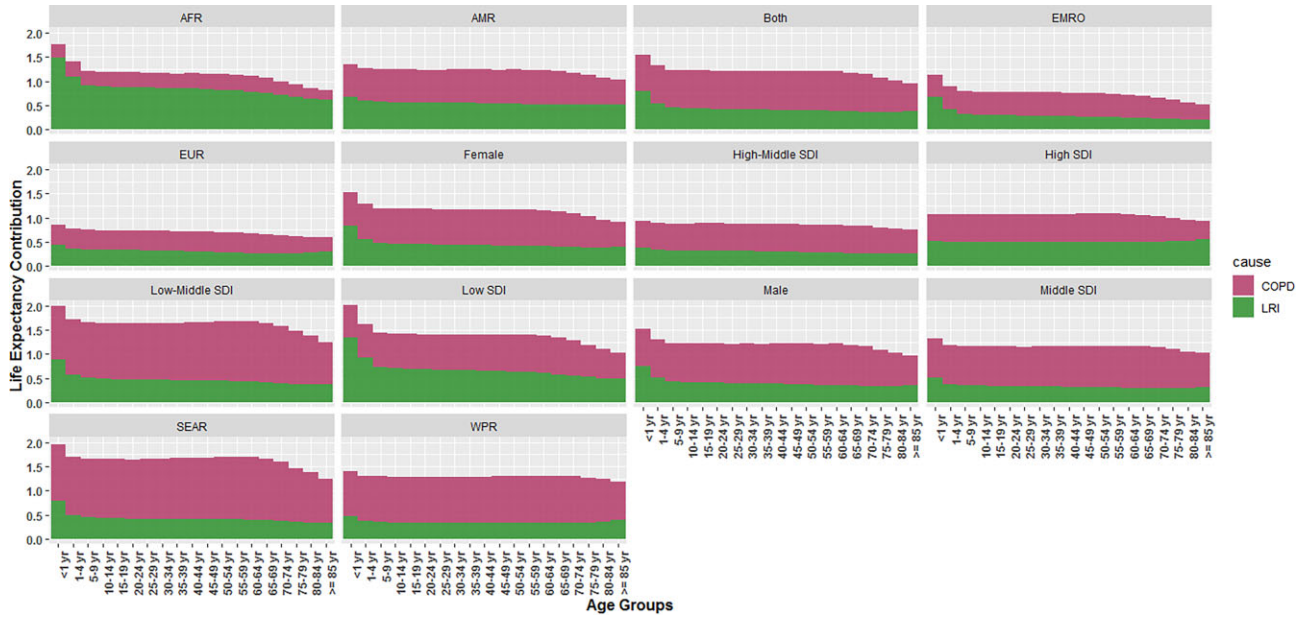

Figure 3. The map of the contribution of COPD and lower respiratory infections (LRI) in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

Figure 4. Map of the contribution of lung cancer and neonatal conditions in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

in women; the Americas, European and Western Pacific regions; and high SDI countries increases LE at all ages more than eliminating deaths from neonatal conditions (Figure 4, Supplementary Tables S1–S14, Supplementary Figures S1–S14).

Finally, the elimination of deaths from Alzheimer's produces the greatest increase in LE in developed areas with a higher SDI, while in these areas death from diarrheal diseases has less health importance (Figure 5, Supplementary Tables S1–S14, Supplementary Figures S1–S14). The contribution of diabetes

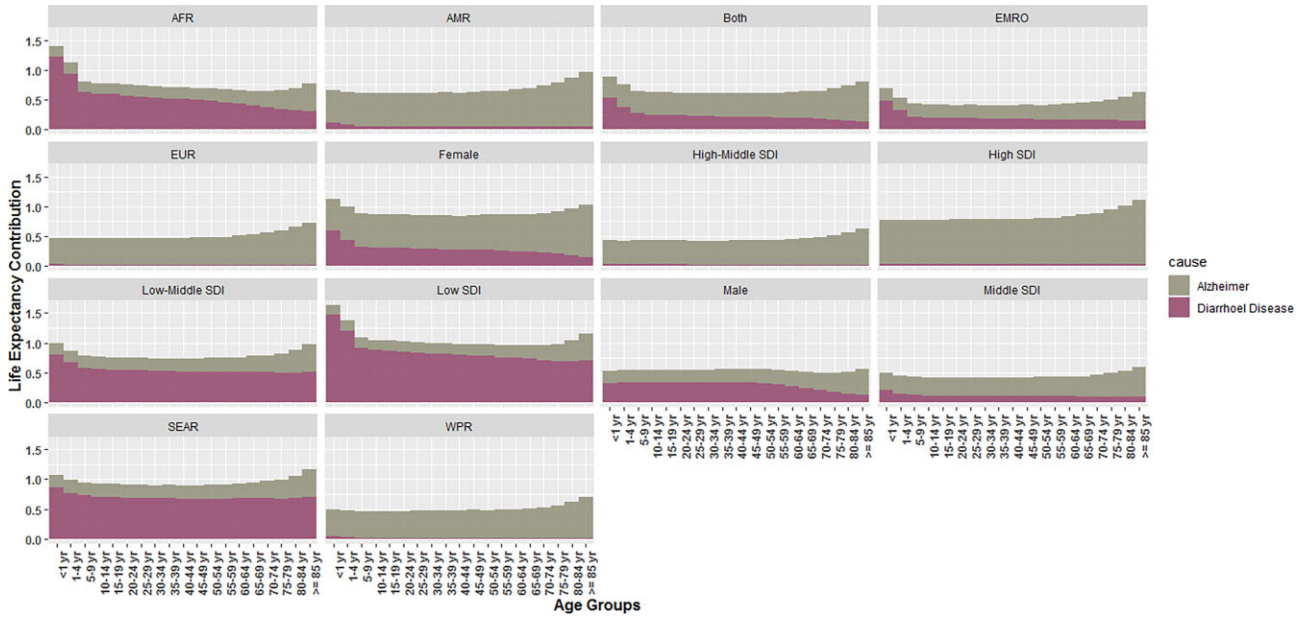

Figure 5. Map of the contribution of Alzheimer's and diarrhoeal diseases in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

mellitus and kidney diseases in LE increases was almost the same in both sexes, all WHO regions and grouping of countries based on the SDI (Figure 6, Supplementary Tables S1–S14, Supplementary Figures S1–S14).

Discussion

Our study showed that at the global level, eliminating deaths from neonatal conditions produced the greatest increase in LE at birth, and elimination of death from ischaemic heart disease and stroke produced the greatest gain in LE in the elderly >85 y of age. Neonatal conditions in high SDI countries do not have much health importance and increase LE at birth by <1 y, but their elimination in low SDI countries increases LE at birth by >9 y. This gap between increases in the LE at birth for different causes of death was also obvious among the six WHO regions. The existence of such disparities in the increase in LE among different societies with different sociodemographic status and among different geographic regions is rooted in imbalanced economic development and the transition from socialist systems that demand an equal share of public benefits for all societies compared with the capitalist system. At the micro level and in lower socio-economic societies, there are low levels of health awareness, e.g. the consumption of tobacco and alcohol is higher, while at the macro level, developed societies are able to provide the necessary resources for modern and expensive medical technologies.

Our estimates revealed that the African and South-East Asia regions and low and low-middle SDI countries obtained the highest LE at birth by completely eliminating deaths from neonatal conditions. The essential part of Sustainable Development Goal (SDG) 3 is to eliminate preventable child deaths and reduce it to <12 deaths per 1000 live births in 2030. According to the GBD study in 2017, the neonatal mortality rate in all regions of the world except sub-Saharan Africa (27.2 deaths per 1000 live births), East and South Africa (24.2 deaths per 1000 live births), West and Central Africa (30.2 deaths per 1000 live births), North Africa and the Middle East (12.6 deaths per 1000 live births) and South-East Asia (26.9 deaths per 1000 live births) is less than the critical level to achieve SDG 3.[12] Considering that the progress of high neonatal mortality regions in reducing neonatal mortality is moderate, it is recommended that policymakers pay more attention and re-examine the main causes of infant mortality in these regions.[13] Based on previous research, these causes are preterm birth and its complications, including sepsis, meningitis, pneumonia, asphyxia and congenital anomalies. Therefore, efforts to reduce inequalities and improve the provision of maternal and child services should be focused on areas where children are born into poverty and suffer most from adverse health outcomes.[14,15] To improve the survival of newborns and increase LE at birth, especially in the African and South-East Asian regions, it is recommended that newborns receive suitable public healthcare and proper nutritional support.[16] Also, preterm birth and low birth weight can be prevented by interventions related to education, maternal health and nutrition.[17] In addition, providing safe and high-quality places for deliveries will improve neonatal survival and increase their LE.[18] Finally, if policymakers analyse the successful strategies implemented in other regions, global neonatal mortality can be decreased and LE will increase, especially in areas with unfavourable neonatal conditions.

Elimination of deaths due to ischaemic heart disease and stroke in 2019 increased LE at birth and in other age groups, especially in the European, Americas and Western Pacific regions and in high and high-middle SDI countries. One hypothesis is that

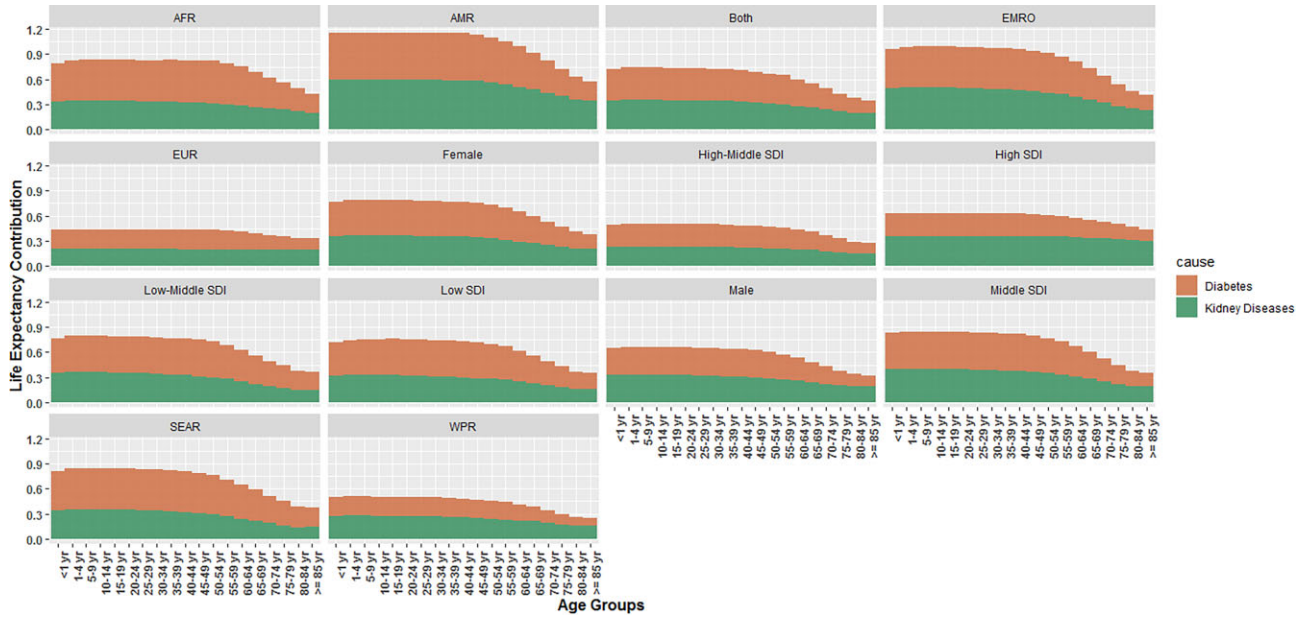

Figure 6. Map of the contribution of diabetes and kidney diseases in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI. Map of the contribution of Alzheimer's and diarrhoeal diseases in the increase of LE in 2019. AMR: Americas region; AFR: African region; EUR: European region; WPR: Western Pacific region; SEAR: South-East Asia region; EMRO: Eastern Mediterranean region; LSDI: low SDI; LMSDI: low-middle SDI; MSDI: middle SDI; HMSDI: high-middle SDI; HSDI: high SDI.

in high SDI countries, the availability of appropriate public health and medical care increases LE to the extent that ischaemic heart disease and stroke become more common, while in low SDI countries, people die due to other causes before reaching the age of stroke and ischaemic heart disease. Based on this hypothesis, middle SDI countries have LEs long enough to have a stroke or ischaemic heart disease, but their access to optimal medical or surgical treatments to treat these diseases is limited.[13,19] There is a similar justification and interpretation for Alzheimer's disease and other dementia diseases that occur in old age.[20]

Eliminating deaths from lung cancer produced the greatest increase in LE in the Americas region, high SDI countries and women. Lung cancer consistently ranked among the top three causes of death and years of life lost in high-income countries. Although the mortality rate and years of life lost from most cancers decreased from 2005 to 2015, lung cancer years of life lost increased in the same period.[13,21,22] Considering that the most important risk factors of lung cancer are smoking and air pollution, most cases of lung cancer can be prevented and LE can be increased not only in developed countries, but also in other parts of the world by controlling these risk factors.[23] Among the reasons for the small increase in LE in deprived areas is the lack of reliable registration of cancer data, the low prevalence of smoking (e.g. the prevalence of smoking in African men is 10% and in African women is <2%) and the low LE of the population, which prevents people from reaching the age of contracting a chronic disease such as lung cancer.[24]

Diarrheal diseases continued to be one of the top 10 causes of death in 2019. Their importance is not the same in all regions. Their complete elimination brings the greatest increase in LE in Africa and South-East Asia and in low and low-middle SDI countries, while in other areas it is not of much health importance. According to previous research, the most important causes of diarrhoea are poverty, malnutrition, poor hygiene, lack of access to safe drinking water, inadequate sanitary toilet coverage and poor home conditions.[25–28] The distribution of the mentioned risk factors is unequal and concentrated in deprived areas. Considering that the risk factors of diarrhoea have been well documented, the interventions in low and middle SDI countries should be increased in order to prevent death from diarrhoea. In general, to reduce these inequalities, providing equal access to high-quality treatment in deprived and marginalized areas should be considered. In addition to providing oral rehydration solutions and rotavirus vaccines, essential public health advancements in water, sanitation and hygiene may have played a significant role in reducing enteric-related deaths. Also, efforts should focus on the development of candidate vaccines targeting enterotoxigenic *Escherichia coli*, *Norovirus* and *Shigella*. By reducing gastrointestinal infections, we can expect to improve LE in the aforementioned regions.

Finally, we compared the findings of our study with the GBD study conducted in 2021. According to the results of this study and concordant with our analysis, the main contributors to age-standardized deaths worldwide remained consistent from 1990 to 2019. They were, in order, ischaemic heart disease, stroke, COPD and lower respiratory infections. However, in 2021, COVID-19 emerged as the second leading cause of death, surpassing stroke. This shift during the COVID-19 pandemic altered the ranking of the top five causes of death, with stroke moving to third place and COPD dropping to fourth. The GBD study in 2021

indicated that the reduction in deaths attributed to COVID-19 led to the greatest increase in LE across nearly all WHO regions. In contrast, prior to the COVID-19 pandemic, the greatest increases in LE in high and low SDI countries were attributed to reductions in deaths caused by ischaemic heart disease and neonatal conditions, respectively, which is consistent with our study. In line with the findings of our study, if we disregard the deaths attributed to the COVID-19 infection, in the Americas region removing deaths attributed to ischaemic heart disease will result in the greatest increase in LE, while the removal of deaths attributed to digestive diseases will produce the smallest increase. When we compare the results of our research with GBD data before the COVID-19 pandemic, between 1990 and 2019, LE has increased in most parts of the world. However, there was a net decrease of 1.6 y in global LE between 2019 and 2021, primarily attributed to increasing death rates from COVID-19 and other pandemic-related causes.[29]

Ultimately, unlike communicable, maternal, neonatal and nutritional diseases, the distribution of non-communicable diseases is not clustered and can be seen more or less in most regions of the world. This situation makes it difficult to implement policies and interventions to control non-communicable outcomes and subsequently increase LE. Thus future interventions should continue to address communicable diseases, particularly in areas where their mortality has become more concentrated. At the same time, policymakers should begin tackling non-communicable health outcomes in resource-limited environments.

This study is useful from several perspectives. First, by identifying and ranking the most important health outcomes for increases in LE in each area, public health programs and policies can be focused to eliminate and control these outcomes. Second, treatments and new medications should be distributed equitably in deprived areas that need more attention. Third, researchers and policymakers need to evaluate the effectiveness of and improvements in interventions.

The key strength of the present study is the calculation of changes in LE by removing the top 10 causes of death, which highlights the disparities between men and women, different countries in terms of sociodemographic status and different WHO regions.

Our study had several limitations that need to be taken into consideration when interpreting the results. First, we used the GBD dataset. GBD uses death registry data, with recording quality varying from one region to another. Second is the role of competing risks, which were not examined in this study. For example, death from ischaemic heart disease prevents deaths from Alzheimer's, kidney diseases or lung cancer, especially in the elderly, or death from neonatal conditions prevents death from other study outcomes later in life. The last limitation is the overlap of some causes of death, especially at older ages. For example, diabetes mellitus is a risk factor for the occurrence of kidney diseases.

Conclusions

In conclusion, our study showed that the greatest increases in LE in low and low-middle SDI countries are created by eliminating deaths from neonatal conditions, lower respiratory tract infections, ischaemic heart disease and diarrhoea, while in high-SDI areas, the elimination of ischaemic heart disease and stroke produces the greatest increase in LE. Diseases such as Alzheimer's and lung cancer, which usually occur in old age, are not of much importance in low SDI areas because people do not live long enough to develop these diseases. Considering the gap between high SDI and low SDI regions, international measures should be taken to reduce these inequalities. Therefore, public health policies should be designed according to each geographic region in order to produce the greatest increases in LE.

Supplementary data

Supplementary data are available at *International Health* online.

Authors' contributions: FS and YM were responsible for the conceptualization, methodology, project administration and review and editing of the manuscript. FS and ZM were responsible for data curation. FS, ZM and SM were responsible for the formal analysis. YM was responsible for funding acquisition. FS and SM were responsible for visualization. FS, SM, ZM and YM wrote the original draft.

Acknowledgments: We greatly appreciate the GBD and United Nations Department of Economics and Social Affairs Population Division websites, which have made data available for researchers around the world to conduct global, regional and national research.

Funding: This work received financial support from the Vice-chancellor of Research and Technology at Hamadan University of Medical Sciences (project code 140306134824).

Competing interests: None declared.

Ethical approval: The study received ethical approval from the Ethics Committee of Hamadan University of Medical Sciences (IR.UMSHA.REC.1403.368).

Data availability: The data underlying this article will be shared on reasonable request to the corresponding author.

References

1 Wéber A, Laversanne M, Nagy P, et al. Gains in life expectancy from decreasing cardiovascular disease and cancer mortality – an analysis of 28 European countries 1995–2019. Eur J Epidemiol. 2023;38(11):1141–52.

2 Vishnevsky A. The epidemiological transition and its interpretations. Demographic Rev. 2021;7(5):4–41.

3 Malvezzi M, Carioli G, Bertuccio P, et al. Relation between mortality trends of cardiovascular diseases and selected cancers in the European Union, in 1970–2017. Focus on cohort and period effects. Eur J Cancer. 2018;103:341–55.

4 World Health Organization. Health topics, the top 10 causes of death 2024. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death [accessed 25 February 2024].

5 Phetsitong R, Soonthorndhada K. Gains in life expectancy due to eliminating major causes of death in Thai older persons. J Health Res. 2016;30(3):181–9.

6 Rutherford MJ, Andersson TM, Björkholm M, et al. Loss in life expectancy and gain in life years as measures of cancer impact. Cancer Epidemiol. 2019;60:168–73.

7 Fadnes LT, Celis-Morales C, Økland J-M, et al. Life expectancy can increase by up to 10 years following sustained shifts towards healthier diets in the United Kingdom. Nat Food. 2023;4(11):961–5.

8 Woolf SH, Masters RK, Aron LY. Changes in life expectancy between 2019 and 2020 in the US and 21 peer countries. JAMA Netw Open. 2022;5(4):e227067.

9 Mohammadi Y, Parsaeian M, Mehdipour P, et al. Measuring Iran's success in achieving Millennium Development Goal 4: a systematic analysis of under-5 mortality at national and subnational levels from 1990 to 2015. Lancet Glob Health. 2017;5(5):e537–44.

10 Woolf SH, Schoomaker H. Life expectancy and mortality rates in the United States, 1959–2017. JAMA. 2019;322(20):1996–2016.

11 Global Burden of Disease. Global Burden of Disease Study 2019 Data Resources. https://vizhub.healthdata.org/gbd-results/ [accessed 20 February 2024].

12 Hug L, Alexander M, You D, et al. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. Lancet Glob Health. 2019;7(6):e710–20.

13 GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388(10053):1459–544.

14 Sousa A, Hill K, Dal Poz MR. Sub-national assessment of inequality trends in neonatal and child mortality in Brazil. Int J Equity Health. 2010;9:21.

15 Fadel SA, Rasaily R, Awasthi S, et al. Changes in cause-specific neonatal and 1–59-month child mortality in India from 2000 to 2015: a nationally representative survey. Lancet. 2017;390(10106):1972–80.

16 Lawn JE, Davidge R, Paul VK, et al. Born too soon: care for the preterm baby. Reprod Health. 2013;10(Suppl 1):S5.

17 Hunter PJ, Muthiani Y, Näsänen-Gilmore PK, et al. A modular systematic review of antenatal interventions to address undernutrition during pregnancy in the prevention of low birth weight. Am J Clin Nutr. 2023;117(Suppl 2):S134–47.

18 Lawn JE, Blencowe H, Oza S, et al. Every newborn: progress, priorities, and potential beyond survival. Lancet. 2014;384(9938):189–205.

19 Feigin VL, Stark BA, Johnson CO, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol. 2021;20(10):795–820.

20 Nichols E, Szoeke CE, Vollset SE, et al. Global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. 2019;18(1):88–106.

21 Zhang J, Li J, Xiong S, et al. Global burden of lung cancer: implications from current evidence. Ann Cancer Epidemiol. 2021;5:4.

22 Malhotra J, Malvezzi M, Negri E, et al. Risk factors for lung cancer worldwide. Eur Respir J. 2016;48(3):889–902.

23 Bidell MR, McLaughlin M, Faragon J. Desirable characteristics of hepatitis C treatment regimens: a review of what we have and what we need. Infect Dis Ther. 2016;5(3):299–312.

24 Barta JA, Powell CA, Wisnivesky JP. Global epidemiology of lung cancer. Ann Glob Health. 2019;85(1):8.

25 Atnafu A, Sisay MM, Demissie GD, et al. Geographical disparities and determinants of childhood diarrheal illness in Ethiopia: further analysis of 2016 Ethiopian Demographic and Health Survey. Trop Med Health. 2020;48:64.

26 Yourkavitch J, Burgert-Brucker C, Assaf S, et al. Using geographical analysis to identify child health inequality in sub-Saharan Africa. PLoS One. 2018;13(8):e0201870.

27 Nilima N, Kamath A, Shetty K, et al. Prevalence, patterns, and predictors of diarrhea: a spatial-temporal comprehensive evaluation in India. BMC Public Health. 2018;18:1288.

28 Edwin P, Azage M. Geographical variations and factors associated with childhood diarrhea in Tanzania: a national population based survey 2015–16. Ethiop J Health Sci. 2019;29(4):513–24.

29 GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2100–32.