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Falling rates, rising deaths: the burden of venomous animal contact in sub-Saharan Africa, 1990 to 2023, and the distance to the WHO 2030 target

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Research Article

Keywords: Snakebite envenoming, venomous animal contact, Global Burden of Disease, sub-Saharan Africa, health inequality, neglected tropical diseases, decomposition analysis

Posted Date: July 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10418535/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Snakebite envenoming, the dominant cause of venomous animal contact in sub-Saharan Africa, is a poverty-related neglected tropical disease controllable through antivenom access and health-system reach, and the focus of a World Health Organization commitment to halve death and disability by 2030. Whether progress has matched population growth, and whether the region will meet that target, has not been established using Global Burden of Disease (GBD) 2023.

Methods

We analysed GBD 2023 estimates of deaths, disability-adjusted life years (DALYs) and incidence from venomous animal contact across 46 sub-Saharan African countries, four regions, five Socio-demographic Index quintiles, 1990 to 2023. We quantified trends with the estimated annual percentage change (EAPC) and joinpoint regression, partitioned the change in deaths into population growth, ageing and epidemiological change by Das Gupta decomposition, measured cross-country inequality with the slope index of inequality (SII) and concentration index, and projected age-standardised mortality to 2030 against the WHO target.

Results

Age-standardised mortality fell 28.9%, from 3.75 to 2.67 per 100,000 (EAPC − 1.26, 95% CI -1.32 to -1.20), yet deaths rose 54.8%, from 15,170 to 23,478, and the region's share of global deaths climbed from 16.3% to 25.1%. Thirty-three of 46 countries recorded a falling rate alongside a rising death count. Decomposition attributed 17,966 additional deaths to population growth and 9,683 averted deaths to epidemiological change, while ageing contributed 25 (0.3%). Burden concentrated in the poorest countries (concentration index − 0.153, 95% CI -0.281 to -0.008). The decline has stalled, from − 1.41% annually between 1995 and 2018 to -0.06% between 2018 and 2023. On the post-2005 trajectory the projected 2030 rate is 2.37 per 100,000, 60.2% above the target of 1.48; meeting it would require an 8.05% annual decline.

Conclusions

Sub-Saharan Africa made real epidemiological progress until 2018 but has since been overtaken by population growth and its improvement has stalled, and it will miss the WHO 2030 target by a wide margin. Because ageing is not a driver, the shortfall reflects intervention that has not scaled rather than demographic inevitability: antivenom access and health-system reach must expand faster than the population, and progress should be tracked against both rates and counts.

Clinical trial number: not applicable.

Background

Snakebite envenoming was reinstated as a category A neglected tropical disease by the World Health Organization (WHO) in 2017, and in 2019 WHO adopted a strategy committing member states to halving snakebite death and disability by 2030 [1, 2]. Sub-Saharan Africa carries a disproportionate share of that burden: a meta-analysis across 41 countries estimated an annual regional burden of 1.03 million disability-adjusted life years (DALYs) [3, 4]. The region combines high densities of medically important snake species, agricultural livelihoods that place people in repeated contact with them, long distances to facilities capable of administering antivenom, and chronic shortages of effective and affordable product. With the exception of South Africa, no antivenom is manufactured on the subcontinent, and supply depends entirely on importation, with affordability and rural access described as grossly suboptimal [5, 6]. Recent global estimates continue to rank sub-Saharan Africa among the regions of highest snakebite mortality, with the greatest mortality burden falling on low-income countries [19].

Progress against the 2030 target has been difficult to audit. The most recent global assessment of snakebite mortality grounded in the Global Burden of Disease (GBD) framework drew on GBD 2019 and reported estimates only to 2019 [7]. It found that mortality had declined over three decades but at a rate insufficient to meet the WHO goal, with sub-Saharan Africa carrying the second largest number of deaths after South Asia. Since then the underlying data have been revised twice. GBD 2023, released in October 2025, provides estimates for 375 diseases and injuries and 292 causes of death across 204 countries and territories through 2023, incorporating substantial methodological revision and three additional years of observation [8, 9]. Recent GBD-based analyses of other poverty-related infections have shown how such data can localise burden and direct control priorities in the worst-affected settings [20, 21].

Two further gaps persist. First, most burden analyses of this cause are global [7, 16], and the aggregate obscures sub-Saharan Africa's distinctive position: a young, rapidly growing population in which the demography of burden differs fundamentally from the ageing populations that dominate global disease trends. Second, and more consequentially, the standard reporting of age-standardised rates can conceal the direction of travel. A falling rate is routinely read as success, but where population growth is rapid a falling rate is entirely compatible with a rising number of deaths. Whether that is what has happened in sub-Saharan Africa, and if so what is driving it, has not been established.

Because snakebite control in the region turns on the reach of a single intervention, antivenom delivered through functioning peripheral health services, the central question is whether that reach has scaled with the population it must cover. We therefore used GBD 2023 to characterise the burden of venomous animal contact in sub-Saharan Africa from 1990 to 2023; to decompose the change in deaths into the contributions of population growth, population ageing and epidemiological change; to quantify socioeconomic inequality in burden using WHO-endorsed measures; and to project mortality to 2030 in order to assess, explicitly, the region's distance from the WHO target.

Methods

Data source and case definition

We extracted estimates from the GBD 2023 study through the GBD Results Tool of the Institute for Health Metrics and Evaluation (IHME). GBD 2023 quantifies health loss for 375 diseases and injuries and 292 causes of death across 204 countries and territories and 660 subnational locations for the years 1990 to 2023, and follows the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) [8, 9, 10].

The cause analysed is venomous animal contact, a cause within the unintentional injuries hierarchy of GBD. We adopt this cause because GBD does not model snakebite envenoming as a standalone cause; snake-specific estimates are derived by applying separately modelled attribution proportions to the venomous animal contact envelope, and those proportions are not distributed through the public results tool [7]. Snakebite is the dominant contributor to venomous animal contact deaths in sub-Saharan Africa, and we interpret our findings on that basis, but the cause is broader than snakebite alone and we treat this as a limitation rather than an equivalence.

We extracted deaths, DALYs and incidence, as numbers, rates and age-standardised rates, with 95% uncertainty intervals (UIs), for both sexes and separately for males and females, for the 46 sub-Saharan African countries, the four GBD sub-Saharan African regions (Western, Eastern, Central and Southern), the sub-Saharan African super-region, the five SDI quintiles, and globally. Age-specific estimates were extracted in 20 non-overlapping bands from under 5 years to 95 years and older. Population estimates for the same locations, ages and years were extracted separately from the GBD 2023 population dataset. SDI values were obtained from the GBD 2023 Socio-demographic Index dataset released through the Global Health Data Exchange [11].

Descriptive and trend analysis

We described the number of cases, crude rates and age-standardised rates for 1990 and 2023 at global, regional, national and SDI-quintile level, and computed percentage change over the period.

Temporal trend was summarised using the estimated annual percentage change (EAPC), derived from the linear regression of the natural logarithm of the age-standardised rate on calendar year, ln(ASR) = alpha + beta x year, with EAPC = 100 x (exp(beta) − 1) and its 95% confidence interval taken from the standard error of beta [12]. A trend was classified as decreasing when both the EAPC and the upper bound of its confidence interval were below zero, increasing when both the EAPC and the lower bound were above zero, and stable otherwise. Local inflections in trend were identified using segmented (joinpoint) regression on the log-transformed age-standardised rate, with the annual percentage change reported for each detected segment.

Decomposition analysis

To identify what drove the change in the number of deaths between 1990 and 2023, we applied the symmetric Das Gupta decomposition [13, 14]. Deaths in an age band are the product of total population,

the share of the population in that band, and the age-specific death rate; the difference in total deaths between two time points can therefore be partitioned exactly into a population growth component, a population age-structure (ageing) component, and an epidemiological component reflecting change in age-specific rates. Components were computed across all 20 age bands and summed. The decomposition is exact by construction, and we verified that the three components summed to the observed change in every location analysed.

Cross-country inequality analysis

Absolute and relative socioeconomic inequality across the 46 sub-Saharan African countries were quantified using the slope index of inequality (SII) and the concentration index, the measures recommended by WHO for health inequality monitoring [15]. Countries were ranked by SDI and assigned a relative rank score corresponding to the midpoint of their band in the cumulative population distribution. The SII is the population-weighted regression coefficient of the age-standardised mortality rate on this relative rank, and estimates the absolute difference in rate between the notionally most and least disadvantaged positions. The concentration index measures relative inequality against the cumulative distribution of burden. Both were computed for 1990 and 2023, with 95% confidence intervals obtained by bootstrap resampling with 3,000 replicates.

We additionally examined whether individual countries carried more or less burden than their level of development would predict by fitting a locally estimated scatterplot smoothing (LOESS) curve of the age-standardised mortality rate on SDI and examining the standardised residuals. We deliberately did not perform a stochastic frontier analysis: the frontier method in the GBD literature is calibrated across all 204 countries, and applying it to a 46-country subset would not be well identified.

Projection and assessment against the WHO target

The WHO strategy commits to halving snakebite death and disability by 2030 against a 2010 baseline [1]. We took the 2010 age-standardised mortality rate for sub-Saharan Africa as the baseline, defined the target as half that value, and projected the rate to 2030 by log-linear extrapolation of the trend observed from 2005 onward, a window chosen to reflect the current epidemiological regime rather than the full 34-year series. We also computed the annual rate of decline that would be required from 2023 to reach the target on time. We report this transparent projection in preference to a Bayesian age-period-cohort model because the latter depends on the INLA library, which is not reliably installable in the computing environment available to us, and because the substantive conclusion does not turn on the choice of method.

Statistical analysis and ethics

Uncertainty intervals for GBD estimates are propagated from 1,000 draws at each step of the modelling process, with the 95% UI defined by the 2.5th and 97.5th ordered values. All analyses were conducted in R version 4.6.1 [17]. Analysis code is available (see Availability of data and materials). This study used publicly available, de-identified, aggregated estimates and did not require ethical approval.

Results

Falling rates alongside rising deaths

In 2023 venomous animal contact caused an estimated 23,478 deaths (95% UI 14,602 to 35,235) in sub-Saharan Africa, up 54.8% from 15,170 (95% UI 7,940 to 27,871) in 1990. Over the same period the age-standardised mortality rate fell 28.9%, from 3.75 (95% UI 1.94 to 6.90) to 2.67 (95% UI 1.67 to 3.93) per 100,000, with an EAPC of -1.26 (95% CI -1.32 to -1.20) (Table 1, Table 2, Fig. 1).

Table 1
Deaths from venomous animal contact, sub-Saharan Africa and comparators, 1990 and 2023

Location	Deaths 1990 (95% UI)	Deaths 2023 (95% UI)	Change (%)
Global	92,934 (55,589 to 146,820)	93,670 (56,312 to 137,066)	+ 0.8
Sub-Saharan Africa	15,170 (7,940 to 27,871)	23,478 (14,602 to 35,235)	+ 54.8
Western sub-Saharan Africa	3,842 (2,023 to 7,471)	7,980 (3,551 to 13,693)	+ 107.7
Eastern sub-Saharan Africa	9,774 (4,944 to 17,804)	12,719 (7,969 to 18,915)	+ 30.1
Central sub-Saharan Africa	1,242 (591 to 2,337)	2,286 (1,281 to 3,997)	+ 84.1
Southern sub-Saharan Africa	312 (180 to 495)	493 (301 to 754)	+ 58.2

UI, uncertainty interval.

Table 2
Age-standardised mortality rate per 100,000 and estimated annual percentage change, 1990 to 2023

Location	ASMR 1990	ASMR 2023	Change (%)	EAPC (95% CI)
Global	1.80	1.13	-37.1	-1.52 (-1.60 to -1.45)
Sub-Saharan Africa	3.75	2.67	-28.9	-1.26 (-1.32 to -1.20)
Western sub-Saharan Africa	2.47	2.18	-11.7	-0.68 (-0.82 to -0.55)
Eastern sub-Saharan Africa	6.43	4.00	-37.8	-1.68 (-1.77 to -1.59)
Central sub-Saharan Africa	2.75	2.13	-22.4	-0.78 (-0.86 to -0.69)
Southern sub-Saharan Africa	0.69	0.61	-11.3	-0.28 (-0.53 to -0.02)
Low SDI	6.07	3.26	-46.3	-2.09 (-2.19 to -2.00)
Low-middle SDI	5.59	3.09	-44.7	-1.77 (-1.85 to -1.69)
Middle SDI	0.83	0.47	-43.7	-1.80 (-1.85 to -1.74)
High-middle SDI	0.93	0.68	-26.8	-1.02 (-1.19 to -0.85)
High SDI	0.11	0.05	-58.1	-3.04 (-3.17 to -2.92)

ASMR, age-standardised mortality rate per 100,000. EAPC, estimated annual percentage change. SDI, Socio-demographic Index.

Globally the number of deaths was almost unchanged, at 92,934 in 1990 and 93,670 in 2023, while the global age-standardised rate fell 37.1% (EAPC − 1.52, 95% CI -1.60 to -1.45). Sub-Saharan Africa's share of global deaths consequently rose from 16.3% to 25.1%. DALYs in the region increased 39.1%, from 961,184 to 1,337,460, while the age-standardised DALY rate fell 36.3% (EAPC − 1.62, 95% CI -1.72 to -1.53). Incident cases nearly doubled, from 1,168,174 to 2,204,570.

The divergence between rate and count was not confined to the aggregate. Of the 46 countries, 39 recorded a fall in the age-standardised mortality rate and 40 recorded a rise in the number of deaths; 33 recorded both simultaneously. Seven countries recorded a rising age-standardised rate: Cabo Verde, Chad, Guinea-Bissau, Mauritania, Niger, Senegal and Zimbabwe.

Regional heterogeneity

Eastern sub-Saharan Africa carried the highest burden in 2023 (4.00 per 100,000, 95% UI 2.53 to 6.04) but also achieved the fastest decline (EAPC − 1.68, 95% CI -1.77 to -1.59), its rate having fallen 37.8% since 1990. Western sub-Saharan Africa presents the opposite profile: a rate of 2.18 per 100,000 that has fallen only 11.7% (EAPC − 0.68, 95% CI -0.82 to -0.55), while its death count more than doubled, rising 107.7% from 3,842 to 7,980. Central sub-Saharan Africa saw deaths rise 84.1% against a 22.4% rate decline. Southern sub-Saharan Africa carries a far lower burden (0.61 per 100,000, roughly one sixth of the Eastern rate) and has seen minimal improvement (EAPC − 0.28, 95% CI -0.53 to -0.02).

At country level, South Sudan had by far the highest age-standardised mortality rate in 2023 at 13.47 per 100,000 (95% UI 3.79 to 30.99), roughly double the next highest, Eritrea (6.72). Madagascar (5.74), Kenya (4.82) and Somalia (4.61) followed. Ethiopia carried the largest absolute burden (3,327 deaths), followed by Nigeria (2,939), Kenya (1,838) and the Democratic Republic of the Congo (1,632). Uganda ranked 14th by rate (3.26 per 100,000, 95% UI 1.80 to 6.01), having reduced its rate by 45.9% while its death count rose 33% to 998 (Table 6, Fig. 5).

Table 6
Ten countries with the highest age-standardised mortality rate, 2023

Country	ASMR 2023 (95% UI)	ASMR change (%)	Deaths 2023	Deaths change (%)
South Sudan	13.47 (3.79 to 30.99)	-20.5	985	+ 38
Eritrea	6.72 (3.56 to 10.99)	-21.4	411	+ 62
Madagascar	5.74 (3.04 to 9.91)	-44.6	1,108	+ 29
Kenya	4.82 (2.62 to 8.07)	-33.3	1,838	+ 67
Somalia	4.61 (1.76 to 8.89)	-25.9	770	+ 97
Ethiopia	4.29 (2.68 to 6.89)	-29.3	3,327	+ 27
Burundi	4.26 (2.00 to 7.72)	-30.4	478	+ 51
Chad	3.98 (1.35 to 10.01)	+ 16.0	461	+ 194
Rwanda	3.82 (2.10 to 6.67)	-51.9	419	-22
Zambia	3.72 (2.14 to 6.82)	-36.0	497	+ 45

ASMR, age-standardised mortality rate per 100,000. Chad is one of seven countries in which the age-standardised rate increased.

The decline has stalled since 2018

Joinpoint regression identified three distinct phases in the sub-Saharan African trend (Table 3). The rate fell slowly between 1990 and 1995 (APC − 0.57%), then declined steadily for more than two decades

between 1995 and 2018 (APC − 1.41%). Since 2018 the decline has effectively ceased, with an APC of -0.06%, indicating a flat trajectory over the most recent five years.

Table 3
Joinpoint regression of the age-standardised mortality rate, 1990 to 2023

Location	Segment	APC (%)
Global	1990 to 1999	-1.13
	1999 to 2015	-1.84
	2015 to 2023	-0.67
Sub-Saharan Africa	1990 to 1995	-0.57
	1995 to 2018	-1.41
	2018 to 2023	-0.06
Western sub-Saharan Africa	1990 to 2001	+ 0.74
	2001 to 2008	-1.79
	2008 to 2023	-0.77
Eastern sub-Saharan Africa	1990 to 2006	-1.96
	2006 to 2018	-1.63
	2018 to 2023	-0.10

APC, annual percentage change within each detected segment. Breakpoints selected by Bayesian information criterion.

The same pattern is visible in Eastern sub-Saharan Africa, the region that had achieved the fastest improvement: its rate fell at -1.96% per year between 1990 and 2006 and − 1.63% between 2006 and 2018, but at only − 0.10% since 2018. Globally the decline also slowed, from − 1.84% per year between 1999 and 2015 to -0.67% thereafter. Western sub-Saharan Africa followed a different course: its rate rose between 1990 and 2001 (APC + 0.74%) before falling, and has declined at only − 0.77% per year since 2008.

This stall is material to the WHO target. Progress has not merely been too slow; it has largely stopped in the five years immediately preceding the assessment year.

Population growth, not ageing, drives the rising death count

Decomposition of the 8,308 additional deaths recorded in sub-Saharan Africa between 1990 and 2023 shows that population growth would, on its own, have added 17,966 deaths. Epidemiological change,

that is improvement in age-specific mortality, averted 9,683 deaths. Population ageing contributed 25 deaths, or 0.3% of the net change (Table 4, Fig. 7).

Table 4
Decomposition of the change in deaths, 1990 to 2023

Location	Population growth	Population ageing	Epidemiological change	Observed net change
Sub-Saharan Africa	+ 17,966	+ 25	-9,683	+ 8,308
Western sub-Saharan Africa	+ 5,738	-206	-1,395	+ 4,137
Eastern sub-Saharan Africa	+ 10,402	+ 213	-7,670	+ 2,945
Central sub-Saharan Africa	+ 1,736	-4	-689	+ 1,044
Southern sub-Saharan Africa	+ 206	+ 29	-53	+ 181

Values are the contribution of each component to the change in the number of deaths, from symmetric Das Gupta decomposition. Components sum exactly to the observed net change.

The negligible contribution of ageing distinguishes this cause sharply from the non-communicable disease burden that dominates the GBD literature, where ageing is typically a principal driver. Venomous animal contact kills across the life course in a population that remains young, and the age distribution of that population changed little over the period. Demography therefore acts on this cause almost purely through the number of people exposed, not through their age distribution.

The regional pattern reinforces the point. Eastern sub-Saharan Africa achieved the largest epidemiological gain in the region, averting 7,670 deaths, but population growth added 10,402, leaving a net increase of 2,945. Western sub-Saharan Africa averted only 1,395 deaths against 5,738 added by growth, yielding the largest net increase of any region (4,137).

Age and sex distribution

Mortality rates rose steeply with age, reaching 26.46 per 100,000 in those aged 95 years and older. The gradient was not monotonic at the youngest ages: the rate in children under 5 (1.71 per 100,000) exceeded that in adolescents aged 15 to 19 (1.17) and young adults aged 20 to 24 (0.94), producing a secondary elevation in early childhood (Fig. 4). Because the population pyramid is young, most deaths nonetheless occurred at working age: 30.5% of deaths occurred before age 15 and 54.0% between the ages of 15 and 64. Males accounted for 13,048 deaths and females 10,430, a ratio of 1.25 to 1, and the male excess widened markedly with age.

Socioeconomic gradient and inequality

Burden was strongly and inversely associated with development. Across the 46 countries the Spearman correlation between SDI and the age-standardised mortality rate strengthened from − 0.492 ($p < 0.001$) in 1990 to -0.607 ($p < 0.001$) in 2023, indicating an increasingly consistent gradient. Across SDI quintiles, the low SDI quintile recorded a 2023 rate of 3.26 per 100,000 against 0.045 in the high SDI quintile, a ratio of 72 to 1 (Fig. 2). The gradient was not strictly monotonic: the middle SDI quintile recorded a lower rate (0.47 per 100,000) than the high-middle quintile (0.68), a reversal present in 1990 as well. Burden is therefore concentrated in the low and low-middle quintiles rather than declining smoothly across the SDI spectrum, consistent with the geographical clustering of medically important snake species in the tropics.

Population-weighted inequality measures give a more nuanced account. The slope index of inequality was − 3.77 (95% CI -5.89 to 0.17) in 1990 and − 2.55 (95% CI -4.44 to -0.25) in 2023, and the concentration index was − 0.161 (95% CI -0.317 to 0.004) in 1990 and − 0.153 (95% CI -0.281 to -0.008) in 2023 (Table 5, Fig. 8). Both remained negative, confirming that burden is concentrated among the most disadvantaged. Absolute inequality narrowed modestly, a consequence of falling rates overall rather than of convergence between rich and poor countries, while relative inequality was essentially unchanged. Notably, both 1990 intervals crossed the null whereas both 2023 intervals did not: the gradient has become statistically discernible even as its absolute magnitude has eased.

Table 5
Cross-country inequality in age-standardised mortality, 46 sub-Saharan African countries

Year	Slope index of inequality (95% CI)	Concentration index (95% CI)
1990	-3.77 (-5.89 to 0.17)	-0.161 (-0.317 to 0.004)
2023	-2.55 (-4.44 to -0.25)	-0.153 (-0.281 to -0.008)

Both measures are population weighted, with countries ranked by Socio-demographic Index. Negative values indicate burden concentrated in lower-SDI countries. Confidence intervals from 3,000 bootstrap replicates.

LOESS modelling of expected burden given SDI identified countries carrying substantially more burden than their development level predicts. South Sudan is the extreme outlier. Kenya is notable in a different way: its SDI of 0.549 is well above the regional norm, yet its rate of 4.82 per 100,000 exceeds that of Somalia (4.61), whose SDI is 0.229. Burden in these settings is not explained by poverty alone (Fig. 6).

Distance from the WHO 2030 target

The 2010 age-standardised mortality rate for sub-Saharan Africa was 2.96 per 100,000, making the WHO 2030 target 1.48 per 100,000. By 2023 the rate had fallen to 2.67, a reduction of just 10.0% against the 2010 baseline, with 13 of the 20 years of the target period elapsed.

Extrapolating the trend observed since 2005 (-1.09% per year) gives a projected 2030 rate of 2.37 per 100,000, which is 60.2% above the target (Fig. 3). Meeting the target from the 2023 position would

require an annual decline of 8.05% sustained for seven years, roughly seven times the rate the region has achieved over the past two decades. On any reasonable reading of the trend, sub-Saharan Africa will not halve mortality from this cause by 2030.

Discussion

Using the most recent GBD round, we find that sub-Saharan Africa is simultaneously succeeding and failing against venomous animal contact. Age-standardised mortality has fallen by more than a quarter since 1990, which is genuine epidemiological progress and should be recognised as such. Yet the number of people dying has risen by more than half, the region's share of the global burden has climbed from a sixth to a quarter, and the WHO 2030 target is now out of reach on current trends.

The decomposition explains the paradox and, we argue, should reframe how progress against this target is judged. The rising death count is not evidence that interventions have failed; interventions averted nearly ten thousand deaths over the period. It is evidence that they have not scaled with the population. Sub-Saharan Africa's population grew from 492 million to 1.21 billion between 1990 and 2023, an increase of 145%, and the per-capita improvement in mortality was simply too slow to absorb that growth. Because population ageing contributed almost nothing, the shortfall cannot be attributed to an unfavourable demographic transition of the kind that drives rising cardiovascular or cancer burden elsewhere. It is a question of coverage and reach.

This has a direct policy implication. Targets expressed as rate reductions, as the WHO target is, are the epidemiologically correct way to measure programme effectiveness, but they can be met, or approached, while the number of people dying rises. Where the target is meant to represent lives saved, both metrics need to be reported together. A country that halves its age-standardised rate while its population doubles has saved no one.

The joinpoint analysis adds a further, and more troubling, dimension. Sub-Saharan Africa did make sustained progress: between 1995 and 2018 the age-standardised rate fell by about 1.4% each year. Since 2018 that decline has effectively stopped. The same reversal is evident in Eastern sub-Saharan Africa, the region that had previously improved fastest. We cannot identify the cause from these data, and we are cautious about attributing it to any single factor, but the timing coincides with the disruption of routine health services during the COVID-19 pandemic and with reported deterioration in antivenom procurement. Whatever the explanation, a target predicated on continued improvement is being assessed against a trend that has flattened.

The regional pattern points to where effort should concentrate. Eastern sub-Saharan Africa has demonstrated that rapid improvement is achievable, cutting its rate by more than a third, though it started from and retains the highest burden. Western sub-Saharan Africa is the clearest failure: an 11.7% rate reduction over 33 years, a rate that was actually rising until 2001, and a doubling of deaths. It is now the region where the largest absolute increase in deaths has occurred, and on present trends it will overtake Eastern sub-Saharan Africa as the principal locus of burden.

The inequality analysis warrants a careful reading, and we want to be explicit about a distinction that is easy to blur. The rank correlation between SDI and mortality strengthened over the period, which might be taken to mean that inequality worsened. It does not. The population-weighted slope index of inequality moved toward zero and the concentration index was flat, meaning absolute inequality narrowed slightly and relative inequality persisted. What strengthened was the consistency of the gradient, not its size. A parallel GBD 2021 analysis of neglected tropical diseases and malaria reported the same divergence, with absolute inequality narrowing while relative inequality persisted [22]. Reporting the correlation alone would have supported a claim of widening inequality that the appropriate measures do not sustain.

Snakebite has long been described as a disease of poverty [18], and our gradient is consistent with that. The outlier analysis is arguably the most actionable finding for national programmes. Kenya carries a higher burden than Somalia despite more than twice the SDI. South Sudan's rate is roughly five times the regional mean. Burden of this magnitude at these development levels is not a straightforward consequence of poverty, and points instead to specific, addressable failures rather than to poverty alone. These are tractable problems [5, 6], and they mark where a national snakebite programme would yield the greatest return.

These findings point to a concrete intervention agenda rather than a verdict of failure. First, antivenom supply must be expanded and stabilised: with no production on the subcontinent outside South Africa, the region depends on importation, and affordability and rural availability remain the binding constraints [5, 6]. Second, that supply must reach the periphery, since the countries carrying burden well above their development level, notably South Sudan and Kenya, are those where antivenom is absent from front-line facilities or arrives too late. Third, surveillance and vital registration must improve, because much of the burden is invisible where deaths occur at home or under traditional treatment and never enter a reporting system [7, 16], and a target cannot be tracked against data that systematically undercount it. Fourth, progress must be judged against both age-standardised rates and absolute counts, since a rate that falls while deaths rise does not represent lives saved. Because population ageing is not a driver, each of these is a question of coverage and reach rather than demographic headwind, and each is therefore actionable within the remaining years of the WHO strategy.

Limitations

Several limitations bear on interpretation. First and most importantly, the cause analysed is venomous animal contact, not snakebite envenoming specifically. Snakebite dominates this cause in sub-Saharan Africa, but scorpion sting and other envenomings are included, and our estimates are therefore an upper bound on snakebite burden. Our assessment against the WHO target should be read with that caveat, though we note that any plausible snake-specific fraction would not alter the direction or the approximate magnitude of the shortfall.

Second, GBD estimates for this cause rest on sparse primary data. Snakebite is heavily under-reported: many deaths occur at home or under traditional treatment and never reach a vital registration system [7, 16, 19]. The wide uncertainty intervals, particularly for South Sudan (95% UI 3.79 to 30.99), reflect this. The direction of that bias is toward underestimation, which means the true burden is likely higher than reported and the distance from the target correspondingly greater.

Third, our projection is a log-linear extrapolation rather than a Bayesian age-period-cohort model. It assumes the trend of the past two decades continues, and it will be wrong if a step change in antivenom access occurs. That is precisely the point: the projection describes the trajectory of the status quo, and the finding is that the status quo does not reach the target.

Fourth, our inequality and outlier analyses are restricted to sub-Saharan Africa. The slope index of inequality is therefore internal to the region and is not comparable with globally computed values. Fifth, we did not conduct a stochastic frontier analysis, for the reasons given in the methods, and our LOESS approach to identifying outliers is descriptive rather than an efficiency estimate. Sixth, the final joinpoint segment covers only five years (2018 to 2023) and is therefore estimated with less precision than the earlier segments; the apparent stall should be confirmed against the next GBD round before being treated as established.

Conclusions

Sub-Saharan Africa has reduced age-standardised mortality from venomous animal contact by 28.9% since 1990 while the number of deaths has risen by 54.8%, and it now bears a quarter of the global burden. Decomposition shows this is driven by population growth outpacing epidemiological progress, with population ageing contributing nothing. Joinpoint analysis shows that the decline has stalled since 2018. On the trajectory of the past two decades the region will miss the WHO 2030 target by approximately 60%, and meeting it would now require an eightfold acceleration in the rate of decline.

Because the shortfall is a problem of scale rather than of demography, it is in principle solvable. Antivenom supply, affordability and peripheral availability must expand faster than the population, and progress should be monitored against both rates and counts. Countries carrying burden well in excess of what their development level predicts, notably South Sudan and Kenya, are where that expansion would save the most lives.

Abbreviations

ASMR
Age-standardised mortality rate
ASR
Age-standardised rate
CI
Confidence interval

DALYs
Disability-adjusted life years
EAPC
Estimated annual percentage change
GATHER
Guidelines for Accurate and Transparent Health Estimates Reporting
GBD
Global Burden of Disease Study
GHDx
Global Health Data Exchange
IHME
Institute for Health Metrics and Evaluation
LOESS
Locally estimated scatterplot smoothing
SDI
Socio-demographic Index
SII
Slope index of inequality
UI
Uncertainty interval
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable. This study analysed publicly available, aggregated, de-identified estimates from the Global Burden of Disease Study 2023 and did not involve human participants.

Consent for publication

Not applicable.

Availability of data and materials

All data analysed in this study are publicly available. GBD 2023 burden and population estimates were obtained from the GBD Results Tool (https://vizhub.healthdata.org/gbd-results/) and Socio-demographic Index values from the Global Health Data Exchange (https://ghdx.healthdata.org/record/gbd-2023-socio-demographic-index-sdi), both maintained by the Institute for Health Metrics and Evaluation. The complete analysis code, the exact data extraction specifications required to reproduce the input files,

and all output tables and figures are openly available in the Open Science Framework repository at https://doi.org/10.17605/OSF.IO/2TWXZ.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Authors' contributions

KCN conceived the study, designed the analysis, extracted and analysed the data, and drafted the manuscript. AN contributed to the analysis design and the interpretation of the inequality and decomposition results, and revised the manuscript. MN contributed to data extraction, verification of the results, and revision of the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors thank the Institute for Health Metrics and Evaluation and the GBD 2023 collaborators for making these estimates publicly available.

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Figures

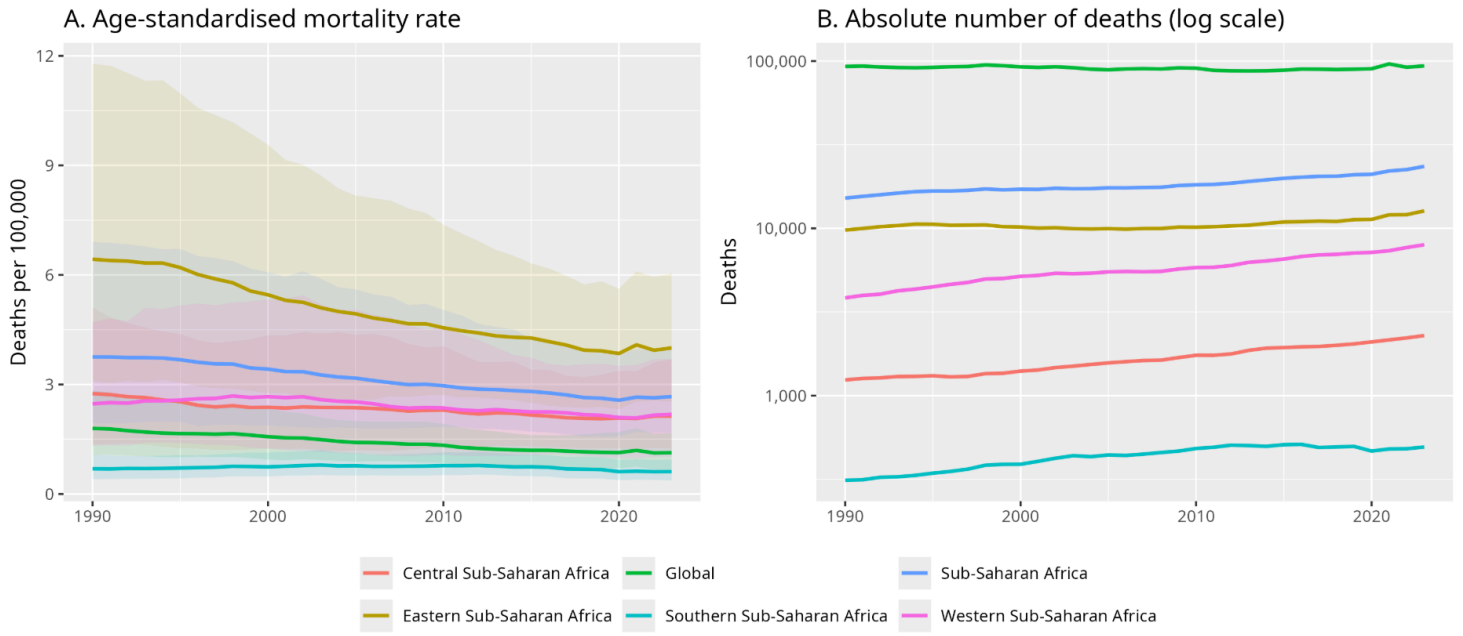


Figure 1

Age-standardised mortality rate (A) and absolute number of deaths, on a logarithmic scale (B), from venomous animal contact, 1990 to 2023, globally and across sub-Saharan Africa and its four regions. Shaded bands in panel A denote 95% uncertainty intervals.

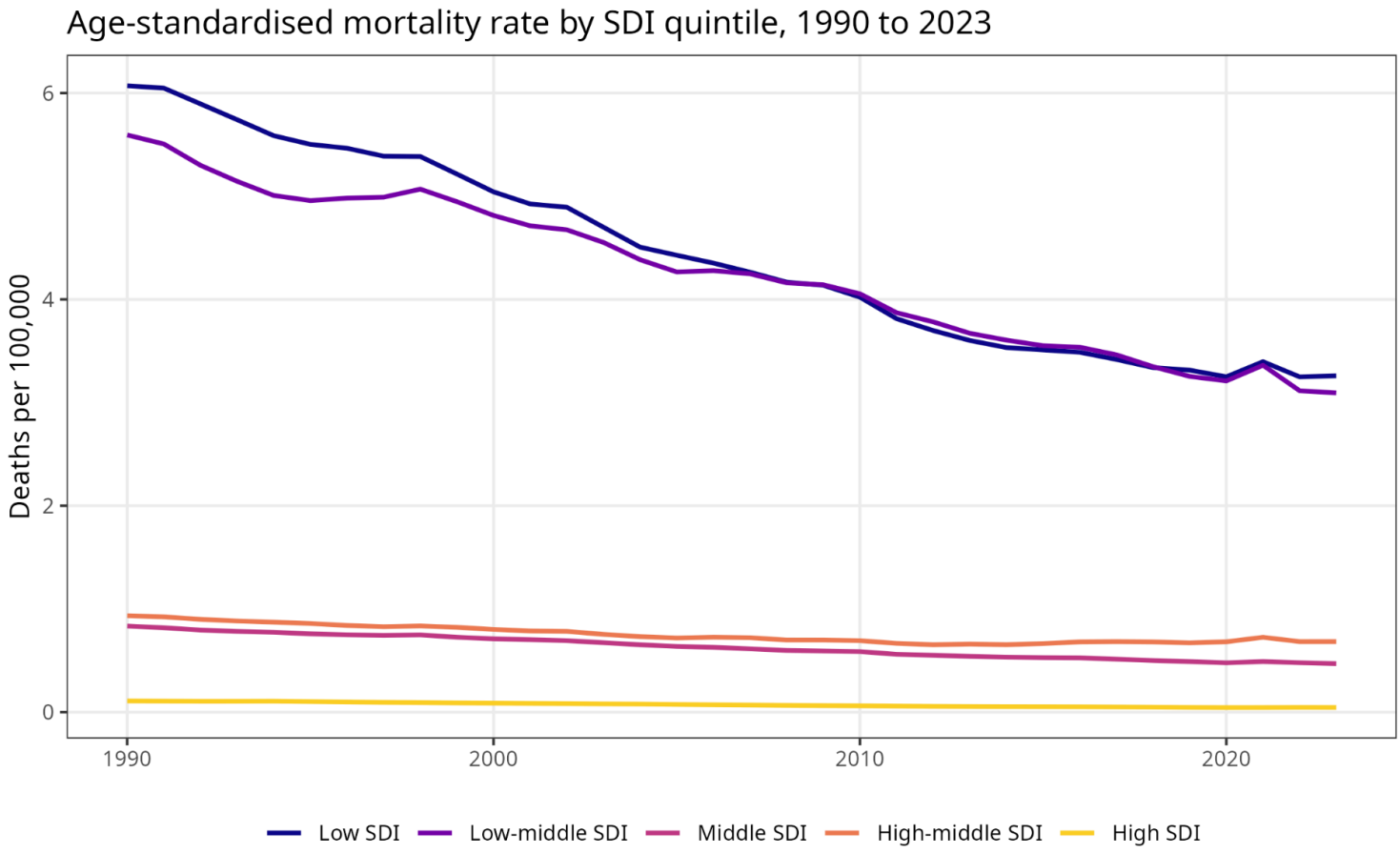


Figure 2

Age-standardised mortality rate from venomous animal contact by Socio-demographic Index quintile, 1990 to 2023.

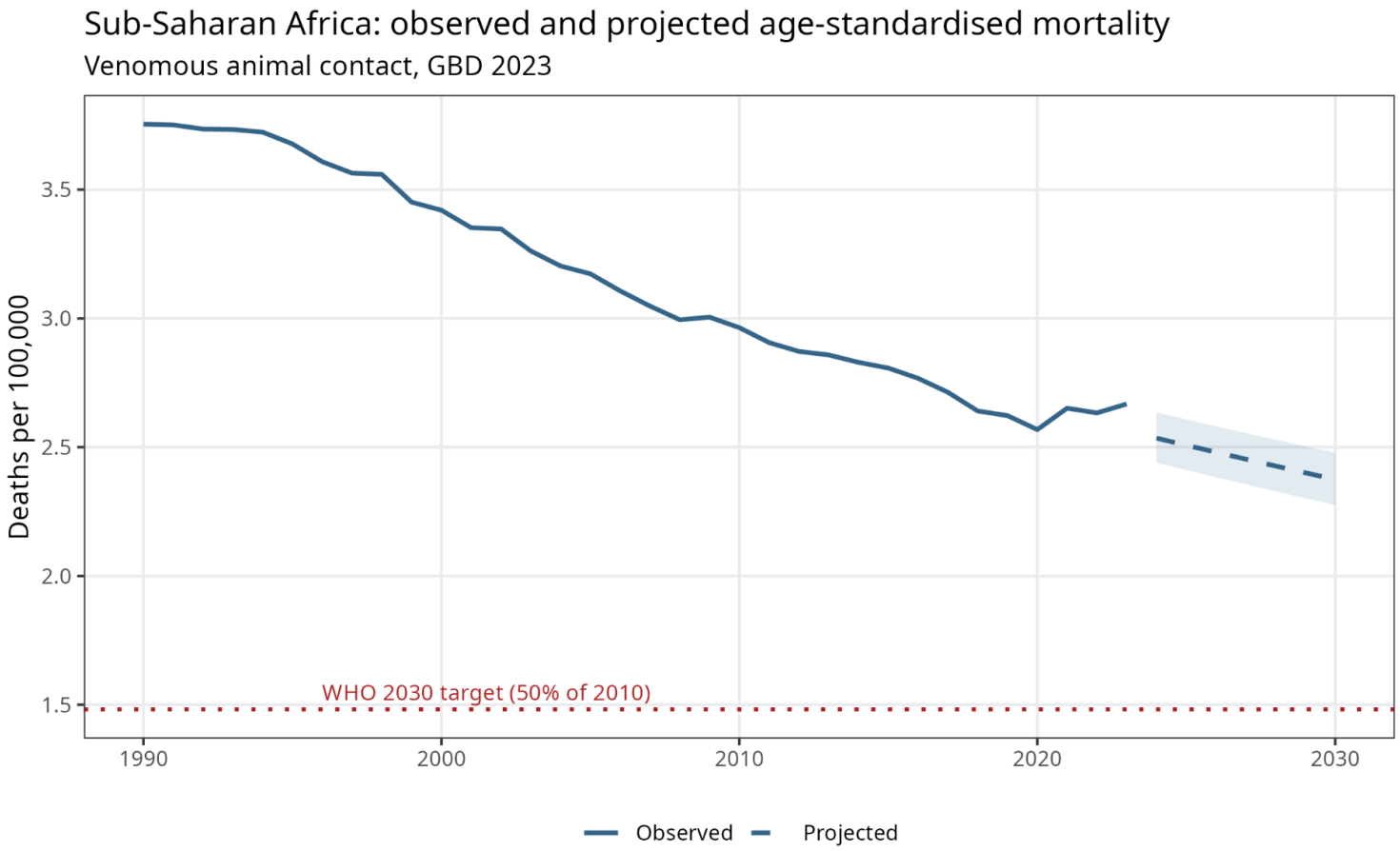


Figure 3

Observed (1990 to 2023) and projected (2024 to 2030) age-standardised mortality rate for sub-Saharan Africa, with the WHO 2030 target shown as a dotted line at half the 2010 baseline. The shaded band denotes the 95% prediction interval.

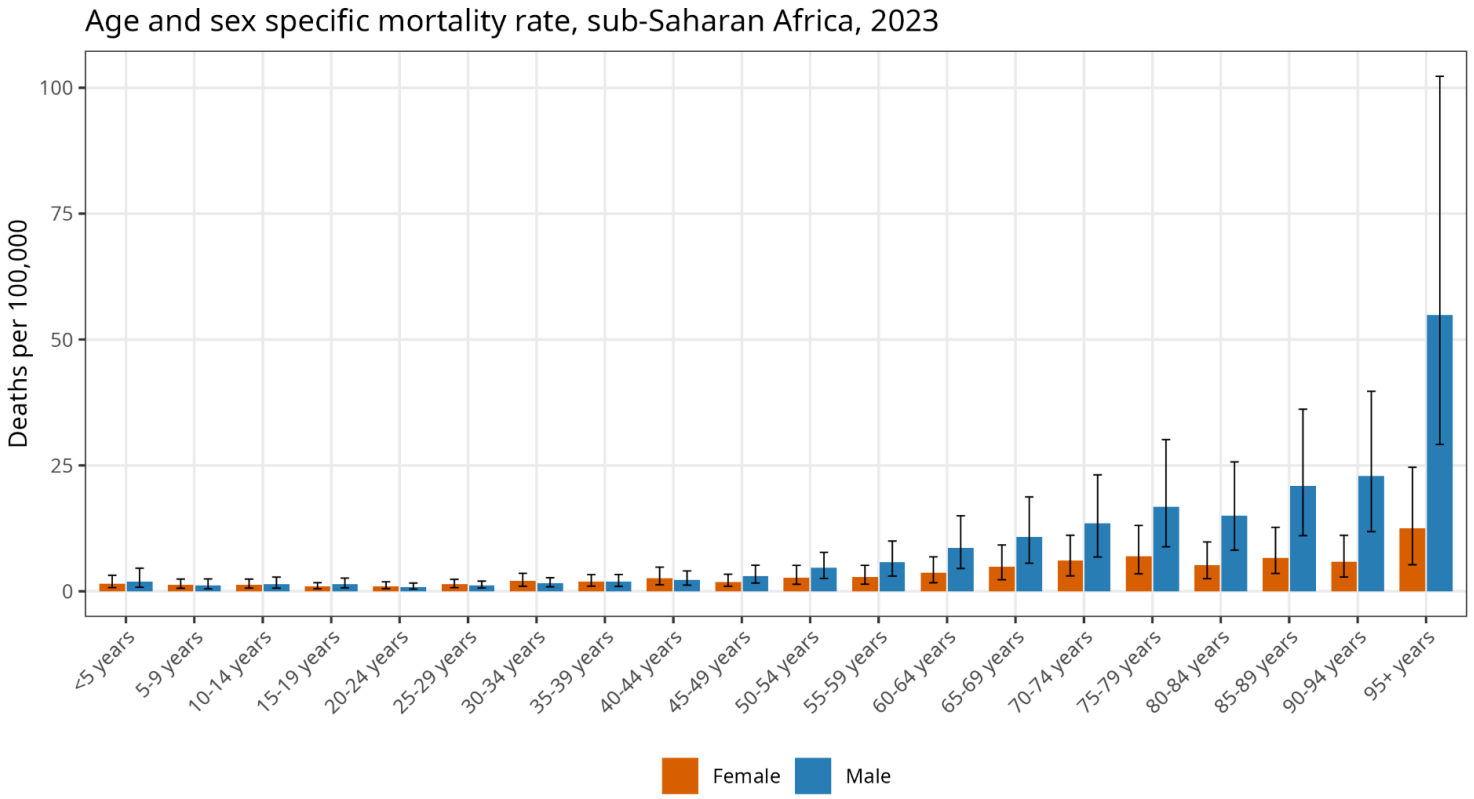


Figure 4

Age and sex specific mortality rate from venomous animal contact, sub-Saharan Africa, 2023. Error bars denote 95% uncertainty intervals.

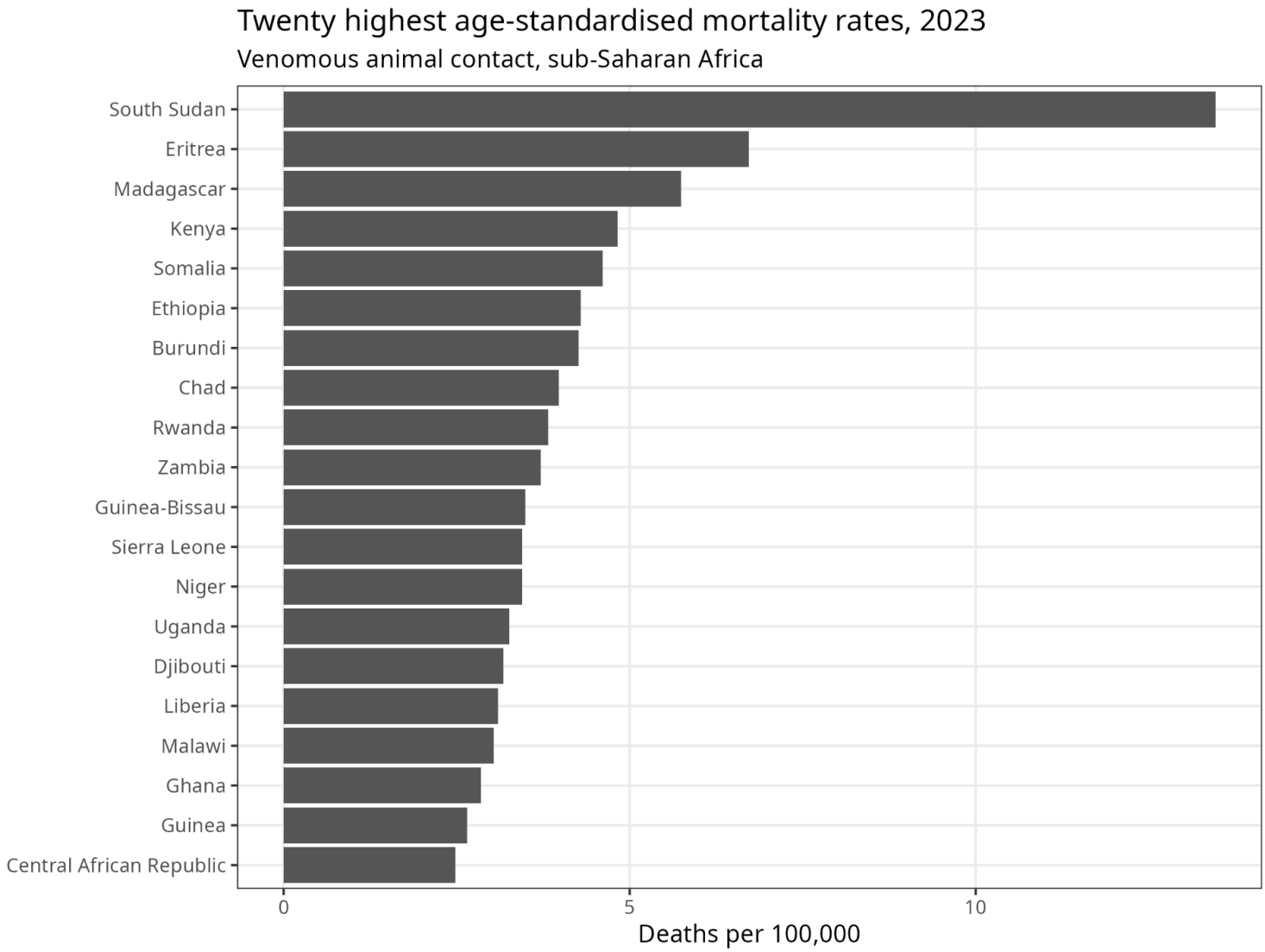


Figure 5

The twenty sub-Saharan African countries with the highest age-standardised mortality rate from venomous animal contact, 2023.

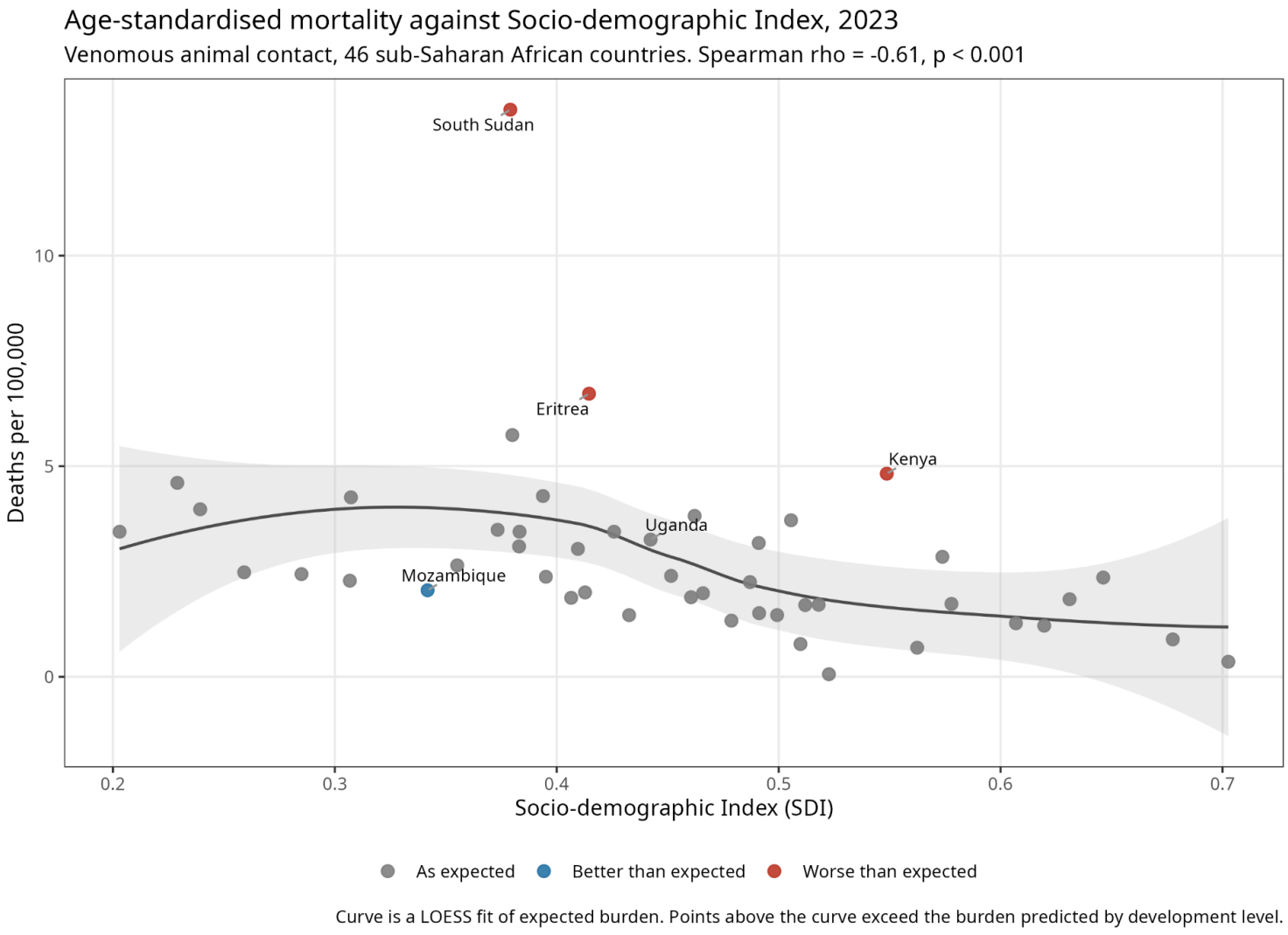


Figure 6

Age-standardised mortality rate against the Socio-demographic Index, 46 sub-Saharan African countries, 2023. The curve is a LOESS fit of expected burden given development level; points above it exceed the burden predicted by SDI. Countries with standardised residuals beyond one standard deviation are labelled, together with Uganda.

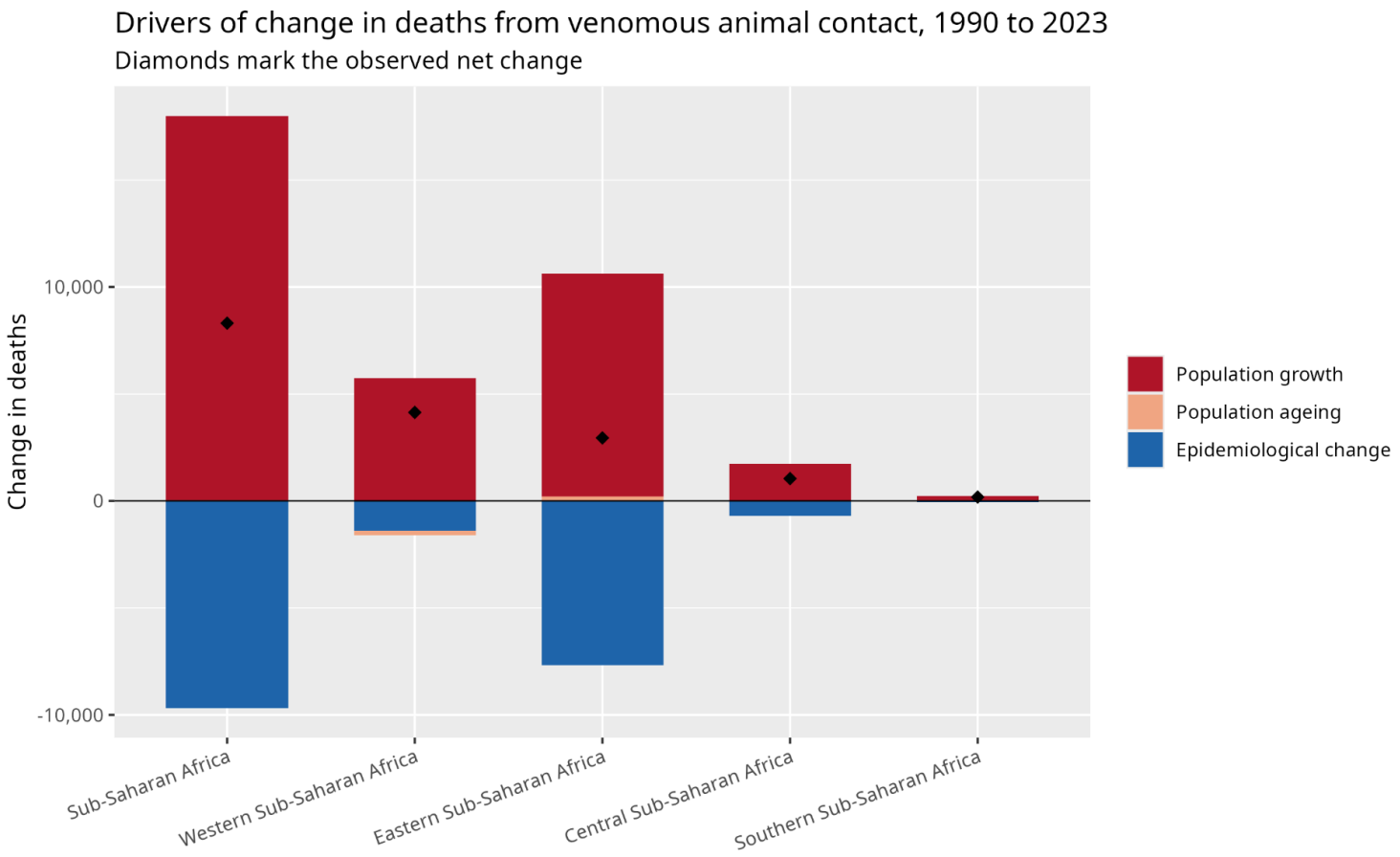


Figure 7

Contribution of population growth, population ageing and epidemiological change to the change in the number of deaths from venomous animal contact, 1990 to 2023. Diamonds mark the observed net change.

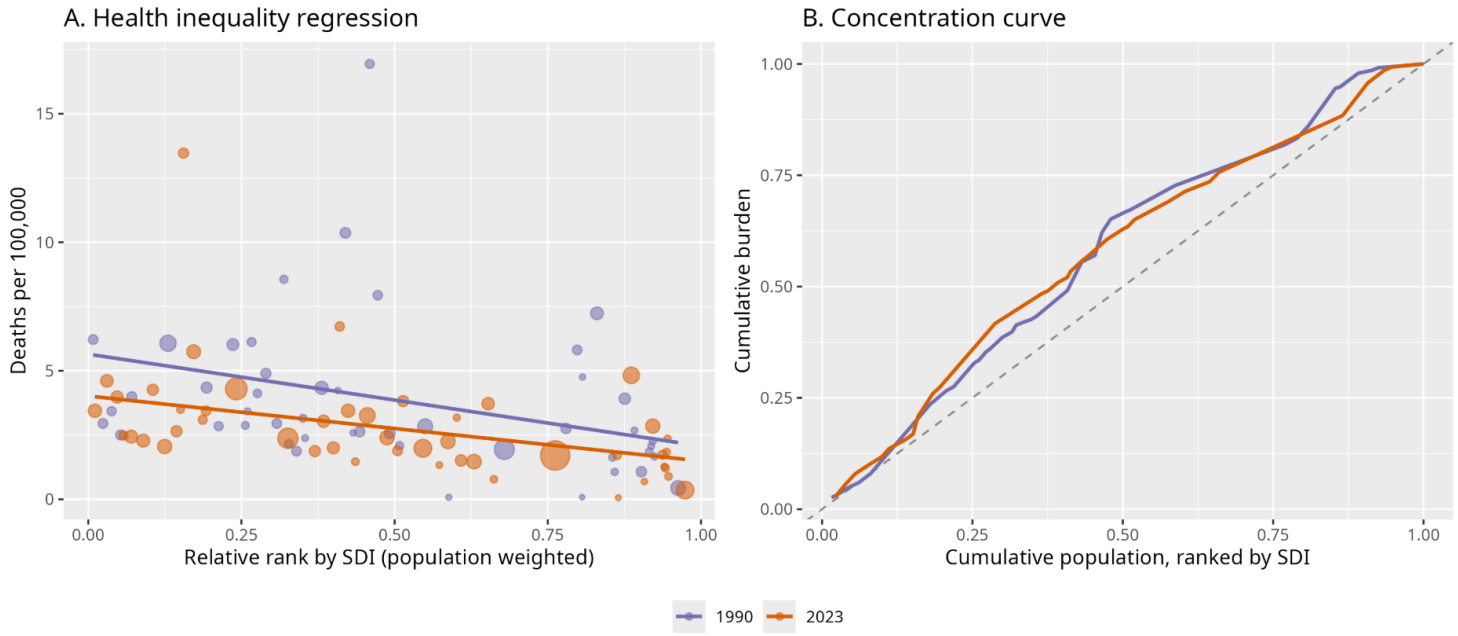


Figure 8

Health inequality regression (A) and concentration curve (B) for age-standardised mortality from venomous animal contact across 46 sub-Saharan African countries, 1990 and 2023. In panel A point size is proportional to population.