

Global burden of enteric infectious diseases, diarrhoeal diseases, and corresponding aetiologies, 1990–2023: a systematic analysis for the Global Burden of Disease Study 2023



GBD 2023 Diarrhoeal Disease and Enteric Infectious Diseases Collaborators*

Summary

Background Enteric infectious diseases claim more than 1 million lives annually and are among the top ten causes of death in children younger than 5 years. Remarkable global investment has been dedicated to enteric infectious disease prevention and control; however, the shifting global health landscape is testing the continuance of progress. To evaluate the current status and guide future interventions, we present the latest epidemiological estimates of enteric infectious diseases from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2023 and assess progress towards the Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD) mortality target of fewer than 20 deaths per 100 000 children younger than 5 years by 2025.

Methods We quantified the incidence, mortality, and disability-adjusted life-years (DALYs) of enteric infectious diseases by age, sex, and year across 204 countries and territories from 1990 to 2023. In GBD 2023, the following were considered under the category of enteric infectious diseases: diarrhoeal diseases, enteric fever (typhoid and paratyphoid), invasive non-typhoidal *Salmonella* spp (iNTS) infections, and other intestinal infectious diseases. We also examined 15 aetiologies contributing to diarrhoeal diseases. Incidence and prevalence were estimated with DisMod-MR (version 2.1), a Bayesian meta-regression tool, drawing on data from systematic reviews, population-based surveys, claims data, and hospital sources. Cause-specific mortality was modelled with Cause of Death Ensemble Modelling based on data from sources including vital registration, mortality surveillance, verbal autopsy, and minimally invasive tissue sampling. Years of life lost and years lived with disability were computed and combined to derive DALYs. For aetiology-specific estimation, population-attributable fractions (PAFs) for 15 pathogens were derived with a counterfactual framework. Point estimates and 95% uncertainty intervals (UIs) were generated from 250 draws from the posterior distribution.

Findings In 2023, enteric infectious diseases resulted in an estimated 1·27 million (95% UI 0·963–1·68) deaths globally, declining from 3·69 million (3·04–4·56) in 1990. The global age-standardised mortality rate (ASMR) decreased from 74·1 (62·0–92·9) per 100 000 population to 16·4 (12·6–21·3) per 100 000 population during the same period. Diarrhoeal diseases accounted for most deaths in 2023 (1·11 million [0·811–1·54]), followed by enteric fever and iNTS. South Asia and sub-Saharan Africa remained the most affected regions in 2023, with 599 000 (441 000–882 000) and 501 000 (373 000–648 000) deaths due to enteric infectious diseases, respectively, predominantly from diarrhoeal disease. Rotavirus was the leading cause of all-age diarrhoeal disease deaths (PAF 16·3% [12·0–21·5]), followed by norovirus (10·2% [2·4–17·0]) and *Shigella* spp (9·3% [5·4–15·2]). Among children younger than 5 years, PAFs of deaths due to diarrhoeal diseases were 40·2% (32·5–48·5) for rotavirus, 24·0% (15·1–36·7) for *Shigella* spp, and 23·4% (13·7–34·3) for adenovirus. Across 204 countries and territories, 141 met the GAPPD mortality target in 2023. The driving aetiologies among countries that did not meet the target in 2023 varied slightly by GBD super-region, but the highest or second-highest number of deaths in children younger than 5 years were consistently attributed to rotavirus. Astrovirus and sapovirus, newly included in GBD 2023, were responsible for 24 600 (6290–49 000) and 18 800 (4650–44 400) deaths, respectively, in 2023, mainly in children younger than 5 years.

Interpretation Our findings show that mortality and ASMRs of enteric infectious diseases declined substantially between 1990 and 2023. This decline is consistent with the expansion of public health measures and broader socioeconomic development. However, the burden in 2023 remains considerably high, with the highest mortality concentrated in sub-Saharan Africa and south Asia. Considering that more than a quarter of all countries had yet to meet the GAPPD mortality target in 2023, sustained efforts are needed to address the persistent burden in affected countries and to adapt to the changing global health landscape.

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Research in context

Evidence before this study

The global burden of diarrhoeal diseases has been estimated by groups such as WHO and the Maternal and Child Epidemiology Estimation Group and the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD). GBD 2021 examined the burden of diarrhoeal diseases, as well as the burden attributable to risk factors and 13 pathogens. We searched PubMed using the search string “(“enteric infection*” AND (“diarrhea*” OR “diarrhoea*” OR “diarrhea”[Mesh]) AND “global” AND (“burden” OR “estimates”))” for articles published between Jan 1, 1990, and May 6, 2025. This search yielded 41 results, of which 11 studies reported diarrhoeal results for selected aetiologies or a subset of countries. One study assessed the mortality of overall enteric infections in the context of climate change. We did not find any studies that quantified the incidence and mortality of specific enteric infectious diseases and a comprehensive list of diarrhoeal aetiologies globally up to the year 2023.

Added value of this study

This study presents the latest estimates from GBD 2023 for the burden of all enteric infectious diseases, which include diarrhoeal

diseases, invasive non-typhoidal *Salmonella* spp, enteric fever (typhoid and paratyphoid), and other intestinal infectious diseases. 15 aetiologies were examined, including, for the first time, astrovirus and sapovirus results in granular age groups in children younger than 5 years. We also present our first evaluation of progress towards the Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD) mortality target (<20 deaths per 100 000 children <5 years by 2025) to provide insights into regional variation and temporal trajectories in the burden of enteric infectious diseases, revealing areas where interventions need to be reinforced.

Implications of all the available evidence

Global mortality from enteric infectious diseases has declined markedly over the past three decades, reflecting the success of public health interventions. However, more than a quarter of countries remained below the GAPPD mortality target for children younger than 5 years. Sustaining progress will require continued investment in proven measures. Meanwhile, context-specific adaptive strategies are imperative to address geographical disparities and emerging drivers of enteric infectious diseases.

Introduction

Enteric infectious diseases, caused by bacteria, viruses, and parasites, and transmitted through the faecal–oral route via contaminated food, water, or hands,^{1–5} remain a leading cause of preventable morbidity and mortality, particularly in low-income and middle-income countries (LMICs).¹ With the expansion of vaccination programmes and sustained improvements in water, sanitation, and hygiene (WASH), and oral rehydration therapy, clinical outcomes have improved substantially. Over the past three decades, enteric infectious diseases have shown the greatest reduction in premature mortality of any major cause,⁶ standing as a dominant driver of gains in life expectancy worldwide.⁶

International partnerships and domestic commitment have been pivotal to this success. Reducing the enteric infectious disease burden has been highlighted as a recurring global priority across multiple international frameworks. The UN Millennium Development Goals identified diarrhoeal disease control as being critical to reducing child mortality, while the UN Sustainable Development Goals reaffirmed commitments to combating waterborne diseases and ensuring access to safe water and sanitation.⁷ WHO and UNICEF established the Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD), which set a target of fewer than 20 deaths per 100 000 children younger than 5 years by 2025.⁸ However, after decades of progress, several emerging threats now risk halting or reversing these gains. Global health financing is undergoing a severe contraction,

with development assistance for health falling by more than half between 2021 and 2025, and projected to remain stagnant in the near term.⁹ The rise of antimicrobial resistance (AMR) is eroding the effectiveness of existing treatments for bacterial enteric infectious diseases, giving rise to new, drug-resistant lineages that are difficult to treat and increasingly widespread.^{10,11} Concurrently, changes in climate, particularly rising ambient temperatures, are reshaping the ecology and geographical distribution of key enteric pathogens such as *Shigella* spp, *Salmonella enterica* serotype Typhi, and *Cryptosporidium* spp, potentially influencing their transmission and burden, particularly in LMICs.¹² The compilation of these challenges casts uncertainty over the sustainability and future direction of global enteric disease prevention and control efforts.

Timely evidence is crucial for assessing current patterns in the face of a rapidly evolving global health landscape. As part of the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2023, we aimed to estimate the incidence, mortality, and disability-adjusted life-years (DALYs) associated with enteric infectious diseases and diarrhoeal diseases for 204 countries and territories from 1990 to 2023, stratified by age, sex, and year. Furthermore, we quantified the burden attributable to 15 enteric aetiologies in granular under-5 age groups and aimed to assess progress towards the GAPPD diarrhoeal mortality target. This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Overview

GBD 2023 quantified the burden of diarrhoeal disease and enteric infectious diseases across 204 countries and territories for the years 1990 to 2023. We defined diarrhoeal disease episodes as three or more abnormally loose stools in a 24-h period. GBD classifies diseases and injuries into a hierarchy with four levels that include both fatal and non-fatal causes (appendix 1 p 4). Diarrhoeal diseases, enteric fever (typhoid and paratyphoid), invasive non-typhoidal *Salmonella* spp (iNTS; defined as any blood culture-confirmed non-typhoidal *Salmonella* spp infection), and other intestinal infectious diseases are Level 3 causes that are aggregated under the Level 2 cause enteric infectious diseases. Modelling was conducted at the draw level, and 95% uncertainty intervals (UIs) were computed as the 2·5th and 97·5th ranked values of 250 draws, which was reduced from 500 draws in GBD 2021 to improve computing power and runtimes. Simulations detailed elsewhere revealed that estimates and uncertainty were minimally affected by this reduction.¹³ The GBD 2023 world population age standard was used to calculate age-standardised rates⁶ for diarrhoeal incidence, mortality, and DALYs. DALYs were calculated as the sum of years of life lost (YLLs) and years lived with disability (YLDs). Results are presented for female and male sexes combined, by age group (all ages, <5 years, 5–14 years, 15–49 years, 50–69 years, and ≥70 years). Details of rounding standards and calculation of annualised rates of change are provided in appendix 1 (p 4). Additional granular results by location, year, age, and sex are available in the GBD Results Tool. Detailed methods used to estimate each of the Level 3 causes of enteric infectious diseases are provided in appendix 1 (pp 53–65). The complete GBD 2023 methodology is available for review elsewhere.^{6,13} This research complies with the GATHER statement;¹⁴ a completed GATHER checklist is provided in appendix 1 (pp 67–69). The University of Washington Institutional Review Board approved this study (STUDY00009060) up to July 26, 2026.

Diarrhoeal disease mortality and morbidity

Fatal results for overall diarrhoeal diseases were produced with Cause of Death Ensemble Modelling (CODEm), which uses a covariate selection algorithm to generate many plausible combinations of covariates, which are evaluated across four model classes, including mixed-effects linear models and spatial-temporal Gaussian Process Regression models. Models were assessed for out-of-sample predictive validity and then combined into an ensemble model based on best predictive performance.^{6,15} Some of the covariates included in the modelling were access to improved water sources, oral rehydration therapy coverage, and the Socio-demographic Index (see appendix 1 p 52 for a full list of covariates). In

terms of input data site-years, defined as the number of years of data available for each location with data, there were 23 970 site-years of data included in diarrhoeal CODEm modelling, and all data were adjusted for incomplete death registration and garbage coding. Specifically, we incorporated 20 261 site-years of vital registration data, 953 site-years of sample-based vital registration data, 2171 site-years of verbal autopsy data, 575 site-years of mortality surveillance data, and ten site-years of minimally invasive tissue sampling data. Complete methods for fatal data processing have been provided elsewhere.⁶

Separately, we modelled diarrhoeal disease morbidity using DisMod-MR (version 2.1),¹³ a Bayesian meta-regression modelling framework. Incidence and prevalence data from a systematic review, population-based surveys, and inpatient data were included to inform our model (appendix 1 pp 6–8). Before modelling, we adjusted our data to be comparable to community-based diarrhoea. We also adjusted survey data for seasonality and transformed data from incidence to prevalence. We then used DisMod-MR to produce internally consistent incidence and prevalence estimates at global and granular levels (appendix 1 pp 6–8).

Diarrhoeal aetiologies

To estimate diarrhoeal aetiologies (pathogens), we used a counterfactual approach that incorporated the pathogen-specific odds of diarrhoeal disease and the prevalence of pathogens in diarrhoea episodes (appendix 1 pp 45–49). We produced population attributable fractions (PAFs) for 15 diarrhoeal pathogens: adenovirus, *Aeromonas* spp, *Campylobacter* spp, *Clostridioides difficile*, *Cryptosporidium* spp, *Entamoeba histolytica*, norovirus, rotavirus, iNTS, *Shigella* spp, heat-stable toxin-producing enterotoxigenic *Escherichia coli* (ST-ETEC), typical enteropathogenic *E coli* (tEPEC), *Vibrio cholerae*, astrovirus, and sapovirus. Of these, astrovirus and sapovirus were modelled for the first time in GBD 2023 to support decision making on candidates for future combination vaccine development. We excluded *Giardia* spp from diarrhoeal aetiology modelling because the available evidence shows it is not positively associated with acute diarrhoea and is often detected more frequently in asymptomatic controls than cases.^{16,17} More details about the input data and methods used to estimate diarrhoeal pathogens are provided in appendix 1 (pp 8–49).

Enteric fever, iNTS, and other intestinal infectious diseases

For typhoid and paratyphoid fever and iNTS infection, mortality was estimated with CODEm for data-rich countries, while other locations used natural history models that multiplied incidence by case fatality rates. We estimated the incidence of typhoid and paratyphoid combined, as well as the incidence of iNTS, through

See Online for appendix 1

For the GBD Results Tool see
<https://vizhub.healthdata.org/gbd-results>

Enteric infectious diseases				Diarrhoeal diseases			Typhoid and paratyphoid fever			Invasive non-typhoidal <i>Salmonella</i> spp			Other intestinal infectious diseases		
Number	Rate per 100 000	ARC, 1990–2023		Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023
Global															
All ages	1270 000	16.4	–4.6% (12.6 to 21.3)	1110 000	14.2	–4.7% (–5.5 to –4.0)	82 800	1.1	–4.8% (0.6 to 1.9)	76 700	1.1	–0.2% (–0.6 to 0.2)	1940	<0.1	–0.7% (–1.8 to 0.4)
<5 years	388 000	60.4	–5.1% (43.8 to 82.3)	317 000	49.3	–5.4% (–6.8 to –4.0)	29 000	4.5	–5.0% (2.4 to 7.6)	42 200	6.6	0.5% (–0.1 to 1.0)	293	<0.1	–2.6% (–5.0 to –0.6)
Central Europe, eastern Europe, and central Asia															
All ages	5140	1.2	–4.8% (–5.1 to –4.5)	5040	1.1	–4.8% (–5.2 to –4.5)	8	<0.1	–3.5% (–4.9 to –2.3)	44	<0.1	–3.7% (–5.3 to –2.5)	48	<0.1	–0.6% (–2.5 to 1.3)
<5 years	1270	5.3	–6.7% (–7.3 to –6.1)	1260	5.2	–6.8% (–7.3 to –6.1)	2	<0.1	–3.2% (–5.0 to –1.8)	3	<0.1	–6.1% (–7.7 to –4.6)	3	<0.1	–1.7% (–6.4 to 4.2)
High income															
All ages	29 300	1.1	1.1% (0.7 to 1.4)	28 800	1.1	1.3% (0.9 to 1.6)	10	<0.1	–7.1% (–7.7 to –6.5)	170	<0.1	–4.8% (–6.5 to –3.1)	316	<0.1	–0.8% (–2.3 to 0.8)
<5 years	335	0.6	–4.1% (–4.6 to –3.6)	327	0.6	–4.1% (–4.6 to –3.6)	0	<0.1	–5.2% (–6.1 to –4.3)	3	<0.1	–5.2% (–7.1 to –3.4)	5	<0.1	–2.4% (–8.1 to 2.5)
Latin America and Caribbean															
All ages	24 600	4.4	–6.1% (–6.3 to –5.8)	24 200	4.3	–6.1% (–6.3 to –5.8)	129	<0.1	–8.2% (–9.3 to –7.2)	60	<0.1	–8.2% (–9.3 to –7.0)	210	<0.1	–0.8% (–2.4 to 0.9)
<5 years	6350	14.4	–8.0% (–8.7 to –7.3)	6300	14.3	–8.0% (–8.7 to –7.3)	17	<0.1	–7.5% (–9.0 to –6.4)	5	<0.1	–8.2% (–9.3 to –7.1)	22	0.1	–3.4% (–7.9 to 0.4)
North Africa and Middle East															
All ages	15 600	3.1	–5.8% (–7.1 to –4.7)	14 100	2.9	–5.8% (–7.2 to –4.7)	827	0.1	–6.9% (0.1 to 0.2)	639	0.1	–1.3% (–1.8 to –0.8)	54	<0.1	–0.8% (–2.7 to 1.0)
<5 years	9780	16.4	–7.0% (–8.9 to –5.3)	9340	15.7	–7.1% (–9.0 to –5.3)	290	0.5	–7.1% (0.2 to 0.9)	142	0.2	–0.9% (–1.6 to –0.2)	10	<0.1	–3.8% (–7.8 to –0.3)
South Asia															
All ages	599 000	46.6	–5.5% (–6.3 to –4.7)	535 000	43.0	–5.5% (–6.3 to –4.7)	59 400	3.3	–5.1% (1.8 to 5.2)	3780	0.2	–1.3% (–1.6 to –0.8)	328	<0.1	–0.4% (–1.4 to 0.9)
<5 years	76 600	47.9	–7.4% (–8.5 to –6.5)	55 700	34.8	–7.9% (–9.1 to –6.9)	20 400	12.7	–5.2% (6.8 to 21.3)	448	0.3	–2.0% (–2.7 to –1.2)	62	<0.1	–2.9% (–5.0 to –0.8)
Southeast Asia, east Asia, and Oceania															
All ages	93 900	4.5	–5.9% (–6.9 to –5.0)	81 100	3.7	–6.1% (–7.2 to –5.1)	9280	0.6	–4.7% (0.3 to 1.0)	2860	0.1	–2.0% (–2.2 to –1.7)	692	<0.1	–0.8% (–1.8 to 0.2)
<5 years	17 000	14.1	–6.8% (–9.1 to 21.2)	13 800	11.4	–7.1% (–8.4 to –5.5)	2980	2.5	–4.7% (1.2 to 4.4)	181	0.1	–2.0% (–2.5 to –1.5)	70	0.1	–2.8% (–5.7 to –0.9)

(Table 1 continues on next page)

Enteric infectious diseases			Diarrhoeal diseases			Typhoid and paratyphoid fever			Invasive non-typhoidal <i>Salmonella</i> spp			Other intestinal infectious diseases		
Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023	Number	Rate per 100 000	ARC, 1990–2023
(Continued from previous page)														
Sub-Saharan Africa														
All ages	501 000 (373 000 to 648 000)	48.1 (35.0 to 65.0)	419 000 (305 000 to 567 000)	42.4 (29.6 to 59.5)	−4.6% (−5.7 to −3.7)	13 100 (6510 to 22 800)	0.9 (0.4 to 1.5)	−5.1% (−5.5 to −4.7)	69 200 (52 200 to 92 300)	4.8 (3.8 to 6.2)	−2.0% (−2.4 to −1.6)	290 (200 to 395)	<0.1 (<0.1 to <0.1)	−0.4% (−1.8 to 0.9)
<5 years	277 000 (194 000 to 385 000)	152.4 (107.0 to 211.8)	230 000 (147 000 to 348 000)	126.6 (80.8 to 191.2)	−5.3% (−7.0 to −4.0)	5310 (2630 to 9420)	2.9 (1.4 to 5.2)	−5.2% (−5.7 to −4.7)	41 400 (27 500 to 60 000)	22.8 (15.1 to 33.0)	−1.4% (−2.0 to −0.9)	121 (61 to 212)	0.1 (<0.1 to <0.1)	−2.4% (−4.9 to −0.1)

Data in parentheses are 95% uncertainty intervals. All age rates represent age-standardised rates. ARC=annualised rate of change.

Table 1: Global and regional deaths due to enteric infectious diseases (counts and rates for 2023, and ARCs between 1990 and 2023)

prospective cohort studies and surveillance data adjusted for diagnostic sensitivity and incomplete case capture, using separate DisMod-MR 2.1 models for high-burden and low-burden regions. These models incorporated country-level covariates, including the proportion of the population living in the Indian Ocean monsoon belt and exposure to unsafe sanitation for typhoid and paratyphoid fever, and HIV mortality, malaria incidence, and exposure to unsafe sanitation for iNTS. Finally, estimates from an aetiological proportion DisMod model were used to split the combined incidence of typhoid and paratyphoid into cause-specific incidence estimates. Other intestinal infectious diseases were analysed through a custom binomial model for mortality, with non-fatal estimates derived from the ratio of YLDs to YLLs. Additional details of the methods for typhoid and paratyphoid fever, iNTS, and other intestinal infectious diseases are described in appendix 1 (pp 53–65).

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

Global and regional mortality of enteric infectious diseases in 1990–2023

Globally, in 2023, enteric infectious diseases were responsible for 1.27 million (95% UI 0.963–1.68) deaths, with an age-standardised mortality rate (ASMR) of 16.4 (12.6–21.3) per 100 000 population. These findings mark a significant decline from 1990, when there was an estimated 3.69 million (3.04–4.56) deaths and an ASMR of 74.1 (62.0–92.9) per 100 000 population (table 1; appendix 2 table S1, figure S4). Diarrhoeal diseases accounted for 1.11 million (0.811–1.54) deaths due to enteric infectious diseases in 2023, typhoid and paratyphoid fever for 82 800 (43 400–135 000) deaths, iNTS for 76 700 (60 100–100 000) deaths, and other intestinal infectious diseases for 1940 (1450–2440) deaths (table 1; figure 1). Since 1990, diarrhoeal diseases have remained the leading cause of death among enteric infectious diseases.

At the GBD super-region level, the largest number of deaths due to enteric infectious diseases in 2023 occurred in south Asia, with a total of 599 000 (95% UI 441 000–882 000) deaths, comprising 535 000 (375 000–804 000) deaths due to diarrhoeal diseases and 59 400 (31 900–94 600) deaths due to typhoid and paratyphoid fever (table 1, appendix 2 table S1). South Asia accounted for more than 70% of global deaths due to typhoid and paratyphoid fever in 2023, with India being the largest contributor to this estimate (43 900 [23 500–70 700] all-age deaths). The GBD super-region with the second largest number of deaths in 2023 was sub-Saharan Africa, with 501 000 (373 000–648 000)

See Online for appendix 2

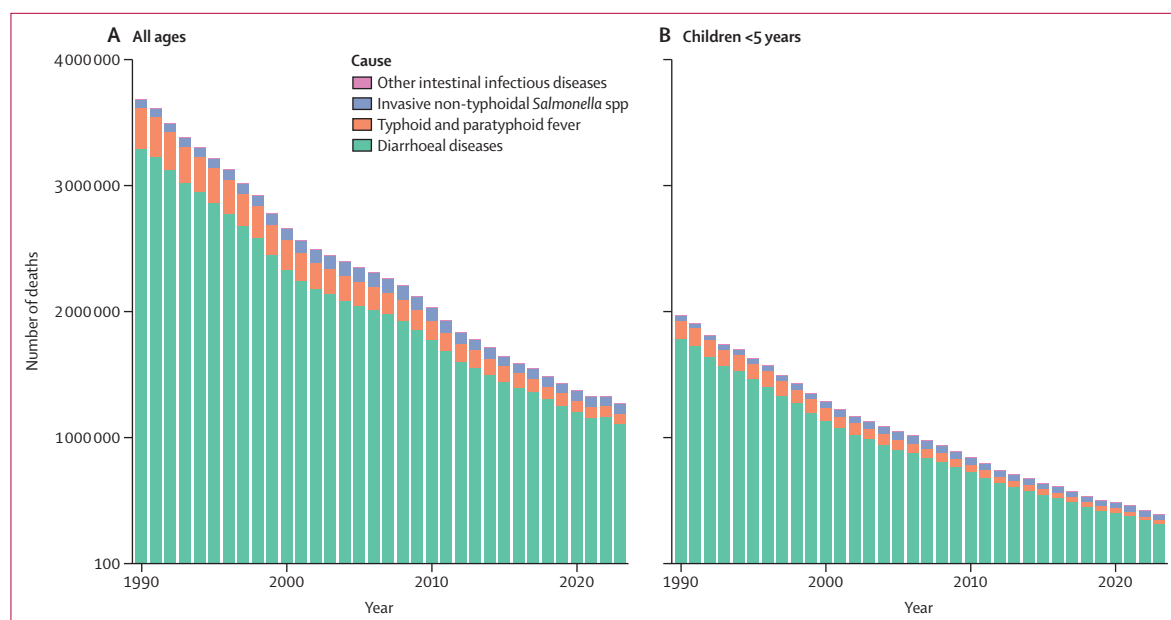


Figure 1: Global deaths due to enteric infectious diseases from 1990 to 2023, for all ages (A) and in children younger than 5 years (B)

deaths overall. Of these, 419 000 (305 000–567 000) were due to diarrhoeal diseases, 69 200 (52 200–92 300) due to iNTS, and 13 100 (6510–22 800) due to typhoid and paratyphoid fever (table 1). Sub-Saharan Africa had the highest burden of iNTS of all GBD super-regions in 2023, accounting for more than 90% of global iNTS deaths, with Nigeria contributing the most at 31 500 (22 200–42 700) deaths (table 1, appendix 2 table S1).

In 2023, the ASMR of enteric infectious diseases was highest in sub-Saharan Africa, estimated at 48.1 (95% UI 35.0–65.0) per 100 000 population, followed by south Asia at 46.6 (33.8–69.2) per 100 000 (table 1). In both super-regions, the ASMR in 2023 had declined substantially from that in 1990, when it was 206.3 (147.0–272.4) per 100 000 in sub-Saharan Africa and 283.1 (232.2–396.0) per 100 000 in south Asia, corresponding to annualised declines of 4.4% (3.6–5.4) and 5.5% (4.7–6.3), respectively (table 1, appendix 2 table S1). Compared with 1990, the ASMR due to enteric infectious diseases declined substantially across all GBD super-regions except for the high-income super-region, where an estimated 1.1% (0.7–1.4) annual increase was observed (table 1, appendix 2 table S1). In the high-income super-region, all enteric infectious diseases were estimated to decrease (or remain stable for other intestinal infectious diseases) annually except for diarrhoeal diseases, which increased annually by 1.3% (0.9–1.6; table 1, appendix 2 table S1). Substantial reduction rates across all enteric infectious diseases were seen in Latin America and the Caribbean, where deaths from diarrhoeal diseases, typhoid and paratyphoid fever, and iNTS decreased by more than 6% annually between 1990 and 2023 (table 1). Significant declines were

particularly observed in typhoid and paratyphoid fever, which declined annually by 8.2% (7.2–9.3), and in iNTS, which declined annually by 8.2% (7.0–9.3).

Global and regional trends in diarrhoeal disease mortality, incidence, and DALYs

In 2023, the global age-standardised incidence rate of diarrhoeal diseases was 52 018.8 (95% UI 45 130.6–61 374.3) per 100 000 population, with an estimated 4.05 billion (3.54–4.76) total episodes (appendix 2 table S2). This represents an improvement from 1990, when the age-standardised incidence rate was 70 483.9 (60 833.9–80 740.0) per 100 000 population and there were an estimated 4.04 billion (3.46–4.65) episodes (appendix 2 table S2). The global ASMR of diarrhoeal diseases in 2023 was 14.2 (10.6–19.2) per 100 000 population, reflecting an annual decline of 4.7% (4.0–5.5) from the estimated 67.4 (55.6–85.5) per 100 000 in 1990 (table 1; appendix 2 table S2). Since 1990, children younger than 5 years had the largest annual reduction in mortality rate due to diarrhoeal diseases (5.4% [4.2–6.8]), followed by adults aged 50–69 years (5.2% [4.2–6.2]), and those aged 5–14 years (4.6% [3.3–5.8]; appendix 2 table S2). Across GBD super-regions, south Asia had the highest diarrhoeal disease ASMR in 2023 (43.0 [29.7–64.0]), followed by sub-Saharan Africa (42.4 [29.6–59.5]) and Latin America and the Caribbean (4.3 [3.9–4.9]; table 1, appendix 2 table S2).

At the country level, 141 of 204 countries and territories included in GBD 2023 met the 2025 GAPPD target of fewer than 20 deaths per 100 000 children younger than 5 years (figure 2). Countries with the highest diarrhoeal ASMRs in 2023 were Chad (175.8 [126.4–248.1]

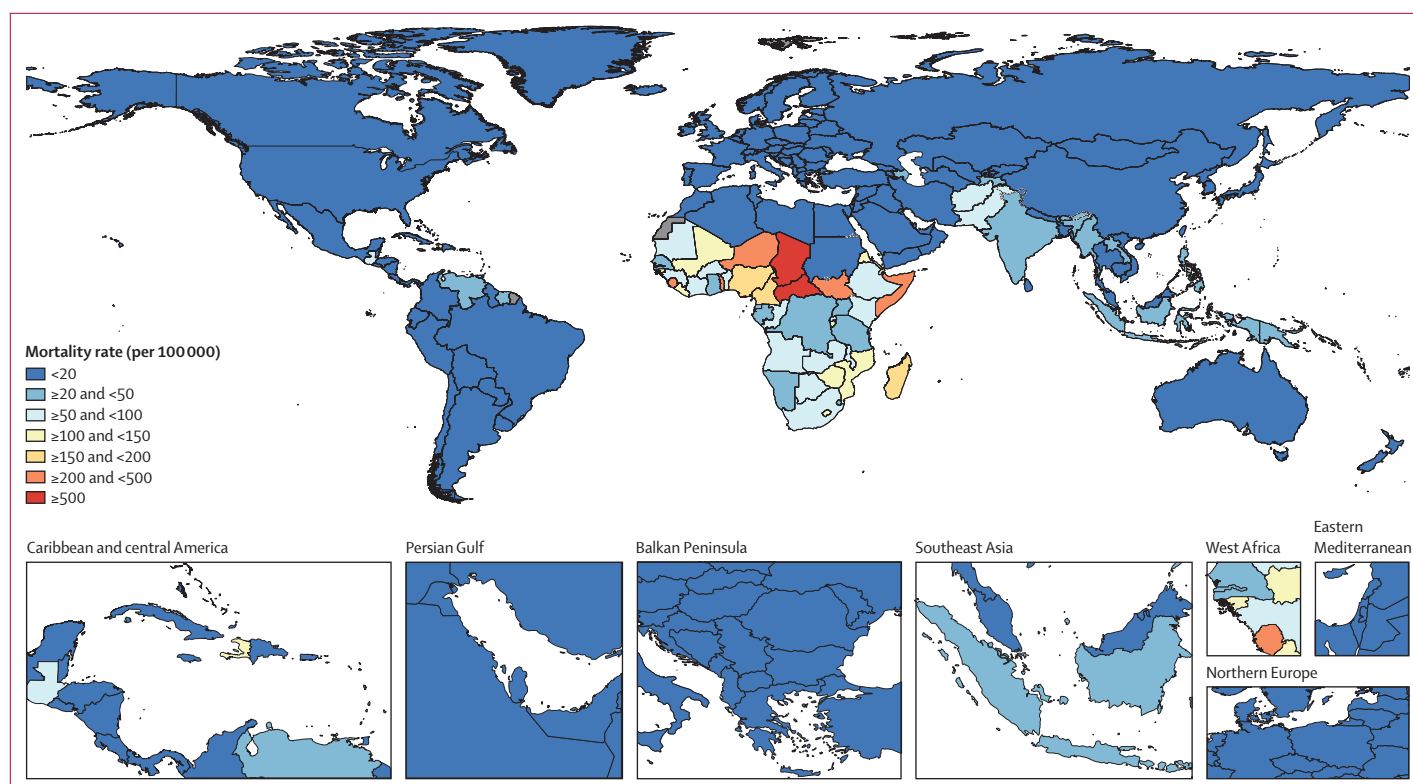


Figure 2: Mortality rate due to diarrhoeal diseases among children younger than 5 years, 2023

The grey areas indicate where no estimates are available (Western Sahara, French Guiana, and Svalbard), as these were not modelled locations in the Global Burden of Diseases, Injuries, and Risk Factors Study 2023. Countries with mortality rates greater than 20 per 100 000 did not meet the Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea target in 2023.

per 100 000), South Sudan (168·8 [99·4–264·7] per 100 000), and the Central African Republic (129·1 [81·5–191·8] per 100 000; appendix 2 table S1, table S2), each at least eight times higher than the global diarrhoeal ASMR (appendix 2 table S2).

Children younger than 5 years accounted for a disproportionate number of deaths due to diarrhoeal disease, contributing 317 000 (95% UI 213 000–462 000) deaths, which corresponded to 29·0% (18·2–41·4) of the 1·11 million (0·811–1·54) global deaths in 2023 (figure 3, table 1, appendix 2 table S2). Sub-Saharan Africa had the highest number of deaths due to diarrhoeal diseases among children younger than 5 years, with 230 000 (147 000–348 000) deaths, followed by south Asia (55 700 [41 200–74 000] deaths) and southeast Asia, east Asia, and Oceania (13 800 [8270–22 000] deaths; table 1, appendix 2 table S2). Countries with the largest numbers of deaths due to diarrhoeal diseases among children younger than 5 years in 2023 were Nigeria, with an estimated 61 000 (30 800–102 000) deaths, accounting for 72·6% (53·3–85·1) of all-age deaths due to diarrhoeal diseases in the country; India, with an estimated 35 300 (26 000–46 200) deaths, representing 7·9% (4·8–12·4) of all deaths due to diarrhoeal diseases; Chad, with an estimated 29 200 (20 100–37 800) deaths, constituting 77·6% (63·5–87·7) of all deaths due to diarrhoeal

diseases; and Pakistan, with an estimated 17 700 (10 100–30 000) deaths, representing 38·0% (18·8–58·2) of all deaths due to diarrhoeal diseases (appendix 2 table S1, table S2, figure S1).

Children younger than 5 years also accounted for a significant proportion of global diarrhoeal disease DALYs in 2023, contributing 28·9 million (95% UI 19·8–42·1) DALYs, which corresponded to 51·1% (38·2–62·4) of the total 56·5 million (43·8–72·7) DALYs (figure 3, table 2). Sub-Saharan Africa had the highest number of diarrhoeal disease DALYs among children younger than 5 years in 2023, at 20·7 million (13·3–31·2), followed by south Asia, at 5·21 million (3·88–6·85), and Southeast Asia, east Asia, and Oceania, at 1·34 million (0·831–2·07; table 2). At the country level, Nigeria had the highest number of diarrhoeal disease DALYs among children younger than 5 years in 2023 (5·48 million [2·81–9·09]), followed by India (3·32 million [2·50–4·30]), Chad (2·60 million [1·80–3·37]), and Pakistan (1·64 million [0·947–2·73]; appendix 2 figure S2, table S2). DALYs among children younger than 5 years represented 78·9% (65·1–88·5) of all diarrhoeal disease DALYs in Nigeria, 22·3% (15·2–31·5) of all diarrhoeal disease DALYs in India, 85·5% (76·3–92·1) of all diarrhoeal disease DALYs in Chad, and 57·9% (39·3–75·1) of all diarrhoeal disease DALYs in Pakistan (appendix 2 figure S1).

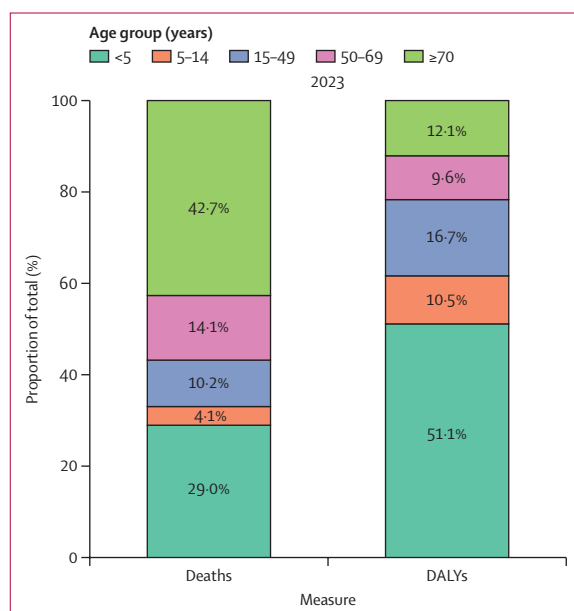


Figure 3: Percentage contribution of age-specific groups to diarrhoeal disease deaths and DALYs in 2023, globally, for both sexes
Disability-adjusted life-years (DALYs) represent diarrhoeal disability-adjusted life-years, the sum of years of life lost (YLLs) and years lived with disability (YLDs).

Regional and age-specific variation in diarrhoeal disease deaths attributable to 15 aetiologies in 2023

The leading aetiologies of all-age diarrhoeal disease deaths in 2023 were rotavirus, with 179 000 (95% UI 127 000–258 000) deaths and a fatal PAF of 16.3% (12.0–21.5); norovirus, with 113 000 (27 400–201 000) deaths and a fatal PAF of 10.2% (2.4–17.0), and *Shigella* spp, with 102 000 (58 700–163 000) deaths and a fatal PAF of 9.3% (5.4–15.2; table 3, appendix 2 figure S3). Globally, among children younger than 5 years, the leading aetiologies of diarrhoeal disease deaths in 2023 were rotavirus, with 128 000 (80 700–200 000) deaths and a PAF of 40.2% (32.5–48.5); *Shigella* spp, with 76 400 (39 400–139 000) deaths and a PAF of 24.0% (15.1–36.7); and adenovirus, with 74 000 (40 100–123 000) deaths and a PAF of 23.4% (13.7–34.3; table 3, figure 4).

Among countries that did not meet the GAPPD mortality target in 2023 (figure 2), the leading causes of deaths due to diarrhoeal diseases in children younger than 5 years were rotavirus and *Shigella* spp, followed by adenovirus and ST-ETEC, although there were some variations by region (appendix 2 table S3). For instance, rotavirus and adenovirus were responsible for deaths in young children in countries that did not meet the GAPPD

	1990		2023		Annualised rate of change, 1990–2023
	DALY count	DALY rate per 100 000	DALY count	DALY rate per 100 000	
Global					
All ages	218 000 000 (176 000 000 to 265 000 000)	3800.2 (3121.3 to 4702.7)	56 500 000 (43 800 000 to 72 700 000)	795.2 (607.1 to 1035.3)	–4.7 (–5.7 to –4.0)
<5 years	161 000 000 (124 000 000 to 203 000 000)	26 265.3 (20 210.7 to 33 021.0)	28 900 000 (19 800 000 to 42 100 000)	4501.3 (3076.2 to 6550.2)	–5.3 (–6.7 to –4.2)
Central Europe, eastern Europe, and central Asia					
All ages	1 800 000 (1 710 000 to 1 900 000)	525.9 (500.7 to 552.8)	265 000 (232 000 to 303 000)	83.7 (72.7 to 97.8)	–5.6 (–6.0 to –5.2)
<5 years	1 660 000 (1 590 000 to 1 750 000)	4583.3 (4375.2 to 4819.1)	125 000 (106 000 to 150 000)	517.7 (438.5 to 623.5)	–6.6 (–7.1 to –6.0)
High income					
All ages	496 000 (400 000 to 614 000)	63.8 (51.9 to 78.7)	682 000 (570 000 to 781 000)	46.7 (38.2 to 57.0)	–0.9 (–1.1 to –0.8)
<5 years	194 000 (168 000 to 227 000)	315.2 (273.1 to 368.5)	63 200 (50 300 to 81 300)	119.7 (95.2 to 154.0)	–2.9 (–3.3 to –2.6)
Latin America and Caribbean					
All ages	10 200 000 (9 680 000 to 10 900 000)	2172.2 (2064.0 to 2299.0)	1180 000 (1050 000 to 1360 000)	233.7 (206.3 to 269.9)	–6.8 (–7.2 to –6.3)
<5 years	9 130 000 (8 670 000 to 9 760 000)	18 348.8 (17 420.4 to 19 623.7)	584 000 (484 000 to 727 000)	1325.8 (1098.7 to 1650.1)	–8.0 (–8.6 to –7.3)
North Africa and Middle East					
All ages	8 190 000 (5 850 000 to 11 400 000)	1617.3 (1169.7 to 2221.7)	1 320 000 (949 000 to 1 830 000)	226.2 (161.5 to 315.6)	–6.0 (–7.4 to –4.7)
<5 years	7 710 000 (5 340 000 to 10 900 000)	14 888.7 (10 310.6 to 21 006.2)	894 000 (569 000 to 1 390 000)	1501.7 (956.3 to 2328.4)	–7.0 (–8.8 to –5.3)
South Asia					
All ages	98 300 000 (80 700 000 to 121 000 000)	9124.3 (7594.5 to 11 673.8)	18 800 000 (15 200 000 to 25 200 000)	1216.9 (965.7 to 1633.5)	–6.1 (–6.8 to –5.4)
<5 years	64 100 000 (49 900 000 to 81 700 000)	42 546.6 (33 147.9 to 54 274.2)	5 210 000 (3 880 000 to 6 850 000)	3257.7 (2428.6 to 4282.2)	–7.8 (–9.0 to –6.8)
Southeast Asia, east Asia, and Oceania					
All ages	24 900 000 (19 000 000 to 32 100 000)	1538.5 (1162.7 to 1996.8)	3 920 000 (2 970 000 to 5 200 000)	232.2 (173.3 to 308.2)	–5.7 (–6.7 to –4.8)
<5 years	19 200 000 (13 600 000 to 25 100 000)	10 993.5 (7806.5 to 14 382.2)	1 340 000 (831 000 to 2 070 000)	1112.7 (687.5 to 1715.1)	–6.9 (–8.7 to –5.5)
Sub-Saharan Africa					
All ages	74 200 000 (54 800 000 to 96 900 000)	10 068.5 (7488.3 to 13 044.6)	30 300 000 (21 900 000 to 40 700 000)	2094.3 (1560.5 to 2792.1)	–4.8 (–5.7 to –3.9)
<5 years	59 400 000 (40 800 000 to 82 500 000)	66 020.8 (45 290.1 to 91 712.4)	20 700 000 (13 300 000 to 31 200 000)	11 400.0 (7323.5 to 17 186.1)	–5.3 (–6.9 to –4.0)
All-age rates represent age-standardised rates. Data in parentheses are 95% uncertainty intervals. DALY=disability-adjusted life-year.					
Table 2: Global and super-regional estimates of diarrhoeal disease DALY rates and counts in 2023					

	All ages		Children <5 years	
	Number of deaths	PAF of diarrhoeal disease deaths	Number of deaths	PAF of diarrhoeal disease deaths
Rotavirus	179 000 (127 000 to 258 000)	16.3 (12.0 to 21.5)	128 000 (80 700 to 200 000)	40.2 (32.5 to 48.5)
<i>Shigella</i> spp	102 000 (58 700 to 163 000)	9.3 (5.4 to 15.2)	76 400 (39 400 to 139 000)	24.0 (15.1 to 36.7)
Adenovirus	91 000 (55 100 to 144 000)	8.3 (4.9 to 12.3)	74 000 (40 100 to 123 000)	23.4 (13.7 to 34.3)
ST-EPEC	70 700 (44 300 to 102 000)	6.4 (4.4 to 9.0)	47 400 (25 700 to 76 000)	15.0 (9.5 to 22.0)
<i>Cryptosporidium</i> spp	60 800 (35 600 to 98 800)	5.5 (3.5 to 8.4)	44 400 (21 600 to 80 300)	13.9 (8.7 to 22.5)
tEPEC	41 600 (19 700 to 77 100)	3.8 (1.8 to 6.6)	39 100 (17 800 to 72 500)	12.3 (6.8 to 20.3)
<i>Campylobacter</i> spp	51 100 (20 600 to 99 200)	4.7 (1.7 to 9.5)	25 400 (10 700 to 51 200)	8.1 (3.8 to 15.5)
Norovirus	113 000 (27 400 to 201 000)	10.2 (2.4 to 17.0)	22 700 (7910 to 42 500)	7.1 (2.6 to 12.0)
Astrovirus	24 600 (6290 to 49 000)	2.2 (0.7 to 4.6)	22 500 (5710 to 44 500)	7.1 (1.7 to 12.7)
Entamoeba	38 300 (19 400 to 63 900)	3.5 (1.7 to 5.7)	17 600 (7080 to 35 500)	5.6 (2.5 to 10.4)
<i>Vibrio cholerae</i>	62 800 (33 900 to 110 000)	5.6 (3.4 to 8.7)	16 500 (7920 to 31 600)	5.2 (2.9 to 8.3)
Non-typhoidal <i>Salmonella</i> spp	28 000 (2220 to 66 500)	2.5 (0.2 to 5.5)	13 200 (2220 to 30 100)	4.2 (0.6 to 8.4)
Sapovirus	18 800 (4650 to 44 400)	1.7 (0.4 to 3.9)	11 500 (2150 to 30 200)	3.6 (0.6 to 8.6)
<i>Aeromonas</i> spp	13 500 (6640 to 24 400)	1.2 (0.6 to 2.2)	10 200 (4400 to 20 100)	3.2 (1.5 to 5.7)
<i>Clostridioides difficile</i>	16 700 (14 100 to 19 900)	1.5 (1.1 to 2.0)	87 (60 to 127)	<0.1 (<0.1 to <0.1)

Data in parentheses are 95% uncertainty intervals. PAF=population attributable fraction. ST-EPEC=heat-stable toxin-producing enterotoxigenic *Escherichia coli*. tEPEC=typical enteropathogenic *Escherichia coli*.

Table 3: Global deaths and PAFs of diarrhoeal disease deaths in 2023 by aetiology, for both sexes combined, ranked by under-5 deaths

mortality target in southeast Asia, east Asia, and Oceania; meanwhile, in parallel, rotavirus and tEPEC were mainly responsible for deaths in young children in Latin America and the Caribbean (appendix 2 table S3). The countries furthest from meeting the GAPPD mortality target in 2023 were Chad, with an estimated 729.6 (95% UI 503.3–946.8) deaths per 100 000 children younger than 5 years; the Central African Republic, with an estimated 552.9 (336.8–777.5) deaths per 100 000 children younger than 5 years; and South Sudan, with an estimated 443.2 (254.4–668.3) deaths per 100 000 children younger than 5 years (figure 2; appendix 2 tables S1, S2). Among these countries, rotavirus was the most prevalent pathogen in all-age diarrhoeal disease deaths, with a PAF of 35.8% (29.1–43.7) in Chad, 27.3% (20.3–35.4) in South Sudan, and 44.6% (35.3–53.5) in the Central African Republic (appendix 2 table S3). Focusing on the three countries with the highest diarrhoeal disease deaths among children younger than 5 years (Nigeria, Chad, and India), rotavirus was also the leading pathogen in two of the three countries (appendix 2 table S3). In 2023, the PAFs of diarrhoeal disease deaths due to rotavirus among children younger than 5 years were 54.6% (44.4–65.9) in Nigeria and 42.9% (35.3–52.3) in Chad. Adenovirus was, however, the leading pathogen in India, with a fatal PAF of 36.4% (21.2–53.2; appendix 2 table S3).

Globally in 2023, 24 600 (95% UI 6290–49 000) deaths were attributable to astrovirus and 18 800 (4650–44 400) were attributable to sapovirus (table 3). 91.4% (22 500 [5710–44 500]) of the astrovirus-attributable deaths occurred among children younger than 5 years, and 61.2% (11 500 [2150–30 200]) of the sapovirus-attributable deaths occurred in the same age group (table 3). More

granularly, children aged 1–5 months were estimated to have the highest deaths attributable to astrovirus and sapovirus (appendix 2 figure S5).

Discussion

This study presents updated evidence from GBD 2023, illustrating global trends in enteric infectious diseases and diarrhoeal diseases. Mortality from enteric infectious diseases declined substantially between 1990 and 2023, from an estimated 3.69 million to 1.27 million deaths. Diarrhoeal diseases accounted for the majority of these deaths, followed by typhoid and paratyphoid fever, and iNTS infections. Although incidence and mortality rates have declined across all age groups, children younger than 5 years continue to bear a disproportionate burden, comprising almost a third of diarrhoeal disease deaths and more than half of related DALYs. Globally, rotavirus was the leading aetiology of all diarrhoeal disease deaths and sub-Saharan Africa remained the super-region with the highest disease burden, accounting for nearly 35% of global deaths due to enteric infectious diseases in 2023. Among children younger than 5 years in 2023, rotavirus, *Shigella* spp, and adenovirus were the leading aetiologies.

Sustained international cooperation with local commitment has been a key driver of the reduction in the global burden of enteric infectious diseases.⁶ Globally, enteric infectious diseases declined substantially in rank for age-standardised DALYs between 1990 and 2023, falling from the fourth to the 16th leading cause.¹³ Of 204 countries and territories, 141 have met the 2025 GAPPD target of fewer than 20 diarrhoeal disease deaths per 100 000 children younger than 5 years. These

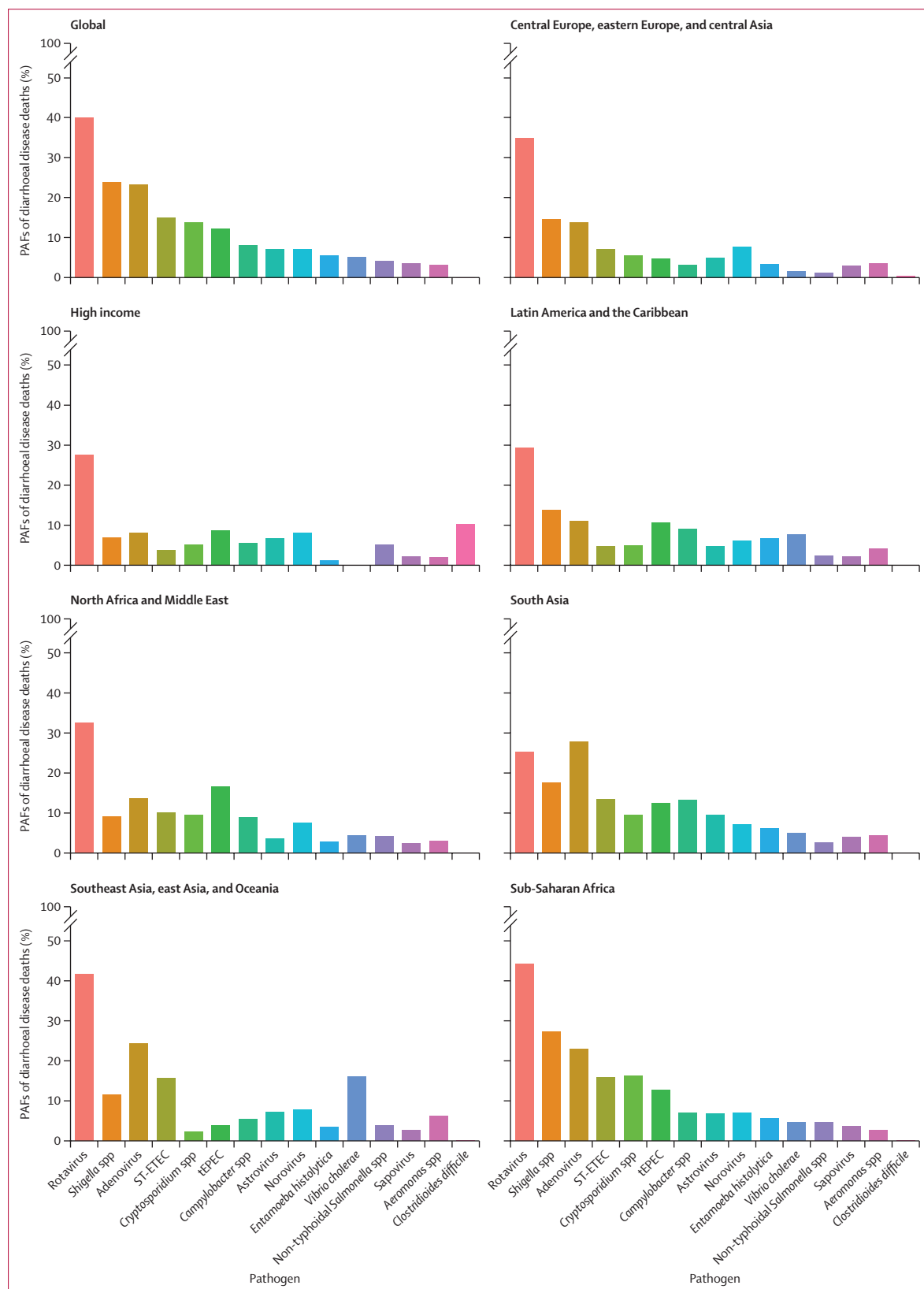


Figure 4: PAFs of diarrhoeal disease deaths by aetiology for children younger than 5 years in 2023, for both sexes combined, globally and by GBD super-region
Clostridioides difficile PAFs are not apparent in the figure but can be viewed in appendix 2 (table S3). GBD=Global Burden of Diseases, Injuries, and Risk Factors Study. PAF=population attributable fraction. ST-EPEC=heat-stable toxin-producing enterotoxigenic *Escherichia coli*. tEPEC=typical enteropathogenic *Escherichia coli*.

gains can be attributed to successful interventions such as oral rehydration therapy, exclusive breastfeeding, improved WASH practices, and rotavirus vaccination. Oral rehydration therapy and exclusive breastfeeding (as opposed to predominant breastfeeding) have been shown to reduce deaths from diarrhoeal disease by 93% and 56%, respectively.^{18,19} Moreover, basic WASH interventions have notably mitigated diarrhoeal risk, with reductions of 30% attributable to handwashing with soap, 52% attributable to safe drinking water access, and 24% attributable to improved sanitation at the population level.²⁰ Additionally, countries that introduced rotavirus vaccination observed a 36% decrease in deaths due to severe diarrhoea.²¹ However, further advancements can be made to support existing interventions. In 2022, an estimated 2.2 billion people did not have access to safe drinking water, 2.0 billion did not have access to basic hygiene services, and 3.5 billion did not have access to safely managed sanitation.²² In a similar manner, despite sub-Saharan Africa having the greatest burden of diarrhoeal disease in this study, only about half of infants aged younger than 6 months were exclusively breastfed over the past decade.^{23–25} Improving access to proven interventions would further reduce diarrhoeal mortality, yet sharp declines in development assistance for health (DAH) threaten to undermine decades of progress.⁹ DAH has dropped by 52% from the peak of US\$80.3 billion in 2021 to an estimated \$39.1 billion in 2025—the lowest level since 2009.^{26–29} Funding declines jeopardise essential enteric disease control efforts, including vaccination campaigns, access to oral rehydration solutions as well as zinc and antibiotics, and the establishment and maintenance of WASH infrastructure.^{26–29} Our results show that more than 60 countries, mostly in sub-Saharan Africa and south Asia, have yet to meet the GAPPD benchmark in 2023, with some observing persistently high ASMRs exceeding 100 per 100 000. Although the leading causes of deaths due to diarrhoeal diseases in these countries are generally responsive to existing interventions, dwindling financial support might further threaten the attainment of the GAPPD target and constrain urgently needed investment in vaccine innovation.³⁰

Suboptimal vaccine performance has been a prevailing issue in many LMICs.³¹ The effectiveness of oral rotavirus vaccines, such as RotaTeq, in LMICs was half of that observed in high-income countries.³² Several factors, including incomplete vaccination,³³ challenges with maintaining cold chain,³¹ disparities in pathogen exposure, and environmental enteropathy^{34–36} might contribute to the diminished benefits of oral rotavirus vaccines in LMICs. Developing next-generation vaccines tailored to the biological and contextual factors shaping vaccine response in LMICs is crucial to narrow the performance gap.³⁷ Meanwhile, there are still no approved vaccines for several high-burden pathogens, such as *Shigella* spp, adenovirus, and norovirus.^{38,39} The misuse of

antibiotics for viral infections and the spread of resistant enteric bacteria accentuate the need for new vaccines to prevent disease and contain resistance.^{40–42} Although several promising candidates have emerged, mobilising sustained financing and building capacity for large-scale trials specifically in resource-limited settings remain challenging.³⁷

Antibiotics remain a cornerstone of management for severe or invasive bacterial enteric infectious diseases.⁴³ However, AMR is widespread across multiple enteric pathogens, compromising the efficacy of current therapeutic regimens.^{44–47} An array of complex factors have contributed to the emergence and proliferation of AMR, including empirical and indiscriminate antibiotic use, weak stewardship and infection-control systems, and unregulated non-therapeutic antibiotic use in livestock and aquaculture,⁴⁸ which are further exacerbated by high infectious disease burdens, insufficient diagnostic capacity, and inadequate WASH infrastructure.^{48–50} Although there are some promising avenues to reduce the effects of AMR, including advances in genomics and bioinformatics, microbiome restoration, and other non-antibiotic therapies,⁴⁹ a coordinated, systems-wide response is needed. The One Health framework has become increasingly recognised in recent years.⁵¹ However, concrete pathways for implementing this framework, particularly in LMICs, remain elusive.⁵²

Results from our aetiological analysis highlight substantial geographical heterogeneity in dominant enteric pathogens. Although rotavirus remained the principal cause of deaths due to diarrhoeal diseases globally, adenovirus predominated among children younger than 5 years in south Asia. When considering countries that did not meet the GAPPD mortality target in 2023, tEPEC was a prominent cause of deaths in young children in Latin America and the Caribbean. Meanwhile, the global distribution of enteric pathogens is expected to shift under changing climatic conditions, with rising temperatures projected to favour *Shigella* spp, *Cryptosporidium* spp, and *S Typhi*.¹² Forward-looking prevention, stronger health systems, and social progress are needed to reduce future climate-related risks.⁵³

Our findings align with those of Black and colleagues⁵⁴ in identifying rotavirus and *Shigella* spp as the leading causes of deaths due to diarrhoeal diseases globally in 2021; however, we observed differences in the ranking of other pathogens. For example, although Black and colleagues⁵⁴ identified norovirus as the third most common aetiology, our analysis ranked norovirus lower. These discrepancies might be explained by differences in data sources and methodological approaches. Notably, our study incorporated a broader range of data, including the Global Pediatric Diarrhea Surveillance (GPDS) network and literature sources that encompass community and hospital-based studies, as well as both single-pathogen and multipathogen studies, and

standardised these sources to ensure comparability. Black and colleagues⁵⁴ excluded non-hospital-based studies and single-pathogen studies. Additionally, Black and colleagues' methods attributed each death to a single cause while our methods allow for co-infection. A key extension of our analysis beyond previous studies, including that of Black and colleagues,⁵⁴ is the provision of pathogen-specific estimates for more granular age groups within children younger than 5 years. These estimates enable a more detailed understanding of the age-specific burden within infancy and early childhood. Furthermore, our analysis includes older children and adults, providing more comprehensive, age-stratified estimates of the diarrhoeal disease burden across the entire lifespan.

Although global enteric infectious disease control has largely focused on early childhood,⁸ the demographic composition of the disease is evolving. In India, Nigeria, Pakistan, and Chad—four countries with the greatest burden of enteric infectious diseases in children younger than 5 years—the age patterns of the disease burden differ markedly. In Chad and Nigeria, children younger than 5 years account for more than 70% of deaths due to diarrhoeal diseases, with only modest contributions from older age groups. By contrast, India shows the opposite pattern: adults aged 70 years and older account for more than 64% of deaths due to diarrhoeal diseases, whereas children younger than 5 years contribute less than 8%. Pakistan lies between these extremes. The high burden of enteric infectious diseases among children younger than 5 years in Chad and Nigeria reflects a delay in intervention—rotavirus vaccination was only introduced in Nigeria in 2022 and in Chad in 2024^{55,56}—compounded by heightened vulnerability from undernutrition and inadequate WASH services. In India, by contrast, sanitation reforms under the 2014 national cleanliness campaign and the introduction of rotavirus vaccination in 2016 have yielded a considerable reduction in the burden of enteric infectious diseases among children younger than 5 years; however, rapid population ageing has begun to shift mortality towards older adults.^{57,58} In Pakistan, uneven progress in WASH provision and persistent undernutrition have hindered a comparable reduction in the enteric infectious disease burden among children younger than 5 years, while population ageing and the epidemiological transition towards non-communicable diseases have increased mortality among adults.^{59–63} The aetiology of enteric infectious diseases varies across the life course, with rotavirus dominant in young children, whereas ageing populations with waning immunity are more susceptible to pathogens such as norovirus and *C difficile*.¹ As global efforts against childhood diarrhoeal diseases press forward, the mounting burden of enteric infectious diseases among older adults warrants concurrent attention.

We acknowledge several important limitations of this study. First, cause of death data for mortality estimates

were obtained primarily from vital registration systems. In many LMICs, vital registration data are often incomplete or inaccurate, resulting in data gaps. These gaps were addressed through the incorporation of alternative data sources (including verbal autopsy data) and the application of meta-analytical techniques that leveraged relevant covariates as well as spatial and temporal relationships to synthesise multiple data inputs. Although verbal autopsy data are subject to potential misclassification, validation studies have shown that their sensitivity and specificity for identifying diarrhoeal diseases in children are generally reasonable.⁶⁴ In settings where data are sparse or sampling errors are substantial, the resulting estimates carry high levels of uncertainty. Second, to calculate odds ratios, we relied solely on data from LMICs for children younger than 5 years, which we applied to both children younger than 5 years and older age groups. Research suggests that several pathogens have similar odds ratios (ORs) across age groups; where ORs differed, they typically had overlapping confidence intervals.⁶⁵ Furthermore, there was no evidence of systematic differences in ORs between low-mortality and high-mortality settings. Additionally, for a few pathogens and age groups, the mean OR was above 1 but not statistically significant. We transformed ORs in log space to prevent exponentiated values from falling below one, which might introduce bias. Addressing these limitations by incorporating more robust OR data from a wider range of regions and age groups is a priority for future GBD publications. Third, we used ORs due to data availability but acknowledge that they might not approximate risk ratios, potentially biasing PAF estimates. Furthermore, although cases and controls in the data sources informing our ORs were matched on age, sex, residence, and enrolment time, residual confounding could remain. Our PAF estimates might also be affected by changes in other risk factors that could result from reducing or eliminating the exposure. Fourth, data for *C difficile* remain sparse in many LMICs, adding challenges to burden estimation. As the epidemiology and aetiology of enteric infectious diseases continue to evolve, robust diagnostic and surveillance systems are crucial to ensure proper alignment between interventions and disease patterns. Finally, our morbidity estimates mainly capture the acute effects of enteric infectious diseases and diarrhoeal diseases, whereas long-term sequelae such as growth faltering, cognitive impairment, and other developmental consequences were not fully quantified.^{66–68} Continued surveillance is essential to characterise these delayed outcomes over time.

In conclusion, global mortality from enteric infectious diseases and diarrhoeal diseases has fallen markedly between 1990 and 2023. However, more than a quarter of all countries had yet to meet the GAPPD diarrhoeal mortality target of fewer than 20 deaths per 100 000 children younger than 5 years in 2023. The

greatest burden remains concentrated in sub-Saharan Africa and south Asia, with rotavirus, *Shigella* spp, and norovirus accounting for a substantial share of global mortality. Scaling up of effective public health measures, such as timely rotavirus vaccination, oral rehydration solutions, and zinc, and continued improvements in WASH, is essential for further reductions in the enteric disease burden. This effort should be coupled with stronger surveillance, AMR control, targeted vaccine development, and sustained global health financing focused on high-burden areas and subnational hotspots.

GBD 2023 Diarrhoeal Disease and Enteric Infectious Diseases Collaborators

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Please see appendix 3 (pp 54–73) for more detailed information about individual author contributions to the research, divided into the following categories: managing the overall research enterprise; writing the first draft of the manuscript; primary responsibility for applying analytical methods to produce estimates; primary responsibility for seeking, cataloguing, extracting, or cleaning data; designing or coding figures and tables; providing data or critical feedback on data sources; developing methods or computational machinery; providing critical feedback on methods or results; drafting the manuscript or revising it critically for important intellectual content; and managing the estimation or publications process.

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To download the data used in these analyses, please visit the Global Health Data Exchange website at: <https://ghdx.healthdata.org/gbd-2023>. The statistical code used for GBD estimation is available upon request; send requests to engage@healthdata.org.

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