The unfinished agenda of communicable diseases among children and adolescents before the COVID-19 pandemic, 1990–2019: a systematic analysis of the Global Burden of Disease Study 2019

*GBD 2019 Child and Adolescent Communicable Disease Collaborators**

Lancet 2023; 402: 313–35

Published Online June 29, 2023 https://doi.org/10.1016/S0140-6736(23)00860-7

See Comment page 269

*Collaborators and their affiliations are listed at the end of the Article

Correspondence to: Prof Peter Azzopardi, Centre for Adolescent Health, Murdoch Children's Research Institute, University of Melbourne, Melbourne, VIC 3004, Australia **peter.azzopardi@mcri.edu.au**

Summary

Background Communicable disease control has long been a focus of global health policy. There have been substantial reductions in the burden and mortality of communicable diseases among children younger than 5 years, but we know less about this burden in older children and adolescents, and it is unclear whether current programmes and policies remain aligned with targets for intervention. This knowledge is especially important for policy and programmes in the context of the COVID-19 pandemic. We aimed to use the Global Burden of Disease (GBD) Study 2019 to systematically characterise the burden of communicable diseases across childhood and adolescence.

Methods In this systematic analysis of the GBD study from 1990 to 2019, all communicable diseases and their manifestations as modelled within GBD 2019 were included, categorised as 16 subgroups of common diseases or presentations. Data were reported for absolute count, prevalence, and incidence across measures of cause-specific mortality (deaths and years of life lost), disability (years lived with disability [YLDs]), and disease burden (disability-adjusted life-years [DALYs]) for children and adolescents aged 0–24 years. Data were reported across the Socio-demographic Index (SDI) and across time (1990–2019), and for 204 countries and territories. For HIV, we reported the mortality-to-incidence ratio (MIR) as a measure of health system performance.

Findings In 2019, there were 3·0 million deaths and 30·0 million years of healthy life lost to disability (as measured by YLDs), corresponding to 288·4 million DALYs from communicable diseases among children and adolescents globally (57·3% of total communicable disease burden across all ages). Over time, there has been a shift in communicable disease burden from young children to older children and adolescents (largely driven by the considerable reductions in children younger than 5 years and slower progress elsewhere), although children younger than 5 years still accounted for most of the communicable disease burden in 2019. Disease burden and mortality were predominantly in low-SDI settings, with high and high-middle SDI settings also having an appreciable burden of communicable disease morbidity (4·0 million YLDs in 2019 alone). Three cause groups (enteric infections, lower-respiratory-tract infections, and malaria) accounted for 59·8% of the global communicable disease burden in children and adolescents, with tuberculosis and HIV both emerging as important causes during adolescence. HIV was the only cause for which disease burden increased over time, particularly in children and adolescents older than 5 years, and especially in females. Excess MIRs for HIV were observed for males aged 15–19 years in low-SDI settings.

Interpretation Our analysis supports continued policy focus on enteric infections and lower-respiratory-tract infections, with orientation to children younger than 5 years in settings of low socioeconomic development. However, efforts should also be targeted to other conditions, particularly HIV, given its increased burden in older children and adolescents. Older children and adolescents also experience a large burden of communicable disease, further highlighting the need for efforts to extend beyond the first 5 years of life. Our analysis also identified substantial morbidity caused by communicable diseases affecting child and adolescent health across the world.

Funding The Australian National Health and Medical Research Council Centre for Research Excellence for Driving Investment in Global Adolescent Health and the Bill & Melinda Gates Foundation.

Introduction

The substantial reductions in burden and mortality from communicable diseases among children younger than 5 years have been one of the success stories of global health.[1,2] Key initiatives contributing to these gains include the WHO Integrated Management of Childhood Illness, the WHO and UNICEF child survival strategy, and the integrated Global Action Plan for Prevention and Control of Pneumonia and Diarrhoea (GAPPD). The Millennium Development Goals also brought a focus to

Research in context

Evidence before this study

The 2016 *Lancet* Commission on Adolescent Health and Wellbeing, a subsequent analysis of 12 headline indicators for adolescent health, and recent analyses of adolescent mortality each identified communicable diseases to be a key contributing cause of mortality and morbidity among adolescents globally. In 2016, 40% of the burden of disease (measured in disability-adjusted life-years [DALYs]) among adolescents was accounted for by communicable, maternal, and nutritional diseases. Yet these analyses report communicable diseases as an aggregate group and do not provide estimates of specific communicable disease burden, essential for targeted policy and programming. We could not find any further analyses of communicable disease burden for adolescents, or indeed for older children. In November, 2021, we searched for reports and publications describing the burden of communicable diseases among children and adolescents aged 0–24 years in the past 10 years (2012–21) using the following search terms: "communicable diseases/epidemiology" AND child* OR adoles* OR youth* OR paed* OR ped*. We also searched for specific causes (including pneumonia, diarrhoea, malaria, HIV, and tuberculosis) supplemented by recent Global Burden of Disease (GBD) publications on pneumonia and diarrhoea in young children. We reviewed peer-reviewed and selected grey literature sources: UN agencies including WHO, UNICEF, and UNAIDS; key policy and monitoring agencies, including the Independent Accountability Panel, The Partnership for Maternal, Newborn and Child Health, and Countdown to 2030; and funding bodies such as The Global Fund to Fight AIDS, Tuberculosis and Malaria and the Bill & Melinda Gates Foundation. We screened more than 6000 titles but found no report or systematic analysis of communicable disease burden across childhood and adolescence. Available evidence either focused on specific age groups (particularly children <5 years of age), specific diseases, or both, or on mortality only. Available summary reports of population health (including the WHO Global Health Observatory and the Institute for Health Metrics and Evaluation GBD capstone papers) often describe communicable disease at an aggregate level, which again is insufficient for targeted policy and actions. Countdown to 2030 and associated country profiles and available data dashboards for child and adolescent health through UNICEF and WHO include indicators of some communicable diseases, but again mostly for young children. Formerly known as the WHO and UNICEF's Child Health Epidemiology Reference Group, the Maternal Child Epidemiology Estimation (MCEE) group published global, national, and regional mortality estimates in 2019 for diarrhoea, malaria, tuberculosis, lower-respiratory-tract infections, and HIV and AIDS for children and adolescents aged 0–19 years in 5-year age groups and disaggregated by sex for those aged 15–19 years. These MCEE estimates make an essential contribution to the literature, but they are focussed on mortality. For tuberculosis, the WHO 2022 Global Tuberculosis Report (and other tuberculosis surveillance data) describes data for children and adolescents aged 0–5 years, 5–14 years, and 15–24 years by WHO region; however, there is no country-level age disaggregated data for children and adolescents. The one exception is a paper by Snow and colleagues that reported tuberculosis notification data by 5-year age groups in people aged 10–24 years. For malaria, the Malaria Atlas Project (which informs the WHO World Malaria Report) reports total all-age estimates of cases and deaths in endemic countries and regions, but does not present detailed specific estimates of incidence or burden by age or sex; data are typically reported in children and adolescents younger than 5 years, aged 5–14 years, and aged 15–49 years. For HIV, UNAIDS provides annual estimates on populations living with HIV but does not typically stratify by age or gender across the developmental window (0–24 years) in their annual global updates, with the WHO Global Health Estimates (informed by UN partners, GBD, and other scientific studies) providing global, regional, and country-level estimates for various age bands, although adolescents older than 15 years are typically aggregated with adults. One exception is a paper by Zhang and colleagues based on GBD 2019 data that reported the burden associated with HIV and sexually transmitted infections for adolescents aged 10–24 years at the global, regional, and national level in 1990–2019. For diarrhoeal disease and pneumonia, available data are focussed on children younger than 5 years.

Added value of this study

This study provides a systematic and comprehensive analysis of communicable disease across the entire developmental window from birth to 24 years of age. Data are reported at a global level, across the gradient of sociodemographic development, and at a country level, disaggregated by age and sex where possible. Although aggregate data enable advocacy, granular data are essential for targeted action and monitoring of progress. We report data on incidence and mortality (typical metrics for communicable diseases), but add value by also reporting morbidity to illustrate the true effect of these largely preventable diseases; this is especially important for children and adolescents living in settings with high sociodemographic development. To further ensure as complete a picture of communicable disease burden as possible, we reviewed all the 369 causes modelled in GBD and included all communicable diseases, their clinical presentations, or direct sequelae in our reported estimates, resulting in 83 million DALYs that are in addition to the 420 million DALYs traditionally reported as communicable diseases in GBD 2019. We report the burden of vaccine-preventable diseases and the mortality-to-incidence ratio for HIV (a non-curable communicable disease) across available age groups as measures of health system performance.

(Panel continues on next page)

(Continued from previous page)

Implications of all the available evidence

Our analysis calls for broader investments in communicable disease control. Although children younger than 5 years must remain a focus, older children and adolescents aged 5–24 years had 71 million DALYs in 2019 caused by communicable disease, a substantial burden of largely preventable disease. Diarrhoea, pneumonia, and malaria must remain a focus of action, but efforts must extend to include tuberculosis and HIV, especially for older children and adolescents. There is evidence that HIV has increased in burden for older children and adolescents, and that adolescents in many settings have excess HIV mortality. We must also extend efforts to address morbidity in addition to mortality; this brings into scope the substantial morbidity from communicable disease in children and adolescents in high-income settings. This new evidence has important implications for global policy, financing, resource allocation, and health systems; in all these efforts we must ensure that policies and services are responsive to the needs of all children and adolescents. This new evidence also requires us to consider the data we collect and report, which provide the essential foundation to accountable action. A shift from mortality to morbidity requires us to move beyond vital registration systems and to invest in strengthened population-based surveillance, which might include household and school-based surveys, but also strengthened health system monitoring. Recommended indicators for adolescents, including those recommended by the Global Action for Measurement of Adolescent health, can go further to include specific indicators of communicable disease. There is also a need to strengthen the evidence base for responsive actions.

diarrhoea and pneumonia and vaccine-preventable diseases for young children (goal 4), and HIV, malaria, and other communicable diseases at a population level (goal 6). This agenda was carried through to the Sustainable Development Goals (SDGs), in which specific targets include ending preventable deaths among children younger than 5 years (target 3.2), ending the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases, and combating hepatitis, water-borne diseases, and other communicable diseases (target 3.3). Global funding initiatives including The Global Fund to Fight AIDS, Tuberculosis and Malaria (HIV, tuberculosis, and malaria), the US Presidents' Emergency Plan for AIDS Relief, the Global Alliance for Vaccines and Immunisation, and the Grand Challenges programme through the Bill & Melinda Gates Foundation have helped drive international commitments, global policy, and national action against these targets.[3]

An important question is whether these targets of policy and action remain relevant today. Most countries (75%) were forecasted to meet the SDG under-5 mortality goal by 2030 before the COVID-19 pandemic,[4] and it is important to consider whether current interventions (largely focused on diarrhoea and pneumonia) will continue to be effective at driving sustained mortality reductions in children younger than 5 years.[5,6] Trends to 2019 have shown that the impressive gains in early childhood mortality have not extended to older children and adolescents.[7–9] We have reported that adolescents have a substantial burden of communicable disease,[10] that communicable diseases are important drivers of excess disease burden for adolescents in many settings,[11] and that population growth (also driven by improvements in child survival) is greatest in settings in which adolescents have the greatest burden of communicable diseases, with clear implications for future health systems and resourcing.[11] Yet the specific communicable diseases that drive disease burden in older children and adolescents have not been described in detail, a barrier to effective actions.[12]

The COVID-19 pandemic (and recent epidemics of mpox [formerly known as monkeypox], H1N1 influenza, Zika virus, Ebola, and severe acute respiratory syndrome, for example)[13] underscores the urgent need to take stock of communicable disease control. Some of these emergent diseases have impacted adolescents more than younger children,[14] challenging the almost exclusive focus on younger children within existing communicable disease control. COVID-19 has exposed deficiencies and inequities in our health systems, with resultant public health measures further entrenching some of these inequities through disruption to health and social services, particularly education.[15–17] Key preventive interventions, such as vaccination and school-based health education and screening, have been impacted, particularly in low-income and middle-income countries.[15,18–20] There are now important opportunities for individual countries to build back better, which include improving health and social services, but to do so, we must understand the foundations upon which we are building.[21] Here, we use the Institute of Health Metrics and Evaluation (IHME) Global Burden of Disease Study 2019 (GBD 2019) to systematically characterise the burden of communicable disease mortality and morbidity between 1990 and 2019 by age, sex, and sociodemographic development, globally and within 204 countries and territories. We focus on the developmental window from birth to 24 years of age, when disease burden changes markedly, as do opportunities for intervention. This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Broader methods relating to GBD 2019, including primary data sources, approaches to disease modelling, and definitions of disease outcomes, are detailed

elsewhere.[22,23] Hereafter we present specific methods and assumptions of relevance to this secondary data analysis.

Data sources

For more on the **IHME Global Health Data Exchange** see http://ghdx.healthdata.org/gbd-results-tool

We used GBD 2019 data accessed from the IHME Global Health Data Exchange. We accessed data between Dec 10, 2021, and Nov 4, 2022 for all causes (at level 4) as absolute numbers and rates per 100 000 population for the following metrics: mortality (deaths and years of life lost [YLLs]); disability (years lived with disability [YLDs]); and disease burden (measured as disability-adjusted life-years [DALYs]). We accessed data for all ages (in 5-year age bands up to 24 years, then for 25 years and older), for males and females, for all years between 1990 and 2019, and for 204 countries and territories. We also accessed the IHME sociodemographic index to group countries at similar levels of sociodemographic development, comprising high, mid-high, middle, mid-low, and low socioeconomic development (appendix pp 1–4). GBD 2019 complies with the Guidelines for Accurate and Transparent Health Estimates Reporting statement and all data input sources and statistical codes are available online.[24,25]

See Online for appendix

Definitions

GBD 2019 includes 369 causes of disease and injury organised within three disease groups: communicable, maternal, neonatal, and nutritional diseases (group A); non-communicable diseases (group B); and injuries (group C; appendix pp 5–6). For this analysis we included all causes of communicable disease in group A (cause groups A1 to A5); these causes include specific infectious diseases (eg, cause group A.1.1, HIV) and clinical presentations of communicable disease (eg, cause group A.2.2, lower-respiratory-tract infection). We then reviewed all other causes included within group B and group C in GBD 2019 and their corresponding International Classification of Disease codes to identify other relevant communicable diseases.[26] Maternal sepsis (A.6.1.2), neonatal sepsis (A.6.2.3), rheumatic heart disease (B.2.1), bacterial skin disease (B.9.3), scabies (B.9.4), fungal skin disease (B.9.5), viral skin disease (B.9.6), liver cancer caused by hepatitis B and C (B.1.7.1 and B.1.7.2), and cirrhosis and chronic liver disease caused by hepatitis B and C (B.4.1.1 and B.4.1.2) were all included within our definition of communicable diseases (appendix pp 5–6). We did not include cervical cancer (B.1.15), given that modelled estimates are not specific to human papillomavirus. Our definition of communicable diseases yielded a total disease burden of 503 296 274 DALYs in 2019 for all age groups compared with 420 392 536 for cause groups A1–A5. All communicable diseases included in our analysis were additionally subcategorised into 16 sub-groupings that represent common communicable diseases or clinical presentations (appendix pp 5–6).

This analysis focused on the developmental window of childhood and adolescence. Consistent with newer understandings of neurodevelopment but also global shifts in the timing of key social role transitions (such as completion of education and parenthood), we define childhood as being younger than 10 years and adolescence as being 10–24 years of age.[27] Data are reported in 5-year age bands within these broad definitions of childhood and adolescence; we did not further disaggregate the under 5-year age band given that these estimates are extensively reported elsewhere. We additionally defined three aggregate groups that represent key target populations within the health sector: young children (younger than 5 years), older children and young adolescents who are still consistently cared for by paediatric services (5–14 years),[28] and older adolescents (15–24 years).[27] We use the Socio-demographic Index, a composite indicator of development based on the geometric mean of total fertility (younger than 25 years), mean education (15 years and older), and lag-distributed income per capita.

Analysis and reporting

Data were reported as absolute count, cases per 100 000 population, and incidence (cases of new disease per 100 000 population per year) across measures of mortality, disability (YLD or morbidity), and disease burden (DALYs). Of note, GBD 2019 does not model deaths caused by scabies, or fungal or viral skin conditions. Estimates were reported for each of 204 locations separately, across sociodemographic development groupings, and for adolescents globally, noting that the global estimate is greater than the sum of 204 individual nations or territories, because it includes people who are stateless and additional nations and territories. We estimated the percentage change between 1990 and 2019 (difference between 2019 and 1990 value divided by the 1990 value and multiplied by 100), reporting this value as an annualised percentage change (dividing by 30 years). Where possible, we also reported the corresponding uncertainty interval (UI) for each estimate. This interval is produced for each estimate by running 1000 draws of the posterior distribution, ordering the draws, and selecting the 25th and 975th draw values.[29] The code that is used to produce the estimates is available online.[25] Given that UIs are obtained during modelling, these intervals are not available for some aggregate estimates that we provide in this analysis (eg, the 0–24-year age group for total communicable disease cause). Uncertainty for each cause that contributes to our aggregate estimates by age, sex, and country is detailed in the appendix (pp 87–167).

As a measure of health system response to communicable disease, we reported the mortality-to-incidence ratio (MIR) for HIV.[20,30] The MIR calculation was only estimated for HIV given that it is a true chronic communicable disease for which a definitive objective diagnosis is typical, and treatment, remission, and several incident infections are not possible. MIR was calculated by dividing the number of cause-specific

deaths by the number of new cases for a given year. We reported this metric for children younger than 5 years, adolescents aged 15–19 years, and adolescents aged 20–24 years; HIV incidence for children and adolescents aged 5–14 years was modelled to be negligible by GBD and is excluded here.

Data were analysed in Stata 17.0 and visualisations prepared in Stata and Tableau 2021.3.20.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Total burden of communicable disease across childhood and adolescence

In 2019, there were 3·0 million deaths and 30·0 million years of healthy life lost to disability (as measured by YLDs) from communicable diseases globally among people aged 0–24 years, corresponding to a total disease burden of 288·4 million DALYs (table 1). This burden represents 57·3% of the total communicable disease burden across all ages. For children and adolescents specifically, communicable disease accounted for 44·1% of the total 6·9 million deaths in this age group, 16·6% of the total disability, and 37·9% of the total 760·0 million all-cause DALYs (table 1). Globally, the proportion of deaths caused by communicable diseases in 2019 was between 41·2% and 55·9% for those aged 0–14 years, decreasing to between 20·6% and 33·9% among those aged 15–24 years (table 1). This pattern was similar for disability, with the proportion of YLDs attributable to communicable diseases consistently declining with increasing age. Communicable disease burden among children and adolescents was predominantly in countries of low sociodemographic development, with 1·8 million deaths (58·2% of all communicable disease deaths among children and adolescents) and 161·4 million DALYs (56·0% of all communicable disease DALYs among children and adolescents; appendix pp 7–10). More than half of the mortality among children and adolescents in settings of low sociodemographic development was caused by communicable diseases compared with just 5·6% of deaths and 7·1% of DALYs in settings of high sociodemographic development (appendix pp 8–10).

There were important changes in communicable disease epidemiology across childhood and adolescence

	Population	Mortality (deaths)			Disability (YLDs)			Disease burden (DALYs)		
		All-cause	Communicable disease	Percentage due to communicable diseases	All-cause	Communicable disease	Percentage due to communicable diseases	All-cause	Communicable disease	Percentage due to communicable diseases
Under 5 years										
Female	320 443 936	2 311 567	1 154 730	50·0%	12 885 506	3 340 269	25·9%	216 237 639	104 465 025	48·3%
Male	342 398 784	2 732 001	1 245 653	45·6%	14 182 583	3 600 909	25·4%	254 728 403	112 733 037	44·3%
5–9 years										
Female	316 754 496	167 708	93 711	55·9%	13 824 110	3 389 243	24·5%	27 539 772	11 053 467	40·1%
Male	337 949 216	210 032	106 164	50·5%	15 108 232	3 693 489	24·4%	32 272 747	12 370 285	38·3%
10–14 years										
Female	310 852 512	129 193	60 936	47·2%	17 981 681	2 794 176	15·5%	27 855 730	7 451 772	26·8%
Male	331 334 176	170 079	70 032	41·2%	16 907 999	2 974 792	17·6%	29 903 595	8 326 975	27·8%
15–19 years										
Female	301 758 880	196 977	66 846	33·9%	23 120 691	2 660 741	11·5%	37 193 646	7 436 890	20·0%
Male	317 782 112	302 328	77 986	25·8%	18 794 347	2 490 160	13·2%	40 371 375	8 058 373	20·0%
20–24 years										
Female	295 776 256	255 141	81 310	31·9%	27 205 707	2 676 953	9·8%	44 184 802	8 087 317	18·3%
Male	304 368 224	437 271	90 184	20·6%	20 650 899	2 420 924	11·7%	49 742 667	8 421 269	16·9%
≥25 years										
Female	2 310 904 064	22 784 061	2 905 445	12·8%	381 599 235	18 658 273	4·9%	837 038 989	92 819 766	11·1%
Male	2 247 142 144	26 830 603	3 589 282	13·4%	298 712 790	18 158 028	6·1%	940 950 706	122 072 101	13·0%
0–24 years										
Female and male	3 179 418 560	6 912 296	3 047 551	44·1%	180 661 755	30 041 657	16·6%	760 030 375	288 404 407	37·9%
Female	1 545 586 080	3 060 585	1 457 533	47·6%	95 017 694	14 861 382	15·6%	353 011 588	138 494 470	39·2%
Male	1 633 832 512	3 851 711	1 590 018	41·3%	85 644 061	15 180 275	17·7%	407 018 787	149 909 938	36·8%

DALYs=disability-adjusted life-years. YLDs=years of life lost to disability.

Table 1: **Age and sex-specific estimates of deaths, YLDs, and DALYs (all-cause and communicable-disease specific), in 2019**

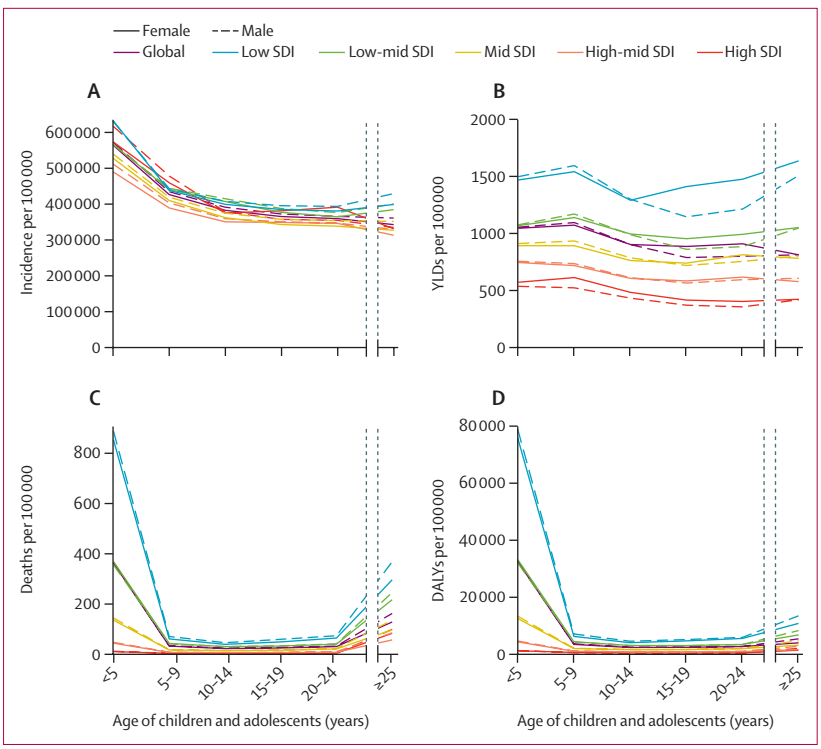


Figure 1: **Communicable disease incidence (A), YLDs (B), mortality (C), and DALYs (D) by age, sex, and SDI, in 2019**

DALY=disability-adjusted life years. SDI=Socio-demographic Index. YLD=years of life lost to disability.

(figure 1). Communicable disease incidence (figure 1A; appendix pp 11–12) was highest in children younger than 5 years (569 924 communicable diseases per 100 000 population for both sexes globally) but remained high across childhood (431 375 communicable diseases per 100 000 population for children aged 5–9 years) and for adolescents aged 15–19 years (369 246 communicable diseases per 100 000 population). There appeared to be little difference in all-cause incidence by sex or socioeconomic development. Disability caused by communicable disease as measured by YLDs (figure 1B; appendix pp 13–14) was relatively similar across age and sex, but with marked variation across socioeconomic development. Communicable diseases in children and adolescents aged 0–24 years caused 1407 YLDs per 100 000 population in settings of low sociodemographic development and 458 YLDs per 100 000 population in settings of high sociodemographic development. There was marked variation in mortality (figure 1C; table 1; appendix pp 15–16) by age and sociodemographic development, with mortality caused by communicable diseases greatest for children younger than 5 years (mortality rate 362·1 per 100 000 population and a total of 2·4 million deaths in 2019), especially for children younger than 5 years in settings of low sociodemographic development (869 deaths per 100 000 population for both sexes). However, the relatively low mortality throughout later childhood and adolescence still corresponded to a substantial number of deaths; overall, 647 169 deaths from communicable diseases occurred among children and adolescents aged 5–24 years in 2019, corresponding to 6·8% of total deaths from communicable diseases and 34·6% of all deaths in this age group (table 1). In 2019, DALYs (figure 1D; appendix pp 17–18) were largely driven by mortality (288·4 million DALYs for individuals aged 0–24 years, comprising 30·0 million YLDs and 258·4 million YLLs), and as a result, trends in DALYs largely mirrored trends in mortality.

Communicable disease epidemiology changed over time from 1990 to 2019 (figure 2). Incidence of communicable diseases (figure 2A) declined most markedly for children younger than 5 years, and especially for those younger than 5 years in settings of low sociodemographic development, with an annual decline of around 0·5% in settings of low sociodemographic development compared with a 0·03% decline in settings of high sociodemographic development. As a result, in 2019 the incidence of communicable diseases for children younger than 5 years in settings of high sociodemographic development (597 655 communicable diseases per 100 000 population) was similar to that in settings of low sociodemographic development (633 509 communicable diseases per 100 000 population). The change in incidence among older children and adolescents across sociodemographic development settings was small. Disability as measured by YLDs (figure 2B) changed little globally for children and adolescents (0·5% for those aged <5 years, 0·4% for those aged 5–14 years, and 0·5% for those aged 15–24 years); however, there were marked reductions in YLDs in settings of low sociodemographic development (1·0% annual decline for individuals aged 0–24 years overall). Mortality caused by communicable diseases (figure 2D; appendix pp 15–16) declined most markedly for children younger than 5 years (2·2% annual decline globally) and those aged 5–14 years (1·9% annual decline globally), with changes for adolescents aged 15–24 years being more modest (1·3% annual decline globally). Declines in mortality between 1990 and 2019 were most marked in settings of low sociodemographic development, where for children younger than 5 years, deaths decreased from 2752 per 100 000 to 869 deaths per 100 000 between 1990 and 2019 (an average decline of 2·3% per year). Shifts in total disease burden (figure 2C) largely mirrored shifts in mortality. At a global level, these relative transitions in epidemiology by age and sociodemographic development resulted in the communicable disease burden increasingly shifting from children younger than 5 years to older children and adolescents between 1990 and 2019 (DALYs in appendix p 20 and mortality in appendix p 21). In 1990, 85% of the communicable disease burden across the developmental window was among children younger than 5 years, decreasing to 75% in 2019.

Total disease burden caused by communicable diseases (as measured by DALYs) for children and adolescents at a country level changed from 1990 to 2019 (figure 3). For

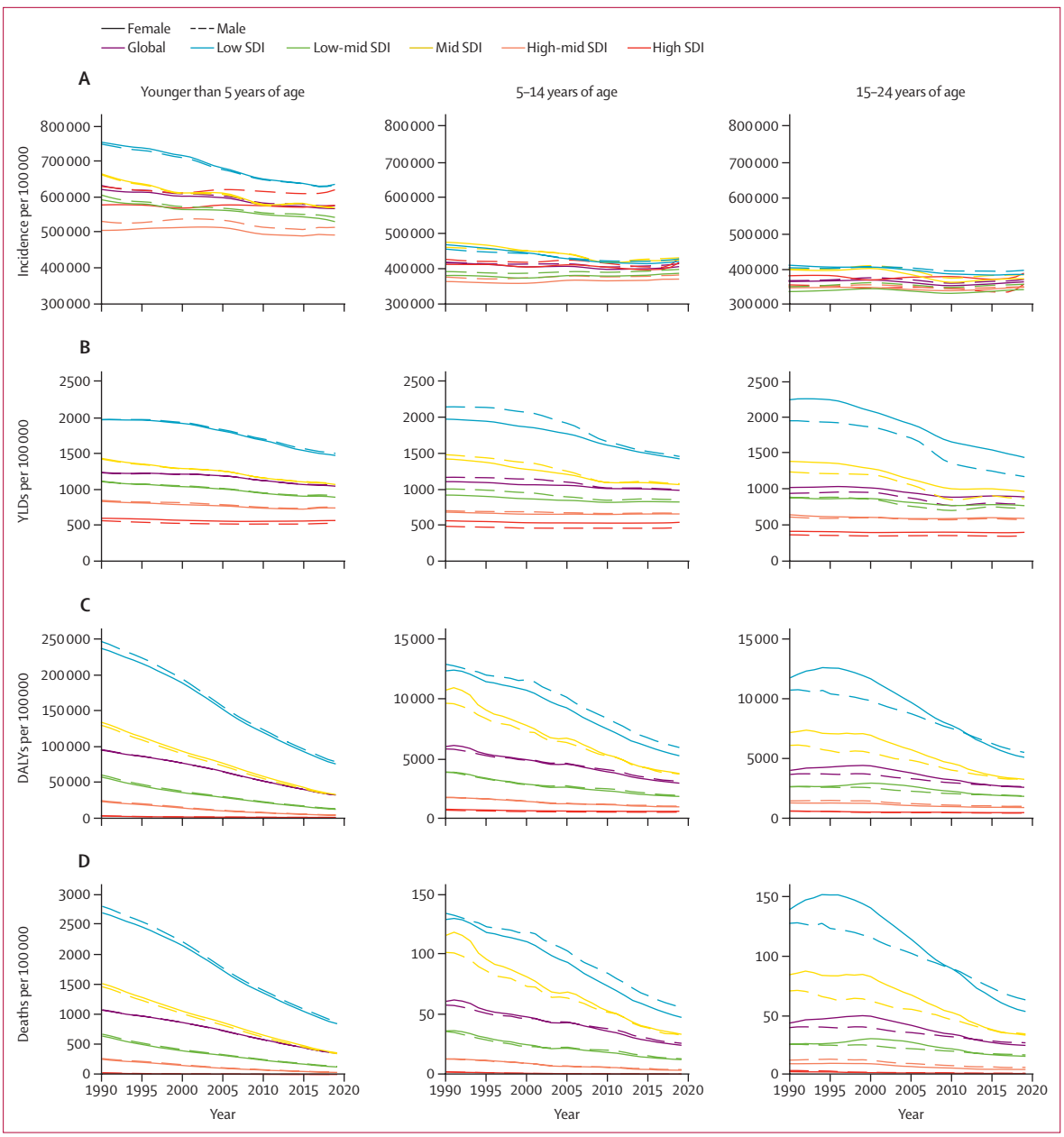


Figure 2: **Trends over time (1990–2019) for communicable disease incidence, deaths, YLDs, and DALYs per 100 000 by age, sex, and SDI**
The incidence graphs start at 300 000 cases per 100 000 per year and the age groups younger than 5 years are on a different y-scale for deaths and DALYs. DALY=disability-adjusted life-years. SDI=Socio-demographic Index. YLD=years of life lost to disability.

children younger than 5 years, there were uniform and significant reductions in the communicable disease burden (especially noting the magnitude of reduction among these children under 5 years given the unique axis values for DALYs in figure 3), compared with children and adolescents aged 5–14 years and adolescents aged 15–24 years. Although most countries showed a decline in communicable disease burden, large increases (>2% annual increase) in burden were seen in Eswatini, Lesotho, and South Africa, for the 15–24-year age group. In 2019, countries in sub-Saharan Africa and some countries in Asia had the largest burden of communicable diseases for children and adolescents.

Cause-specific estimates of communicable diseases in children and adolescents

60% of communicable disease burden (as measured by DALYs) among children and adolescents was accounted for by three cause groups in 2019 (table 2), comprising enteric infections (69·5 million DALYs, 24·1% total),

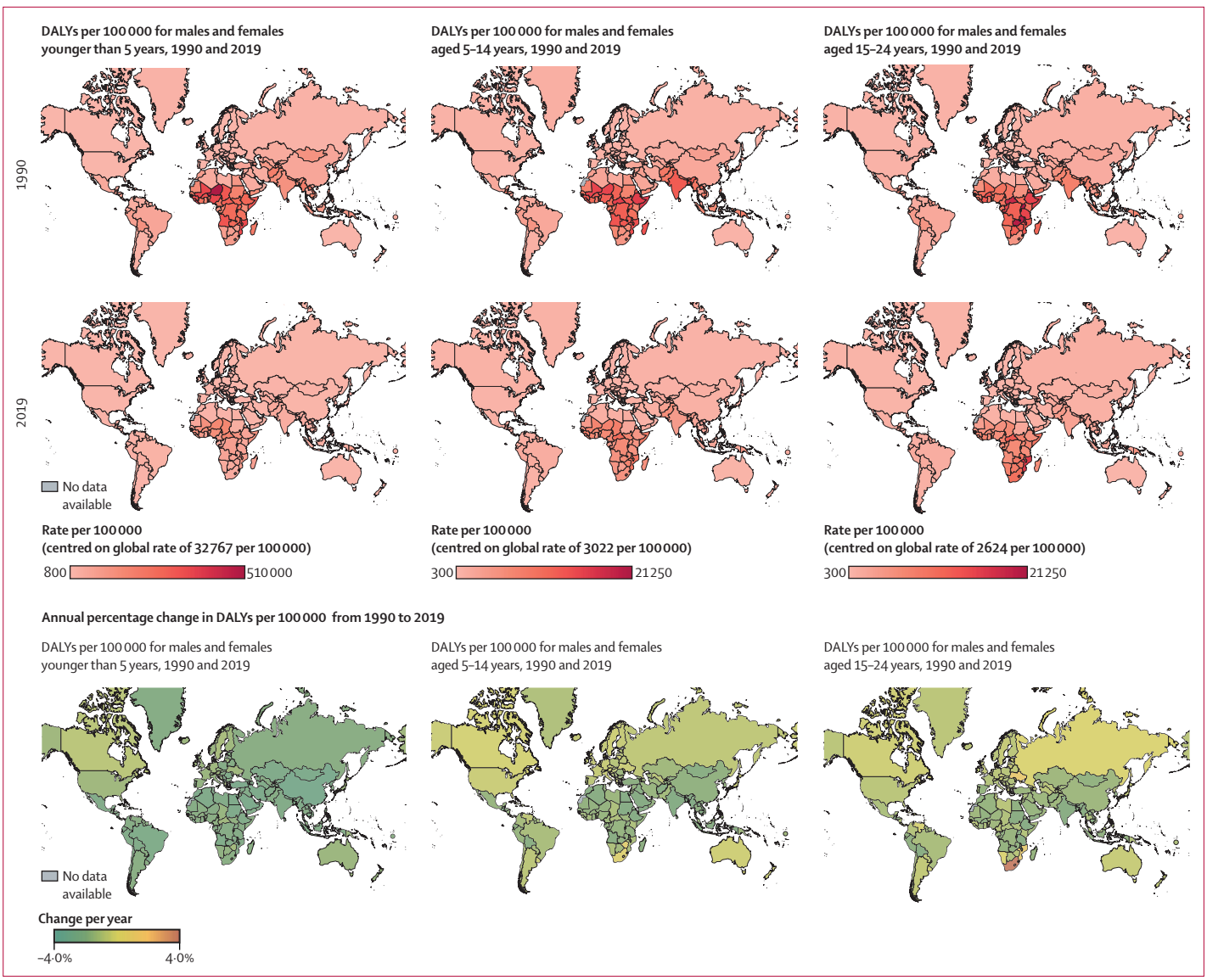


Figure 3: **Communicable disease burden in 1990 and 2019, and its annual rate of change by country and age**
The colour scheme for the DALY rate in 1990 and 2019 is specific for each age group and the colour band is centred around the global rate of DALYs and reported on each legend. DALY=disability-adjusted life-years.

lower-respiratory-tract infections (LRTIs; 64·7 million DALYs, 22·4% total), and malaria (38·3 million DALYs, 13·3% total). These same cause groups together accounted for almost two-thirds of all deaths caused by communicable diseases among children and adolescents: enteric infections (763 545 deaths, 25·1% of deaths caused by communicable diseases), LRTIs (743 546 deaths, 24·4% of deaths caused by communicable diseases), and malaria (427 469 deaths, 14·0% of deaths caused by communicable diseases).

Contributors to communicable disease burden (as measured by DALYs) by age, sex, and sociodemographic development are presented in the appendix (p 19). LRTIs and enteric infections were the leading causes of communicable disease burden across childhood and early-to-mid adolescence globally. For older adolescents aged 20–24 years, HIV and tuberculosis emerged as leading causes. HIV caused 20·9% of the communicable disease burden in females and 10·3% in males, and 28·3% of age-specific deaths in females and 13·2% in males aged 20–24 years (appendix pp 15, 18). Tuberculosis caused 18·7% of the communicable disease burden in males and 14·0% in females, and 22·6% of age-specific deaths in males and 15·9% in females aged 20–24 years. Rheumatic heart disease, maternal sepsis, and sexually transmitted infections (STIs; excluding HIV) were other communicable diseases that predominantly emerged during adolescence, albeit with a considerably smaller burden.

Causes of communicable diseases varied substantially by sociodemographic development (appendix pp 11–19). In settings of low sociodemographic development, enteric diseases and LRTIs were the leading causes of DALYs among children and adolescents (with enteric diseases causing 25·9% of the burden and LRTIs causing 21·6% of the burden in settings of low sociodemographic development), whereas infectious skin conditions and upper-respiratory-tract infections (URTIs) were the leading causes in settings of high sociodemographic development (with infectious skin diseases causing 28·7% of the burden and URTIs causing 22·1% of the burden).

	Mortality (deaths)			Disability			Disease Burden		
	Number of deaths	Deaths per 100 000 (percentage change per year)	Percentage of deaths caused by communicable diseases	Number of YLDs	YLDs per 100 000 (percentage change per year)	Percentage of YLDs caused by communicable diseases	Number of DALYs	DALYs per 100 000 (percentage change per year)	Percentage of DALYs caused by communicable diseases
Enteric infections									
Female	355 016	23·0 (–2·3%)	24·4%	2 426 525	157·0 (–0·4%)	16·3%	32 420 734	2 097·6 (–2·2%)	23·4%
Male	408 529	25·0 (–2·2%)	25·7%	2 599 957	159·1 (–0·4%)	17·1%	37 102 149	2 270·9 (–2·2%)	24·7%
Lower-respiratory-tract infections									
Female	363 980	23·5 (–2·4%)	25·0%	102 760	6·6 (–1·4%)	0·7%	31 693 882	2 050·6 (–2·4%)	22·9%
Male	379 566	23·2 (–2·4%)	23·9%	119 028	7·3 (–1·3%)	0·8%	33 012 492	2 020·6 (–2·4%)	22·0%
Malaria									
Female	211 315	13·7 (–1·5%)	14·5%	1 126 500	72·9 (0·0%)	7·6%	19 166 971	1 240·1 (–1·5%)	13·8%
Male	216 154	13·2 (–1·5%)	13·6%	889 966	54·5 (–0·2%)	5·9%	19 172 678	1 173·5 (–1·4%)	12·8%
Neonatal sepsis and other neonatal infections									
Female	100 303	6·5 (–0·8%)	6·9%	1 000 143	64·7 (7·9%)	6·7%	9 908 325	641·1 (–0·6%)	7·2%
Male	126 214	7·7 (–0·8%)	7·9%	1 060 359	64·9 (8·8%)	7·0%	12 270 216	751·0 (–0·7%)	8·2%
Vaccine-preventable disease									
Female	117 278	7·6 (–2·8%)	8·0%	105 275	6·8 (–2·0%)	0·7%	10 215 674	661·0 (–2·8%)	7·4%
Male	111 480	6·8 (–2·8%)	7·0%	94 315	5·8 (–2·1%)	0·6%	9 703 923	593·9 (–2·8%)	6·5%
Meningitis and encephalitis									
Female	82 954	5·4 (–2·2%)	5·7%	257 998	16·7 (–1·1%)	1·7%	7 207 750	466·3 (–2·2%)	5·2%
Male	101 377	6·2 (–2·0%)	6·4%	274 568	16·8 (–1·3%)	1·8%	8 767 715	536·6 (–2·0%)	5·8%
HIV and AIDS									
Female	74 914	4·8 (0·2%)	5·1%	345 448	22·4 (2·4%)	2·3%	6 051 479	391·5 (0·2%)	4·4%
Male	64 035	3·9 (0·8%)	4·0%	219 471	13·4 (6·1%)	1·4%	5 226 905	319·9 (0·6%)	3·5%
Tuberculosis									
Female	54 313	3·5 (–2·5%)	3·7%	708 837	45·9 (–1·3%)	4·8%	4 985 849	322·6 (–2·4%)	3·6%
Male	62 201	3·8 (–2·3%)	3·9%	492 195	30·1 (–1·1%)	3·2%	5 287 041	323·6 (–2·3%)	3·5%
Neglected tropical diseases									
Female	15 834	1·0 (–2·4%)	1·1%	2 330 032	150·8 (–1·4%)	15·7%	3 621 573	234·3 (–1·9%)	2·6%
Male	24 779	1·5 (–2·3%)	1·6%	2 476 188	151·6 (–1·7%)	16·3%	4 465 254	273·3 (–2·1%)	3·0%
Infectious skin conditions									
Female	3278	0·2 (–1·3%)	0·2%	3 344 347	216·4 (–0·1%)	22·5%	3 617 997	234·1 (–0·3%)	2·6%
Male	2421	0·1 (–1·5%)	0·2%	3 678 489	225·1 (–0·1%)	24·2%	3 872 745	237·0 (–0·2%)	2·6%
Sexually transmitted infections excluding HIV									
Female	37 374	2·4 (–0·9%)	2·6%	75 221	4·9 (0·4%)	0·5%	3 378 042	218·6 (–0·9%)	2·4%
Male	45 258	2·8 (–0·9%)	2·8%	58 207	3·6 (0·2%)	0·4%	4 068 741	249·0 (–0·9%)	2·7%
Upper-respiratory-tract infections									
Female	2043	0·1 (–2·8%)	0·1%	1 991 663	128·9 (–0·1%)	13·4%	2 167 122	140·2 (–1·1%)	1·6%
Male	2915	0·2 (–2·7%)	0·2%	2 282 909	139·7 (–0·1%)	15·0%	2 532 781	155·0 (–1·0%)	1·7%
Other unspecified infectious diseases									
Female	10 559	0·7 (–1·2%)	0·7%	562 619	36·4 (–0·2%)	3·8%	1 452 672	94·0 (–0·9%)	1·0%
Male	14 644	0·9 (–1·3%)	0·9%	515 999	31·6 (–0·3%)	3·4%	1 723 549	105·5 (–1·1%)	1·1%
Hepatitis									
Female	14 837	1·0 (–2·3%)	1·0%	91 598	5·9 (–0·2%)	0·6%	1 249 223	80·8 (–2·3%)	0·9%
Male	21 079	1·3 (–2·1%)	1·3%	105 110	6·4 (–0·3%)	0·7%	1 714 000	104·9 (–2·1%)	1·1%

(Table 2 continues on next page)

	Mortality (deaths)			Disability			Disease Burden		
	Number of deaths	Deaths per 100 000 (percentage change per year)	Percentage of deaths caused by communicable diseases	Number of YLDs	YLDs per 100 000 (percentage change per year)	Percentage of YLDs caused by communicable diseases	Number of DALYs	DALYs per 100 000 (percentage change per year)	Percentage of DALYs caused by communicable diseases
(Continued from previous page)									
Rheumatic heart disease									
Female	8719	0·6 (–1·9%)	0·6%	351 987	22·8 (0·9%)	2·4%	987 240	63·9 (–1·5%)	0·7%
Male	9366	0·6 (–1·6%)	0·6%	313 517	19·2 (0·9%)	2·1%	989 751	60·6 (–1·2%)	0·7%
Maternal sepsis and other maternal infections									
Female	4815	0·3 (–2·3%)	0·3%	40 429	2·6 (–1·2%)	0·3%	369 940	23·9 (–2·2%)	0·3%
Male	..	..	..	..	..	..	..	..	..
Total communicable diseases									
Female	1 457 533	94·3 (–2·2%)	100·0%	14 861 382	961·5 (–0·4%)	100·0%	138 494 470	8960·4 (–2·2%)	100·0%
Male	1 590 018	97·3 (–2·2%)	100·0%	15 180 275	929·1 (–0·5%)	100·0%	149 909 936	9175·6 (–2·2%)	100·0%

Results are ordered by largest DALYs burden. For skin disease, only bacterial skin disease contributes to the value for deaths, because there were no deaths recorded for fungal and viral skin diseases or scabies. DALY=disability-adjusted life-years. YLD=years of life lost to disability.

Table 2: **Cause-specific estimates of DALYs and deaths for each communicable disease in 2019 and annual rate of change since 1990, for children and adolescents aged 0–24 years by sex**

Of note, DALYs caused by skin infections and URTIs were mostly caused by YLDs, with little mortality attributed to these causes (total of 10 647 deaths globally, 0·3% of the total communicable disease deaths). Conditions such as neonatal sepsis, maternal sepsis, and meningitis predominantly affected children and adolescents in settings of low and middle sociodemographic development, with rheumatic heart disease and neglected tropical diseases exclusively so. By contrast, hepatitis and STIs affected children and adolescents across all sociodemographic development settings.

There was an overall reduction in burden (as measured by DALYs) for the key causes of communicable diseases globally between 1990 and 2019 (table 2). Annual declines in DALYs of at least 2% were seen for eight cause groups, comprising enteric infections, LRTIs, vaccine-preventable diseases, meningitis and encephalitis, tuberculosis, neglected tropical diseases, hepatitis, and maternal sepsis and other maternal infections. Malaria burden only declined 1·5% annually and declines in infectious skin conditions, neonatal infections, and STIs were less than 1% annually. These declines were seen largely in settings of low and middle sociodemographic development (appendix p 17). The only disease to increase in burden over time was HIV (0·2% annual increase for males and 0·6% for females). HIV burden increased most for children and adolescents in settings of middle sociodemographic development (14·3% annual increase for females and 12·1% for males; appendix p 17), and across settings, increases were most marked for children aged 5–9 years (13·3% annual increase for females and 13·5% increase for males globally), those aged 10–14 years (128·2% for females and 83·6% for males globally), and male adolescents aged 15–19 years (22·3% annual increase; appendix p 18). With respect to incidence, the causes where there has been an increased incidence over time globally included rheumatic heart disease and neglected tropical diseases (particularly among adolescents), and STIs in some settings of low and low-middle sociodemographic development.

Key findings by leading cause groups for children and adolescents

In this section we focus on five major contributors to overall communicable disease burden in children and adolescents, comprising enteric infections, LRTIs, and malaria, as well as tuberculosis and HIV which both emerged as key causes of burden in older adolescents; these five conditions accounted for 71·9% of communicable disease-related deaths and 67·3% of DALYs in those aged 0–24 years (69·7% of DALYs for children <5 years, 58·8% for those aged 5–14 years, and 61·2% for adolescents aged 15–24 years; appendix p 18). The countries that contribute the largest burden for these five causes are reported in table 3 (the specific burden in each country is reported in figure 4). It is worth additionally noting the burden of vaccine-preventable disease given that it is a marker of health-system performance. In 2019, globally there were 228 758 deaths in children and adolescents from diphtheria, pertussis, tetanus, measles, and varicella, 153 169 (66·9%) of which occurred in settings of low sociodemographic development.

In 2019, there were about 69·5 million DALYs caused by enteric infections among children and adolescents (table 2; appendix pp 18, 22–26), of which about 41·9 million occurred in settings of low sociodemographic development and 19·6 million in settings of low-middle sociodemographic development (88·3% of total combined). Globally, almost three quarters of this burden (74·5%) was in children younger than 5 years, but the burden among those aged 5–24 years was substantial (17·7 million DALYs and 190 487 deaths globally). Three

countries (India, Nigeria, and Pakistan) together accounted for almost half (47·7%) of the total burden of enteric infection globally for children and adolescents (table 3). The largest burden per capita (figure 4) was in Chad (21 278 DALYs per 100 000 population), Central African Republic (16 202 DALYs per 100 000), Niger (14 883 DALYs per 100 000), and Nigeria (11 323 DALYs per 100 000). Most countries (187 [92%] of 204) saw reductions in enteric disease burden for children and adolescents between 1990 and 2019 (appendix p 22–26), with the greatest reductions seen in Equatorial Guinea (a decrease of 3·3% per year) and Nicaragua (a decrease of 3·2% per year). Among specific groups, boys aged 5–14 years in Zimbabwe (an increase of 2·1% per year, 95% UI –0·13 to 6·0), and boys aged 15–24 years in Puerto Rico (an increase of 1·7% per year) showed the greatest increases.

In 2019, there were a total of 64·7 million DALYs caused by LRTIs among children and adolescents (table 2; appendix pp 18, 22–26). Similar to enteric infections, the

	Enteric infections	Lower-respiratory-tract infections	Malaria	Tuberculosis	HIV and AIDS
<5 years					
1	Nigeria (27·1%)	Nigeria (19·2%)	Nigeria (26·8%)	Nigeria (14·2%)	Mozambique (19·8%)
2	India (11·2%)	India (19·2%)	Democratic Republic of the Congo (12·4%)	India (10·2%)	Nigeria (12·9%)
3	Pakistan (6·3%)	Pakistan (6·9%)	Uganda (4·9%)	Pakistan (10·0%)	Ethiopia (6·8%)
4	Chad (4·4%)	Ethiopia (2·9%)	Niger (4·6%)	Democratic Republic of the Congo (8·6%)	Zambia (6·2%)
5	Ethiopia (4·4%)	Niger (2·6%)	Burkina Faso (4·6%)	Somalia (4·1%)	Kenya (5·2%)
6	Niger (4·4%)	Tanzania (2·5%)	Côte d'Ivoire (3·9%)	Tanzania (3·2%)	South Africa (3·9%)
7	Democratic Republic of the Congo (3·7%)	Burkina Faso (2·4%)	Mali (3·9%)	Ethiopia (3·1%)	India (3·8%)
8	Cameroon (2·5%)	China (2·2%)	Tanzania (3·7%)	Angola (3·1%)	Uganda (3·6%)
9	Burkina Faso (2·2%)	Somalia (2·1%)	Ethiopia (3·2%)	Chad (3·0%)	Zimbabwe (2·9%)
10	Madagascar (1·9%)	Democratic Republic of the Congo (2·1%)	Ghana (2·8%)	Burkina Faso (3·0%)	Tanzania (2·7%)
5–14 years					
1	India (35·6%)	India (21·3%)	Nigeria (24·5%)	India (20·2%)	Mozambique (14·4%)
2	Pakistan (11·7%)	Pakistan (7·5%)	India (15·2%)	Pakistan (17·6%)	South Africa (12·7%)
3	Nigeria (9·9%)	Nigeria (5·7%)	Democratic Republic of the Congo (8·8%)	Democratic Republic of the Congo (7·4%)	Ethiopia (6·0%)
4	Bangladesh (4·0%)	Bangladesh (4·1%)	Mozambique (4·9%)	Nigeria (5·2%)	Kenya (5·8%)
5	Ethiopia (2·7%)	Democratic Republic of the Congo (3·8%)	Pakistan (4·0%)	Indonesia (4·2%)	Uganda (5·4%)
6	Indonesia (2·5%)	Ethiopia (3·3%)	Uganda (3·6%)	Philippines (3·6%)	Nigeria (5·0%)
7	Democratic Republic of the Congo (2·0%)	Philippines (3·2%)	Côte d'Ivoire (3·4%)	Bangladesh (3·4%)	Zimbabwe (4·8%)
8	Tanzania (1·6%)	China (2·6%)	Cameroon (2·7%)	Ethiopia (2·6%)	Tanzania (4·5%)
9	Kenya (1·5%)	Egypt (2·4%)	Niger (2·5%)	Somalia (2·3%)	Malawi (4·3%)
10	Mali (1·3%)	Tanzania (2·4%)	Burkina Faso (2·4%)	South Africa (2·2%)	Zambia (3·5%)
15–24 years					
1	India (39·7%)	India (18·3%)	Nigeria (29·2%)	India (26·8%)	South Africa (14·7%)
2	Pakistan (9·7%)	Nigeria (4·8%)	India (6·2%)	Pakistan (9·3%)	Mozambique (12·4%)
3	Nigeria (6·4%)	Democratic Republic of the Congo (4·0%)	Democratic Republic of the Congo (6·0%)	Indonesia (6·2%)	Kenya (6·9%)
4	Ethiopia (3·4%)	Ethiopia (3·5%)	Côte d'Ivoire (4·7%)	Democratic Republic of the Congo (4·8%)	Nigeria (6·6%)
5	Indonesia (3·3%)	Philippines (3·4%)	Yemen (4·5%)	Ethiopia (4·1%)	India (5·4%)
6	Bangladesh (3·0%)	Pakistan (3·2%)	Cameroon (4·0%)	Nigeria (3·8%)	Ethiopia (5·1%)
7	Kenya (1·9%)	China (2·9%)	Ghana (3·9%)	Somalia (2·9%)	Uganda (4·4%)
8	Democratic Republic of the Congo (1·9%)	Brazil (2·7%)	Mozambique (3·7%)	Mozambique (2·8%)	Tanzania (4·2%)
9	Tanzania (1·6%)	Tanzania (2·0%)	Burkina Faso (3·0%)	Tanzania (2·4%)	Zambia (3·5%)
10	China (1·5%)	Kenya (2·0%)	Uganda (2·5%)	Philippines (2·3%)	Cameroon (2·7%)

(Table 3 continues on next page)

	Enteric infections	Lower-respiratory-tract infections	Malaria	Tuberculosis	HIV and AIDS
(Continued from previous page)					
0–24 years					
1	Nigeria (22·4%)	India (19·3%)	Nigeria (26·7%)	India (18·4%)	Mozambique (15·6%)
2	India (17·8%)	Nigeria (18·0%)	Democratic Republic of the Congo (11·6%)	Pakistan (10·8%)	South Africa (10·2%)
3	Pakistan (7·5%)	Pakistan (6·9%)	Uganda (4·6%)	Nigeria (8·6%)	Nigeria (8·7%)
4	Ethiopia (4·0%)	Ethiopia (3·0%)	India (4·3%)	Democratic Republic of the Congo (6·9%)	Kenya (6·1%)
5	Niger (3·5%)	Tanzania (2·5%)	Burkina Faso (4·3%)	Indonesia (4·3%)	Ethiopia (6·0%)
6	Chad (3·5%)	Niger (2·5%)	Niger (4·2%)	Ethiopia (3·4%)	Zambia (4·5%)
7	Democratic Republic of the Congo (3·2%)	Burkina Faso (2·3%)	Côte d'Ivoire (3·9%)	Somalia (3·3%)	India (4·3%)
8	Cameroon (2·0%)	China (2·3%)	Mali (3·5%)	Tanzania (2·6%)	Uganda (4·3%)
9	Indonesia (2·0%)	Democratic Republic of the Congo (2·3%)	Tanzania (3·4%)	Mozambique (2·5%)	Tanzania (3·7%)
10	Burkina Faso (1·9%)	Somalia (2·1%)	Mozambique (2·9%)	Philippines (2·2%)	Zimbabwe (3·2%)

The denominator is the total number of DALYs associated with the condition and age grouping. DALY=daily-adjusted life-years.

Table 3: **The ten countries with the highest percentage burden (DALYs) for enteric infections, HIV and AIDS, lower-respiratory-tract infections, malaria, and tuberculosis, for the three age groups**

burden of LRTIs was greatest in settings of low and low-middle sociodemographic development (54·4 million DALYs) and in children younger than 5 years globally (59·2 million DALYs, 95% UI 48·5 to 72·7). Nigeria, India, and Pakistan accounted for the largest cause-specific burden (44·2% of the global burden of LRTIs for 0–24 year olds), although it is noteworthy that the percentage burden in Nigeria and Pakistan is greater for enteric infection compared with LRTI (table 3). Countries with the largest per-capita burden (figure 4) of LRTIs were Chad (11 090 DALYs per 100 000 population), Burkina Faso (10 277 per 100 000), and Somalia (9708 per 100 000). In six countries across Asia and Europe, more than half of the disease burden for children and adolescents was accounted for by LRTIs (Azerbaijan [65%], Cambodia [51%], Romania [51%], Tajikistan [56%], Turkmenistan [68%], and Uzbekistan [73%]). With the exception of Dominica (with an increase of 0·1% per year), all countries showed a decline in LRTI-related DALYs between 1990 and 2019 (appendix p 22–26), with the greatest being in Türkiye and Equatorial Guinea (both with declines of 3·2% per year). However, increases over time were seen within specific groups, with the greatest increases among adolescent males aged 15–24 years in Argentina (an increase of 2·9% per year), Sao Tome and Principe (increase of 3·0% per year), and Ukraine (increase of 2·9% per year). Given that enteric disease and LRTIs are the focus of combined intervention such as the GAPPD, the relationship between these two diseases at a country level is detailed in the appendix (p 57). Overall, there was a strong relationship between these two diseases (R^2 0·7).

There were 38·3 million DALYs in 2019 caused by malaria across 89 countries (115 countries had no malaria burden; table 2, appendix pp 18, 22–26). 299 052 malaria deaths, representing 70·0% of all malaria deaths globally in those aged 0–24 years, occurred in settings of low sociodemographic development (appendix p 15). Although global disease burden from malaria was highest in children younger than 5 years, with 31·6 million DALYs (95% UI 15·1 to 55·3) and 356 363 deaths (95% UI 169 469 to 630 387), there were 6·7 million DALYs and 71 106 deaths among children and adolescents aged 5–24 years in 2019. Nigeria alone accounted for 26·7% of the malaria burden among children and adolescents globally (table 3), with the highest per-capita burden (figure 4) found in Burkina Faso (11 083 DALYs per 100 000 population), Niger (9827 DALYs per 100 000), and Sierra Leone (13 267 DALYs per 100 000). Most countries demonstrated decreasing burden of malaria (appendix pp 22–56). Within countries with low sociodemographic development, the greatest rate of malaria DALY change was observed in Nepal and Bhutan (a decrease in burden of 3·3% per year). However, notable increases in malaria burden (DALYs) were observed in countries with low-to-middle sociodemographic development, such as North Korea (increase of 196·0% per year) and Cabo Verde (increase of 23·1% per year).

In 2019 there were 10·3 million DALYs caused by tuberculosis among children and adolescents (table 2; appendix pp 18, 22–26), most from drug-susceptible tuberculosis (appendix p 79). Tuberculosis-related mortality and DALYs were greatest in children younger than 5 years (globally, 4·6 million DALYs, 95% UI 3·6 to 5·7, and 50 163 deaths, 95% UI 39 248 to 63 385), but incidence and disability from tuberculosis, as measured by YLDs, increased mostly after the age of

14 years. India, Nigeria, and Pakistan together accounted for 38% of the global tuberculosis burden (table 3) across the developmental window (similar to enteric infections and LRTIs). The largest per-capita burden (figure 4) was in the Central African Republic (5159 DALYs per 100 000 population), Chad (1631 DALYs per 100 000), Lesotho (2380 DALYs per 100 000), and Somalia (2478 DALYs per 100 000). Most countries showed

		Total communicable diseases	Enteric infections	Lower-respiratory-tract infections	Malaria	Neonatal sepsis and other neonatal infections	Vaccine-preventable diseases	Meningitis and encephalitis	HIV and AIDS	Tuberculosis	Neglected tropical diseases	Infectious skin conditions	Sexually transmitted infections excluding HIV	Upper-respiratory-tract infections	Other unspecified infectious diseases	Hepatitis	Rheumatic heart disease	Maternal sepsis and other maternal infections
Low SDI	Afghanistan	11669	1969	5142	110	446	1839	557	46	242	374	135	134	142	252	195	56	30
	Benin	30462	4941	5890	9559	2076	3774	1645	521	591	583	229	230	120	117	96	64	24
	Burkina Faso	41123	8987	10277	11083	2572	2122	2473	484	1183	680	254	454	147	228	74	77	27
	Burundi	25578	7857	3444	7426	1739	757	861	694	1323	481	300	96	228	130	72	101	70
	Central African Republic	50271	16202	9280	7681	1613	3824	1600	1715	5159	759	252	1227	353	243	118	120	128
	Chad	51713	21278	11090	4023	2384	4843	2970	723	1631	854	233	980	140	233	184	74	73
	Côte d'Ivoire	26317	3789	5367	9607	1888	1060	786	1490	622	548	219	540	124	142	62	55	17
	DR Congo	21986	4051	2628	7997	999	1410	604	379	1280	978	228	864	185	151	66	77	88
	Eritrea	14704	5382	3533	296	1150	664	716	494	1019	320	302	234	200	138	73	103	77
	Ethiopia	16020	4056	2761	1589	1864	1412	846	969	510	574	407	552	200	98	74	75	31
	The Gambia	11821	2525	2121	1337	1629	799	652	693	436	464	213	547	95	147	79	54	33
	Guinea	36418	5658	8474	9749	2069	3610	2751	635	919	1103	233	601	127	196	169	68	55
	Guinea-Bissau	23532	5973	2683	2821	1731	5339	1105	1018	568	648	225	945	122	160	102	73	19
	Haiti	16129	4509	4572	232	828	1128	1295	1082	352	232	282	988	188	134	51	187	69
	Liberia	22883	5613	2097	7560	1291	1152	724	499	352	1328	210	1622	130	93	86	55	69
	Madagascar	20319	7189	3594	2016	1044	1805	598	195	795	245	274	1387	175	774	52	128	47
	Malawi	18572	3400	3385	3777	1163	801	1056	2187	790	235	290	990	203	107	78	87	23
	Mali	38738	7652	7207	9121	3934	3480	3071	459	858	731	302	1260	130	298	102	79	55
	Mozambique	29005	3017	3640	5630	2389	996	792	8934	1310	319	311	1118	233	146	73	76	21
	Nepal	6664	1247	2076	2	774	794	290	95	219	331	190	238	150	43	121	87	7
	Niger	50571	14883	9596	9827	2402	7442	3699	123	927	741	239	107	145	201	83	79	74
	Pakistan	12838	3935	3334	184	809	792	1141	62	838	254	204	314	151	380	222	204	15
	Papua New Guinea	19004	3041	7852	610	506	1972	872	665	455	449	352	1400	131	207	66	396	30
	Rwanda	12972	2485	2770	2855	1287	553	654	442	508	325	294	337	182	102	71	79	29
	Senegal	14657	4042	2566	2576	1597	1221	786	209	347	538	215	168	120	151	42	52	26
	Sierra Leone	34895	4677	7799	13267	2081	1304	2102	615	957	804	231	458	118	219	130	74	58
	Solomon Islands	10312	1656	2747	197	181	567	243	181	88	959	341	2394	133	232	84	271	37
	Somalia	38405	7640	9708	1885	2302	8795	2102	499	2478	656	307	813	539	232	189	132	128
	South Sudan	33922	6243	8079	6411	1802	2302	2339	831	1336	2025	313	1564	263	209	97	84	25
	Tanzania	18127	1908	4514	3625	1697	1670	580	1161	755	382	353	952	212	162	56	79	21
	Togo	22713	9638	2985	4942	1347	589	610	900	464	430	213	208	126	124	62	55	19
	Uganda	21044	2226	2513	6356	1479	2143	906	1747	690	292	293	1921	199	120	51	86	22
	Yemen	7679	3242	1513	701	213	700	182	57	68	261	132	189	155	115	55	65	33
Low-middle SDI	Angola	18563	4089	2812	3397	1111	2029	793	1049	1121	340	239	1058	191	184	64	70	15
	Bangladesh	5735	1389	1709	6	938	300	132	8	238	219	202	228	164	46	85	68	2
	Belize	2550	342	655	1	538	13	104	263	63	81	233	7	139	37	17	52	7
	Bhutan	5414	1173	1369	4	503	75	517	135	183	222	201	530	145	134	122	99	3
	Bolivia	6837	697	2523	2	1555	321	204	280	256	139	254	314	153	66	17	43	13
	Cabo Verde	3614	714	657	228	629	89	206	280	88	169	188	112	107	59	41	44	2
	Cambodia	7716	799	4028	39	752	371	227	184	421	141	286	21	130	120	125	64	6
	Cameroon	25932	7816	4181	6036	1403	1863	879	1409	495	563	202	671	136	120	82	52	26
	Comoros	12415	2781	3287	1146	1084	1563	722	6	530	185	290	401	167	115	52	80	6
	Congo	14365	3262	1236	3156	878	1149	378	2338	524	279	229	536	155	118	43	67	17
	Djibouti	13798	2427	3753	454	1404	1927	818	886	578	281	299	455	192	148	55	73	48
	Dominican Republic	5204	664	623	2	2005	378	285	118	148	159	227	333	128	29	32	65	7
	El Salvador	2242	393	496	0	301	126	61	306	15	87	199	32	139	28	15	38	4
	Eswatini	18599	3496	3759	84	951	592	490	6369	1524	179	185	529	138	160	49	87	7
	Ghana	16891	2431	2105	6157	2187	687	829	777	435	431	177	381	111	74	56	47	8
	Guatemala	5423	1278	2587	2	577	50	136	100	53	152	211	7	139	56	28	38	8
	Honduras	3508	1043	446	2	662	182	175	27	44	380	203	43	154	82	26	33	8
	India	7133	1928	1949	257	557	386	446	76	296	274	240	100	142	116	251	106	9
	Kenya	13900	3737	2132	1682	1064	770	537	2276	454	269	279	278	192	73	73	67	17
	Kiribati	8812	1714	1350	0	327	1439	868	88	832	335	347	701	134	189	133	339	16
	Kyrgyzstan	2662	389	1262	0	182	5	159	52	109	80	123	6	152	46	47	47	4
	Laos	9548	1428	3922	28	1057	1092	395	151	487	253	289	84	145	58	40	112	7
	Lesotho	23537	4063	4969	0	1026	376	502	8907	2380	92	182	541	150	160	54	102	34
	Maldives	2249	438	224	0	456	178	90	6	29	296	282	35	133	35	11	34	1
	Marshall Islands	5359	538	1602	0	227	881	188	149	193	202	339	490	126	75	48	293	8
	Mauritania	12048	3811	1928	2535	1226	642	387	6	156	260	204	566	111	109	42	43	21
	Federated States of Micronesia	4379	486	1033	0	165	428	144	530	142	157	336	448	126	67	45	265	9
	Mongolia	4120	475	1862	0	241	149	251	5	205	46	132	487	101	40	80	40	5
	Morocco	2758	799	643	0	112	335	119	73	116	70	128	125	138	35	24	38	3
	Myanmar	8012	1137	2517	48	1029	848	450	193	402	354	289	185	144	292	55	59	11
	Nicaragua	2931	436	999	5	547	19	140	203	35	90	211	31	131	17	20	42	4
	Nigeria	36959	11323	8490	7441	1808	2080	2417	714	644	727	280	572	126	187	76	59	14
	North Korea	2192	342	683	1	92	78	165	70	150	37	280	48	123	37	31	44	8
	Palestine	1562	313	271	0	420	70	70	12	10	32	130	37	134	25	17	20	2
	São Tomé and Príncipe	6036	868	1463	730	914	386	280	3	105	434	205	246	109	166	57	65	5
	Sudan	6708	2468	1228	550	216	652	210	151	70	268	132	370	134	75	101	63	19
	Tajikistan	6821	1467	3843	1	281	293	171	6	253	61	117	33	128	29	82	52	3
	Timor-Leste	8131	1317	2666	3	882	747	397	767	348	234	307	139	136	56	31	84	18
	Tuvalu	3771	399	958	0	193	569	147	121	94	119	336	406	125	64	44	189	5
	Vanuatu	6937	1081	1953	17	258	993	231	165	203	208	324	928	129	68	58	312	11
	Venezuela	3004	470	640	183	850	34	128	89	34	164	198	13	139	30	12	8	11
	Zambia	19520	3796	3048	2606	1374	595	828	4389	648	393	295	1041	178	150	83	81	14
	Zimbabwe	18077	1856	4950	1643	1194	996	644	3938	1511	188	186	420	159	66	52	217	57

(Figure 4 continues on next page)

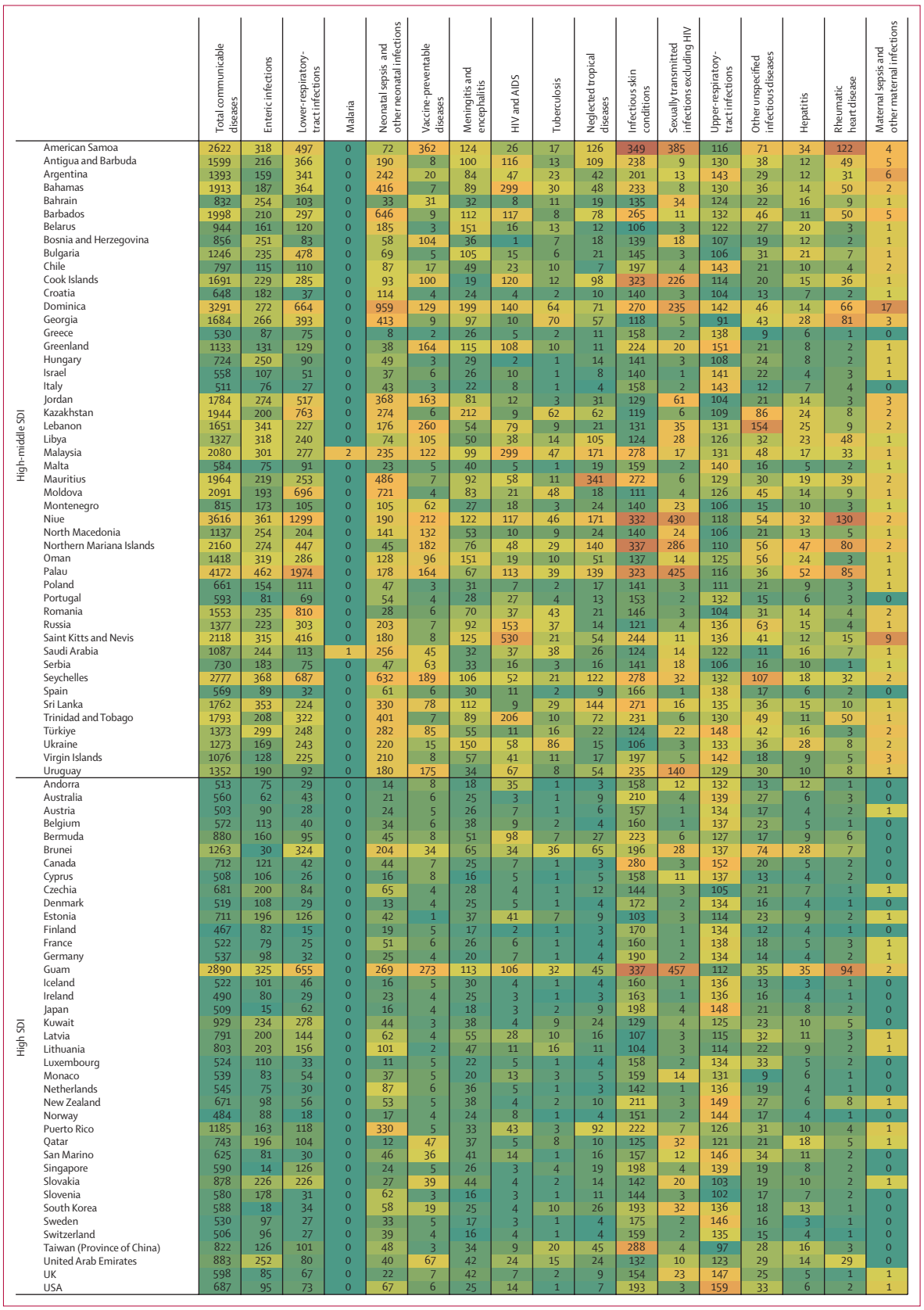
decreasing tuberculosis burden between 1990 and 2019 (appendix pp 22–26), except for Ukraine (increase of 3·4% per year) and Zimbabwe (increase of 0·5% per year). These increases were largely driven by male adolescents aged 15–24 years in Ukraine (increase in males of 7·0% and increase in females of 3·8%) and in Zimbabwe (increase in males of 1·7% and increase in females of 0·8%).

In 2019, there were 138 949 deaths and about 11·3 million DALYs caused by HIV and AIDS among children and adolescents (table 2; appendix pp 16, 18, 27–56), predominantly in settings of low-to-middle sociodemographic development, where 11·0 million DALYs were recorded, accounting for 97% of the global HIV burden. HIV burden varied substantially by age and sex (appendix pp 17, 18); it was high among children younger than 5 years (4·3 million DALYs, 95% UI 3·4 to 5·4, and 48 928 deaths, 95% UI 38 663 to 61 262), lower during childhood 5–9 years (1·1 million DALYs, 95% UI 889 333 to 1 299 952, and 12 379 deaths, 95% UI 10 049 to 15 024), but higher again during adolescence, such that adolescents aged 15–24 years accounted for 4·7 million DALYs and 62 529 deaths. Mozambique, Nigeria, and South Africa together accounted for 34·5% of all HIV burden across the developmental window (table 3), with the largest burden of HIV and AIDS per capita (figure 4) in Eswatini (6369 DALYs per 100 000 population), Lesotho (8907 DALYs per 100 000), and Mozambique (8934 DALYs per 100 000). There were also important sex differences in burden. Countries with the greatest HIV burden for females aged 15–24 years included Lesotho (15 826 DALYs per 100 000 population *vs* 7283 per 100 000 for males), Mozambique (12 503 per 100 000 *vs* 6535 per 100 000 for males), Eswatini (10 992 per 100 000 *vs* 5383 per 100 000 for males), and South Africa (10 253 per 100 000 *vs* 4688 per 100 000 for males). Over time there has been an increased HIV burden in many settings, with HIV burden only declining in 47 (23%) of 204 countries for children and adolescents aged 5–14 years and 65 (32%) of 204 locations for adolescents aged 15–24 years.

The HIV MIR for children younger than 5 years, adolescents aged 15–19 years, and adolescents aged 20–24 years, and the MIR at a country level are shown in the appendix (pp 84–86). The highest MIRs were observed for adolescents aged 15–19 years and mostly for males in settings of low sociodemographic development (MIR >3 in Burkina Faso, Burundi, Côte d'Ivoire,

		Total communicable diseases	Enteric infections	Lower-respiratory-tract infections	Malaria	Neonatal sepsis and other neonatal infections	Vaccine-preventable diseases	Meningitis and encephalitis	HIV and AIDS	Tuberculosis	Neglected tropical diseases	Infectious skin conditions	Sexually transmitted infections excluding HIV	Upper-respiratory-tract infections	Other unspecified infectious diseases	Hepatitis	Rheumatic heart disease	Maternal sepsis and other maternal infections
Middle SDI	Albania	1659	261	757	0	16	50	122	2	3	25	139	28	138	54	17	45	2
	Algeria	1781	381	473	0	195	180	79	16	14	41	131	44	131	44	24	26	4
	Armenia	2348	292	995	0	578	4	65	5	32	48	117	5	119	31	15	39	2
	Azerbaijan	5182	431	3405	0	225	206	304	7	154	43	116	47	122	30	39	51	2
	Botswana	11130	1963	2791	68	758	471	406	2410	921	186	175	594	135	136	28	76	11
	Brazil	2756	376	651	7	658	28	120	112	34	159	279	28	177	55	16	50	6
	China	1435	135	381	0	178	37	90	32	33	42	279	45	118	22	21	22	1
	Colombia	2269	266	544	12	598	24	120	74	26	151	208	14	167	46	11	4	5
	Costa Rica	1105	186	176	0	103	4	80	62	7	53	197	9	136	32	14	45	2
	Cuba	1143	163	174	0	160	7	83	42	3	42	234	8	138	32	9	47	2
	Ecuador	2882	317	864	1	441	212	108	113	78	81	251	185	147	23	13	42	6
	Egypt	3810	1619	1338	0	100	89	176	3	15	54	143	25	111	37	46	53	3
	Equatorial Guinea	14347	766	906	4814	657	725	324	3535	267	305	211	1490	146	100	36	59	6
	Fiji	4675	856	1264	0	390	338	226	55	77	284	360	256	121	183	29	232	4
	Gabon	9845	1190	946	3180	761	585	348	1085	316	427	219	403	154	116	45	62	8
	Grenada	2152	245	619	0	530	10	70	53	12	78	261	8	134	50	13	67	2
	Guyana	4081	616	828	162	927	9	170	336	118	374	230	15	138	58	24	70	7
	Indonesia	5338	1266	806	19	535	395	348	138	400	519	298	293	158	60	84	16	3
	Iran	1328	347	253	1	154	44	66	50	12	22	132	20	139	36	20	31	1
	Iraq	2439	412	498	0	497	305	192	14	35	108	121	48	129	29	24	27	2
	Jamaica	1976	182	209	0	714	3	90	189	7	83	224	8	134	47	11	74	2
	Mexico	2123	299	526	0	590	21	87	65	23	62	209	6	155	36	23	18	3
	Namibia	12139	1882	2160	688	874	283	288	3772	824	333	178	484	139	138	23	66	8
	Nauru	5396	494	2433	0	264	138	275	128	124	158	338	539	121	73	44	259	6
	Panama	2914	563	768	1	538	9	121	271	108	62	204	8	153	48	12	41	6
	Paraguay	2938	355	498	0	261	96	112	351	48	81	270	605	164	36	11	44	5
	Peru	4034	459	878	7	1089	195	140	445	112	92	255	116	152	37	16	36	4
	Philippines	6955	927	1820	3	1180	757	370	251	393	431	309	179	161	44	22	105	3
	Saint Lucia	1795	266	306	0	419	12	118	52	29	86	239	14	134	48	12	58	2
	Saint Vincent and the Grenadines	2437	315	415	0	717	9	123	210	27	75	247	14	142	64	12	64	2
	Samoa	3420	361	642	0	163	720	110	138	72	133	332	388	123	52	32	154	2
	South Africa	11993	1716	1709	34	738	565	217	4724	721	128	177	831	145	207	17	60	5
	Suriname	4036	553	642	8	1177	81	221	255	27	268	282	234	135	80	16	52	5
	Syria	1973	312	563	0	122	227	171	5	15	165	122	29	129	33	24	53	2
	Thailand	2120	347	296	1	311	120	96	282	33	72	280	16	174	40	20	30	1
	Tokelau	3171	366	630	0	209	543	115	133	46	119	332	361	123	51	34	107	4
	Tonga	3907	296	707	0	402	591	460	47	49	250	335	330	124	110	113	90	4
	Tunisia	1281	271	266	0	142	109	66	38	9	36	129	29	130	28	18	8	1
	Turkmenistan	5282	379	3621	0	285	6	283	8	190	47	119	5	116	47	106	67	2
	Uzbekistan	5517	223	4046	0	270	4	239	16	133	81	118	6	156	74	71	75	4
	Viet nam	2905	351	659	4	586	224	231	98	108	121	283	61	121	22	25	10	1

(Figure 4 continues on next page)



		Total communicable diseases	Enteric infections	Lower-respiratory-tract infections	Malaria	Neonatal sepsis and other neonatal infections	Vaccine-preventable diseases	Meningitis and encephalitis	HIV and AIDS	Tuberculosis	Neglected tropical diseases	Infectious skin conditions	Sexually transmitted infections excluding HIV	Upper-respiratory-tract infections	Other unspecified infectious diseases	Hepatitis	Rheumatic heart disease	Maternal sepsis and other maternal infections
High-middle SDI	American Samoa	2622	318	497	0	72	362	124	26	17	126	349	385	116	71	34	122	4
	Antigua and Barbuda	1599	216	366	0	190	8	100	116	13	109	238	9	130	38	12	49	5
	Argentina	1393	159	341	0	242	20	84	47	23	42	201	13	143	29	12	31	6
	Bahamas	1913	187	364	0	416	7	89	299	30	48	233	8	130	36	14	50	2
	Bahrain	832	254	103	0	33	31	32	8	11	19	135	34	124	22	16	9	1
	Barbados	1998	210	297	0	646	9	112	117	8	78	265	11	132	46	11	50	5
	Belarus	944	161	120	0	185	3	151	16	13	12	106	3	122	27	20	3	1
	Bosnia and Herzegovina	856	251	83	0	58	104	36	1	7	18	139	18	107	19	12	2	1
	Bulgaria	1246	235	478	0	69	5	105	15	6	21	145	3	106	31	21	7	1
	Chile	797	115	110	0	87	17	49	23	10	7	197	4	143	21	10	4	2
	Cook Islands	1691	229	285	0	93	100	19	120	12	98	323	226	114	20	15	36	1
	Croatia	648	182	37	0	114	4	24	4	2	10	140	3	104	13	7	2	1
	Dominica	3291	272	664	0	959	129	199	140	64	71	270	235	142	46	14	66	17
	Georgia	1684	266	393	0	413	9	97	10	70	57	118	5	91	43	28	81	3
	Greece	530	87	75	0	8	2	26	5	2	11	158	2	138	9	6	1	0
	Greenland	1133	131	129	0	38	164	115	108	10	11	224	20	151	21	8	2	1
	Hungary	724	250	90	0	49	3	29	2	1	14	141	3	108	24	8	2	1
	Israel	558	107	51	0	37	6	26	10	1	8	140	1	141	22	4	3	1
	Italy	511	76	27	0	43	3	22	8	1	4	158	2	143	12	7	4	0
	Jordan	1784	274	517	0	368	163	81	12	3	31	129	61	104	21	14	3	3
	Kazakhstan	1944	200	763	0	274	6	212	9	62	62	119	6	109	86	24	8	2
	Lebanon	1651	341	227	0	176	260	54	79	9	21	131	35	131	154	25	9	2
	Libya	1327	318	240	0	74	105	50	38	14	105	124	28	126	32	23	48	1
	Malaysia	2080	301	277	2	235	122	99	299	47	171	278	17	131	48	17	33	1
	Malta	584	75	91	0	23	5	40	5	1	19	159	2	140	16	5	2	1
	Mauritius	1964	219	253	0	486	7	92	58	11	341	272	6	129	30	19	39	2
	Moldova	2091	193	696	0	721	4	83	21	48	18	111	4	126	45	14	9	1
	Montenegro	815	173	105	0	105	62	27	18	3	24	140	23	106	15	10	3	1
	Niue	3616	361	1299	0	190	212	122	117	46	171	332	430	118	54	32	130	2
	North Macedonia	1137	254	204	0	141	132	53	10	9	24	140	24	106	21	13	5	1
	Northern Mariana Islands	2160	274	447	0	45	182	76	48	29	140	337	286	110	56	47	80	2
	Oman	1418	319	286	0	128	96	151	19	10	51	137	14	125	56	24	3	1
	Palau	4172	462	1974	0	178	164	67	113	39	139	323	425	116	36	52	85	1
	Poland	661	154	111	0	47	3	31	7	2	17	141	3	111	21	9	3	1
	Portugal	593	81	69	0	54	4	28	27	4	13	153	2	132	15	6	3	0
	Romania	1553	235	810	0	28	6	70	37	43	21	146	3	104	31	14	4	2
	Russia	1377	223	303	0	203	7	92	153	37	14	121	4	136	63	15	4	1
	Saint Kitts and Nevis	2118	315	416	0	180	8	125	530	21	54	244	11	136	41	12	15	9
	Saudi Arabia	1087	244	113	1	256	45	32	37	38	26	124	14	122	11	16	7	1
	Serbia	730	183	75	0	47	63	33	16	3	16	141	18	106	16	10	1	1
	Seychelles	2777	368	687	0	632	189	106	52	21	122	278	32	132	107	18	32	2
	Spain	569	89	32	0	61	6	30	11	2	9	166	1	138	17	6	2	0
	Sri Lanka	1762	353	224	0	330	78	112	9	29	144	271	16	135	36	15	10	1
	Trinidad and Tobago	1793	208	322	0	401	7	89	206	10	72	231	6	130	49	11	50	1
	Türkiye	1373	299	248	0	282	85	55	11	16	22	124	22	148	42	16	3	2
	Ukraine	1273	169	243	0	220	15	150	58	86	15	106	3	133	36	28	8	2
	Virgin Islands	1076	128	225	0	210	8	57	41	11	17	197	5	142	18	9	5	3
	Uruguay	1352	190	92	0	180	175	34	67	8	54	235	140	129	30	10	8	1
High SDI	Andorra	513	75	29	0	14	8	18	35	1	3	158	12	132	13	12	1	0
	Australia	560	62	43	0	21	6	25	3	1	9	210	4	139	27	6	3	0
	Austria	503	90	28	0	24	5	26	7	1	6	157	1	134	17	4	2	1
	Belgium	572	113	40	0	34	6	38	9	2	4	160	1	137	23	5	1	0
	Bermuda	880	160	95	0	45	8	51	98	7	27	223	6	127	17	9	6	0
	Brunei	1263	30	324	0	204	34	65	34	36	65	196	28	137	74	28	7	0
	Canada	712	121	42	0	44	7	25	7	1	3	280	3	152	20	5	2	0
	Cyprus	508	106	26	0	16	8	16	5	1	5	158	11	137	13	4	2	0
	Czechia	681	200	84	0	65	4	28	4	1	12	144	3	105	21	7	1	1
	Denmark	519	108	29	0	13	4	25	5	1	4	172	2	134	16	4	1	0
	Estonia	711	196	126	0	42	1	37	41	7	9	103	3	114	23	9	2	1
	Finland	467	82	15	0	19	5	17	2	1	3	170	1	134	12	4	1	0
	France	522	79	25	0	51	6	26	6	1	4	160	1	138	18	5	3	1
	Germany	537	98	32	0	25	4	20	7	1	4	190	2	134	14	4	2	1
	Guam	2890	325	655	0	269	273	113	106	32	45	337	457	112	35	35	94	2
	Iceland	522	101	46	0	16	5	30	4	1	4	160	1	136	13	3	1	0
	Ireland	490	80	29	0	23	4	25	3	1	3	163	1	136	16	4	1	0
	Japan	509	15	62	0	16	4	18	3	2	9	198	4	148	21	8	2	0
	Kuwait	929	234	278	0	44	3	38	4	9	24	129	4	125	23	10	5	0
	Latvia	791	200	144	0	62	4	55	28	10	16	107	3	115	32	11	3	1
	Lithuania	803	203	156	0	101	2	47	11	16	11	104	3	114	22	9	2	1
	Luxembourg	524	110	33	0	11	5	22	5	1	4	158	2	134	33	5	2	0
	Monaco	539	83	54	0	37	5	20	13	3	5	159	14	131	9	6	1	0
	Netherlands	545	75	30	0	87	6	36	5	1	3	142	1	136	19	4	1	0
	New Zealand	671	98	56	0	53	5	38	4	2	10	211	3	149	27	6	8	1
	Norway	484	88	18	0	17	4	24	8	1	4	151	2	144	17	4	1	0
	Puerto Rico	1185	163	118	0	330	5	33	43	3	92	222	7	126	31	10	4	1
	Qatar	743	196	104	0	12	47	37	5	8	10	125	32	121	21	18	5	1
	San Marino	625	81	30	0	46	36	41	14	1	16	157	12	146	34	11	2	0
	Singapore	590	14	126	0	24	5	26	3	4	19	198	4	139	19	8	2	0
	Slovakia	878	226	226	0	27	39	44	4	2	14	142	20	103	19	10	2	1
	Slovenia	580	178	31	0	62	3	16	3	1	11	144	3	102	17	7	2	0
	South Korea	588	18	34	0	58	19	25	4	10	26	193	32	136	18	13	1	0
	Sweden	530	97	27	0	33	5	17	3	1	4	175	2	146	16	3	1	0
	Switzerland	506	96	27	0	39	4	16	4	1	4	159	2	135	15	4	1	0
	Taiwan (Province of China)	822	126	101	0	48	3	34	9	20	45	288	4	97	28	16	3	0
	United Arab Emirates	883	252	80	0	40	67	42	24	15	24	132	10	123	29	14	29	0
	UK	598	85	67	0	22	7	42	7	2	9	154	23	147	25	5	1	1
	USA	687	95	73	0	67	6	25	14	1	7	193	3	159	33	6	2	1

Figure 4: **Country-level heatmap of communicable disease DALYs by cause for children and adolescents aged 0–24 years in 2019, grouped by SDI**
The shading ranges from green, which indicates a low number of DALYs per 100 000 for that country within the disease, whereas the highest rates are shaded in a dark orange colour, which indicates a country has a large DALY burden. DALY=disability-adjusted life-years. SDI=Socio-demographic Index.

Ethiopia, Eritrea, Somalia, and Togo), with females aged 15–19 years in Syria having an MIR of 32.

Discussion

Much remains to be done to reduce the 3 million deaths each year from communicable diseases among children and adolescents globally, approximately one death every 10 sec. Our analysis supports a continued focus on mortality reduction among children under 5 years in settings of low sociodemographic development, with a continued focus on gastroenteritis, pneumonia, and malaria.[4,31] However, policy and programming actions need to be inclusive of older children and adolescents, who accounted for 647 168 deaths from communicable diseases in 2019. Within this action, we also need to shift our focus to other diseases, including HIV and tuberculosis; the marked increases in deaths in older children and adolescents infected with HIV in some settings are at odds with overall reductions in communicable diseases across the developmental window. We also need to look beyond mortality reduction and focus on morbidity reduction; the 30 million years of healthy life lost to disability in 2019 among children and adolescents signifies an opportunity for health gain; this estimated burden does not include effects on education or social engagement, and as such, effects on human capital will be even greater. This reframing also brings into scope the substantial burden of disability related to communicable diseases in countries of high and high-middle sociodemographic development (8·9 million DALYs and 4·0 million YLDs in 2019 alone), often at the margins of communicable disease control.

This analysis documents the substantial unmet needs in communicable disease control before the COVID-19 pandemic. These findings highlight the need for health systems, particularly in settings of low sociodemographic development where disease burden is focussed, to continue to build capacity to respond to communicable diseases across the life course. Excess mortality-to-incidence ratios for HIV, especially for male adolescents in settings of low sociodemographic development, suggests barriers (supply or demand) to quality health care. The findings also suggest the need to strengthen prevention. Required preventive efforts include established interventions, such as immunisation (the large number of vaccine-preventable deaths suggests incomplete coverage), but also investment in broader approaches that address social determinants. For example, the excess burden of HIV among female individuals in some settings suggests harmful gender norms that might drive differential risk exposure (eg, intimate partner violence),[32] or limit access to quality health care; these same gender norms might be driving the excess mortality-to-incidence ratio for male adolescents.[33] The findings also highlight the need for communicable disease-focussed programme policies to be inclusive of older children and adolescents. As such, although the replenishment of The Global Fund is welcomed, these resources need to stretch further, and especially if we are to extend our focus while also maintaining efforts where progress has been made.[34]

To our knowledge, this study is the first systematic analysis of all causes of communicable-disease morbidity and mortality across the developmental window. Available estimates of diarrhoea and pneumonia have been largely limited to children younger than 5 years and focussed on mortality.[35–37] Estimates of malaria and tuberculosis have typically not reported disaggregated data for adolescents,[38,39] and global data coverage for HIV in adolescents remains limited,[33,40] but is improving. Our HIV results replicate, yet extend, previously published GBD 2019 incidence and DALY data disaggregated for adolescents aged 10–14 years, 15–19 years, and 20–24 years.[41] We also extend upon currently available HIV data from UNAIDS that are limited to incidence and mortality.[20] In short, existing reporting frameworks do not consistently disaggregate data for children and adolescents,[42] focus on conditions in isolation, or are limited to measures of mortality. This incomplete reporting is reflected in key data dashboards, including Countdown to 2030[43] (dependent on available primary data), and means that there are important areas of data and knowledge scarcity in policy and programming. As an example, the inter-UN agency OneHealth tool, developed to inform national strategical planning and resource allocation, does not model interventions for diarrhoea and pneumonia beyond the age of 5 years.[44]

Our analysis, which explored all causes of communicable diseases for children and adolescents across the globe, identified some clear targets for action. Five cause groups (enteric infection, LRTIs, malaria, tuberculosis, and HIV) account for more than two-thirds of the burden from communicable diseases across the developmental window. There are also some countries that contribute the greatest burden of these conditions, allowing for targeted actions. India, Nigeria, and Pakistan together account for 47·7% of disease burden related to enteric infections among children and adolescents, 44·2% of lower-respiratory-tract infections, and 37·8% of tuberculosis cases. For tuberculosis, these three countries are identified as priority countries in the WHO Global Tuberculosis Report,[45] but countries such as Chad and Somalia that we identified as having an excess tuberculosis burden for children and adolescents were not included. For malaria, we found that the Democratic Republic of the Congo, Nigeria, and Uganda together account for 42·9% of the malaria burden among children and adolescents, consistent with priority countries in the WHO World Malaria Report.[46] For HIV, just six sub-Saharan countries (Ethiopia, Kenya, Mozambique, Nigeria, South Africa, and Zambia) contribute to more than half of the global HIV burden for children and adolescents. These findings can help inform where efforts can be focussed, but not at the expense of children and adolescents in other settings, and not at the expense

of opportunities to tackle morbidity. In this regard, it is important to also keep in scope the diseases for which the overall burden might be small, but for which the incidence has increased over time (including STIs, rheumatic heart disease, and neglected tropical diseases), because they pose future threats.

We identify that HIV needs to be a particular priority for global health action. Our trend analysis (annualised change over the past 30-year period and less sensitive to recent improvements as reported elsewhere)[41,47] showed that although incidence has declined, mortality and burden have increased over time for older children and adolescents. These findings probably reflect the success of Prevention of Parent to Child Transmission interventions and early antiretroviral therapy on improved survival in young children, but unmet health-care needs in older children and adolescents living with HIV. For example, we found that male adolescents in Burkina Faso, Burundi, Côte d'Ivoire, Ethiopia, Eritrea, Somalia, and Togo and female adolescents in Syria have an MIR higher than 3, substantially greater than other age groups and greater than the global all-age average of 1·6 as reported by UNAIDS. As such, accessible and responsive health care for adolescents living with HIV must be prioritised along with efforts to prevent HIV transmission and acquisition. High-quality subnational data are central to this endeavour, including data on the mode and timing of HIV acquisition.

Our analysis provides estimates up to 2019, and there is no doubt that the COVID-19 pandemic has radically shifted the landscape for communicable disease control. COVID-19 vaccine hesitancy and disruptions to education and primary care services pose real risks to preventive and promotive interventions for communicable disease.[16,17] However, the COVID-19 pandemic has also highlighted the need to address social inequity and has highlighted interventions (decreasing social contact when unwell, hand sanitation, and interventions to improve air quality)[48] that might favourably affect broader communicable disease control.[49–51] There are additional threats that will probably affect communicable disease control. The first is climate change, which increases the incidence and burden associated with numerous communicable diseases, particularly malaria and enteric infections.[52] Global warming impacts the built environment and natural habitats, causing expansion in the range and movement of wildlife vectors present in populated areas. In response, proven and effective tools to fight malaria will need to be introduced to new areas. The second is population growth, with the global population forecast to peak in 2064.[53] In 2100 it is forecasted that the majority of the world's population (including children and adolescents) will live in countries of low and low-middle sociodemographic development (eg, Democratic Republic of the Congo, India, and Nigeria),[53] settings that have an excess burden of communicable diseases. The third is an increasing demand on the shrinking global health budget. Mental health and non-communicable diseases, long neglected, are increasingly included within global health policy, and rightly so; however, these investments must not displace the required efforts to address communicable diseases.

To maximise data coverage and ensure comparability across locations and over time we used modelled data from the GBD 2019 Study. The disease models employed within the GBD 2019 Study are robust for communicable diseases, and a particular strength is that they harmonise what are often disparate (and sometimes conflicting) epidemiological surveillance data.[29] Indeed, burden of disease data are increasingly being used in global health, including in the UNICEF adolescent health dashboard.

In these analyses we extended the definition of communicable diseases to include all communicable diseases and their direct sequalae, as modelled in the GBD 2019 Study, resulting in 83 million DALYs in addition to the 420 million DALYs traditionally reported as communicable diseases in GBD 2019. There are also some important limitations associated with using GBD data. Notably, the quality of primary data for communicable diseases is dependent on diagnostic accuracy and population-based surveillance; the burden of diseases such as tuberculosis, STIs, rheumatic heart diseases, and neglected tropical diseases might be underestimated.[54] Data are also limited in settings of low sociodemographic development (in which burden is greatest) and for older children and adolescents; however, we detailed UIs for each cause, and these give some indication of where the data need to be strengthened (appendix p 87–167). Historical data are also limited in quality, and these limitations might have affected our trend analysis. Cause of death data might also underestimate the contribution of some communicable diseases; for example, deaths among people with HIV might be caused by other causes such as tuberculosis. Within GBD, estimates of morbidity are dependent on disease weights, which are not age or gender specific, and do not include educational and social burdens, which are especially relevant for children and adolescents. GBD also does not include the lifelong or intergenerational effects of disease, and so the true burden might be underestimated. However, these modelled estimates do provide guidance on where the burden of disease is and can inform current efforts to strengthen measurement and reporting of child and adolescent health globally.[55,56]

Following the COVID-19 pandemic, communicable disease control among children and adolescents must be central to efforts ensuring sustainable development.[21] Our findings support the continued focus of policy and action on diarrhoea, pneumonia, and malaria, and on young children. However, widening the scope to include older children and adolescents, extending the disease focus to include tuberculosis and HIV, and investing in actions to reduce morbidity and mortality are needed to

ensure that children and adolescents not only survive through this crucial period of development, but thrive and realise their full potential.

GBD 2019 Adolescent Communicable Disease Collaborators

Peter S Azzopardi*, Jessica A Kerr*, Kate L Francis*, Susan M Sawyer, Elissa Clare Kennedy, Andrew C Steer, Stephen Michael Graham, Russell M Viner, Joseph L Ward, Julie Hennegan, Minh D Pham, Christine Marie D Habito, Jaameeta Kurji, Karly I Cini, James G Beeson, Alex Brown, Christopher J L Murray, Mohsen Abbasi-Kangevari, Hassan Abolhassani, Victor Adekanmbi, Suneth Buddhika Agampodi, Muktar Beshir Ahmed, Marjan Ajami, Hossein Akbarialiabad, Mostafa Akbarzadeh-Khiavi, Tareq Mohammed Ali AL-Ahdal, Musa Mohammed Ali, Shohreh Alian Samakkhah, Yousef Alimohamadi, Vahid Alipour, Adel Al-Jumaily, Sohrab Amiri, Mohammad Hosein Amirzade-Iranaq, Amir Anoushiravani, Davood Anvari, Jalal Arabloo, Morteza Arab-Zozani, Mesay Arkew, Benedetta Armocida, Ali A Asadi-Pooya, Zatollah Asemi, Saeed Asgary, Seyyed Shamsadin Athari, Hiva Azami, Mohammadreza Azangou-Khyavy, Hosein Azizi, Nader Bagheri, Sara Bagherieh, Francesco Barone-Adesi, Sandra Barteit, Sanjay Basu, Melaku Ashagrie Belete, Luis Belo, Alemshet Yirga Berhie, Ali Bijani, Boris Bikbov, Katrin Burkart, Giulia Carreras, Periklis Charalampous, Endeshaw Chekol Abebe, Natália Cruz-Martins, Xiaochen Dai, Lalit Dandona, Rakhi Dandona, Sayih Mehari Degualem, Andreas K Demetriades, Alemayehu Anley Demlash, Abebaw Alemayehu Desta, Mostafa Dianatinasab, Saeid Doaei, Fariba Dorostkar, Diyan Ermawan Effendi, Amir Emami, Luchuo Engelbert Bain, Sharareh Eskandarieh, Firooz Esmaeilzadeh, Ali Faramarzi, Ali Fatehizadeh, Pietro Ferrara, Getahun Fetensa, Florian Fischer, Luisa S Flor, Ali Forouhari, Masoud Foroutan, Santosh Gaihre, Nasrin Galehdar, Silvano Gallus, Rupesh K Gautam, Mesfin Gebrehiwot, Teferi Gebru Gebremeskel, Lemma Getacher, Motuma Erena Getachew, Seyyed-Hadi Ghamari, Mohammad Ghasemi Nour, Pouya Goleij, Mohamad Golitaleb, Giuseppe Gorini, Vijai Kumar Gupta, Maryam Hashemian, Hadi Hassankhani, Mohammad Heidari, Demisu Zenbaba Heyi, Gaetano Isola, Jalil Jaafari, Fatemeh Javanmardi, Jost B Jonas, Jacek Jerzy Jozwiak, Mikk Jürisson, Ali Kabir, Zubair Kabir, Laleh R Kalankesh, Rohollah Kalhor, Joonas H Kauppila, Harkiran Kaur, Gbenga A Kayode, Leila Keikavoosi-Arani, Mohammad Khammarnia, Moien AB Khan, Khaled Khatab, Hamid Reza Khayat Kashani, Ali-Asghar Kolahi, Hamid Reza Koohestani, Ai Koyanagi, G Anil Kumar, Om P Kurmi, Hmwe Hmwe Kyu, Carlo La Vecchia, Tea Lallukka, Stephen S Lim, Joana A Loureiro, Soleiman Mahjoub, Razzagh Mahmoudi, Azeem Majeed, Elaheh Malakan Rad, Afshin Maleki, Fariborz Mansour-Ghanaei, Abdoljalal Marjani, Alexander G Mathioudakis, Fereshteh Mehri, Alexios-Fotios A Mentis, Tomislav Mestrovic, Andreea Mirica, Awoke Misganaw, Abdollah Mohammadian-Hafshejani, Hussen Mohammed, Shafiu Mohammed, Ali H Mokdad, Peyman Mokhtarzadehazar, Lorenzo Monasta, Maryam Moradi, Maliheh Moradzadeh, Negar Morovatdar, Ulrich Otto Mueller, Francesk Mulita, Getaneh Baye B Mulu, Saravanan Muthupandian, Ganesh R Naik, Abdulqadir J J Nashwan, Seyed Aria Nejadghaderi, Henok Biresaw Netsere, Nurulamin M Noor, Maryam Noori, Bogdan Oancea, Ayodipupo Sikiru Oguntade, Hassan Okati-Aliabad, Adrian Otoiu, Alicia Padron-Monedero, Reza Pakzad, Anamika Pandey, Shahina Pardhan, Romil R Parikh, Jay Patel, Umberto Pensato, Prince Peprah, Norberto Perico, Dimitri Poddighe, Maarten J Postma, Fakher Rahim, Vafa Rahimi-Movaghar, Shayan Rahmani, Vahid Rahmanian, Salman Rawaf, Iman Razeghian-Jahromi, Misganu Teshoma Regasa, Giuseppe Remuzzi, Mohsen Rezaeian, Abanoub Riad, Esperanza Romero-Rodríguez, Luca Ronfani, Koushik Roy Pramanik, Siamak Sabour, Saeid Sadeghian, Mohammad Reza Saeb, Azam Safary, Amirhossein Sahebkar, Biniyam Sahiledengle, Sara Samadzadeh, Arash Sarveazad, Yashendra Sethi, Saeed Shahabi, Fariba Shahraki-Sanavi, Mehran Shams-Beyranvand, Kiomars Sharafi, Nigussie Tadesse Sharew, Aziz Sheikh, Rahim Ali Sheikhi, Rahman Shiri, Bogdan Socea, Mohammad Sadegh Soltani-Zangbar, Rafael Tabarés-Seisdedos, Shima Tabatabai, Moslem Taheri Soodejani, Razieh Tavakoli Oliaee, Amir Tiyuri, Marcos Roberto Tovani-Palone, Abdul Rohim Tualeka, Rohollah Valizadeh, Jef Van den Eynde, Tommi Juhani Vasankari, Theo Vos, Mandaras Tariku Walde, Yanzhong Wang, Fei-Long Wei, Ronny Westerman, Vikas Yadav, Sanni Yaya, Iman Zare, Bin Zhu, Mohammad Zoladl, Alimuddin Zumla, Simon I Hay, and George C Patton. *Joint first authors.

Affiliations

Centre for Adolescent Health, Population Health Theme, Murdoch Children's Research Institute (Prof P S Azzopardi PhD, J A Kerr PhD, K L Francis MBiostat, Prof S M Sawyer MD, K I Cini MClinEpi, Prof G C Patton MD), Department of Paediatrics (Prof P S Azzopardi, Prof S M Sawyer MD, Prof A C Steer PhD, Prof S M Graham PhD, Prof G C Patton MD, J A Kerr PhD, K L Francis MBiostat, K I Cini MClinEpi), Melbourne School of Population and Global Health (J Hennegan PhD), University of Melbourne, Melbourne, VIC, Australia; Infection and Immunity Theme, Murdoch Children's Research Institute, Melbourne, VIC, Australia (Prof A C Steer PhD); Maternal, Child and Adolescent Health Program, International Development Discipline, Burnet Institute, Melbourne, VIC, Australia (Prof P S Azzopardi PhD, C D Habito PhD, K I Cini MClinEpi, E C Kennedy MPH, J Hennegan PhD, Prof J G Beeson PhD, Prof S M Graham PhD, M D Pham PhD); Adolescent Health and Wellbeing (Prof P S Azzopardi PhD), Telethon Kids Institute, Adelaide, Australia; Department of Psychological Medicine (J A Kerr PhD), University of Otago, Christchurch, New Zealand; School of Public Health and Preventive Medicine (E C Kennedy MPH, M D Pham PhD), Central Clinical School and Department of Microbiology (Prof J G Beeson PhD), Monash University, Melbourne, VIC, Australia; UCL Great Ormond Street Institute of Child Health (Prof R M Viner PhD, J L Ward PhD), Medical Research Council Clinical Trials Unit (N M Noor MRCP), Institute of Cardiovascular Science (A S Oguntade MSc), Department of Infection (Prof A Zumla PhD), University College London, London, UK; Department of Aboriginal Health Equity (J Kurji PhD), South Australian Health and Medical Research Institute, Adelaide, SA, Australia; School of Epidemiology and Public Health (J Kurji PhD), University of Ottawa, Ottawa, Canada; National Centre for Indigenous Genomics (Prof A Brown PhD), Australian National University, Canberra, ACT, Australia; Department of Indigenous Genomics (Prof A Brown PhD), Telethon Kids Institute, Adelaide, SA, Australia; Non-Communicable Diseases Research Center (M Abbasi-Kangevari MD, M Azangou-Khyavy MD, S Ghamari MD, S Rahmani MD), Research Center for Immunodeficiencies (H Abolhassani PhD), Universal Scientific Education and Research Network (USERN) (M Amirzade-Iranaq DDS), Digestive Diseases Research Institute (A Anoushiravani MD, M Hashemian PhD), Department of Epidemiology and Biostatistics (H Azizi PhD), Multiple Sclerosis Research Center (S Eskandarieh PhD), Department of Pediatric Cardiology (Prof E Malakan Rad MD), Department of Environmental Health Engineering (Prof A Maleki PhD), Sina Trauma and Surgery Research Center (Prof V Rahimi-Movaghar MD), Tehran University of Medical Sciences, Tehran, Iran; Department of Biosciences and Nutrition (H Abolhassani PhD), Karolinska University Hospital, Huddinge, Sweden; Department of Obstetrics and Gynecology (V Adekanmbi PhD), University of Texas, Galveston, TX, USA; Department of Community Medicine (Prof S B Agampodi MD), Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka; Department of New Initiatives (Prof S B Agampodi MD), International Vaccine Institute, Seoul, South Korea; Department of Epidemiology (M B Ahmed MPH), Department of Public Health (M E Getachew MPH), Jimma University, Jimma, Ethiopia; Australian Center for Precision Health (M B Ahmed MPH), University of South Australia, Adelaide, SA, Australia; Department of Food and Nutrition Policy and Planning Research (M Ajami PhD), National Institute of Nutrition, Tehran, Iran; National Nutrition and Food Technology Research Institute (M Ajami PhD), Research Institute of Dental Sciences (Prof S Asgary MSc), Social Determinants of Health Research Center (M Azangou-Khyavy MD, S Ghamari MD, A Kolahi MD), Department of Community Nutrition (S Doaei PhD), Department of Neurosurgery (H Khayat Kashani MD), School of Medicine (S Nejadghaderi MD,

S Rahmani MD), Department of Epidemiology (S Sabour PhD), Department of Medical Education (S Tabatabai PhD), Shahid Beheshti University of Medical Sciences, Tehran, Iran; Department of Public Health and Community Medicine (H Akbarialiabad MD), Epilepsy Research Center (Prof A A Asadi-Pooya MD), Department of Epidemiology (M Dianatinasab MSc), Microbiology Department of Burn and Wound Healing Research Center (A Emami PhD), Student Research Committee (A Faramarzi MD), Department of Otolaryngology (A Faramarzi MD), Burn and Wound Healing Research Center (F Javanmardi MSc), Cardiovascular Research Center (I Razeghian-Jahromi PhD), Health Policy Research Center (S Shahabi PhD), Department of Parasitology and Mycology (R Tavakoli Oliaee PhD), Basic Sciences in Infectious Diseases Research Center (R Tavakoli Oliaee PhD), Shiraz University of Medical Sciences, Shiraz, Iran; Liver and Gastrointestinal Diseases Research Center (M Akbarzadeh-Khiavi PhD), Research Center of Psychiatry and Behavioral Sciences (H Azizi PhD), School of Nursing and Midwifery (H Hassankhani PhD), Connective Tissue Diseases Research Center (A Safary PhD), Department of Immunology (M Soltani-Zangbar MSc), Tabriz University of Medical Sciences, Tabriz, Iran; Institute of Global Health (T M A AL-Ahdal MPH), Eijkman Institute for Molecular Biology, Heidelberg, Germany; School of Medical Laboratory Sciences, Hawassa University, Hawassa, Ethiopia (M M Ali PhD); Department of Food Hygiene (S Alian Samakkhah PhD), Amol University of Special Modern Technologies, Amol, Iran; Health Research Center (Y Alimohamadi PhD), Quran and Hadith Research Center (S Amiri PhD), Baqiyatallah University of Medical Sciences, Tehran, Iran; Health Management and Economics Research Center (V Alipour PhD, J Arabloo PhD), Department of Health Economics (V Alipour PhD), Department of Medical Laboratory Sciences (F Dorostkar PhD), Minimally Invasive Surgery Research Center (A Kabir MD), Student Research Committee (M Noori MD), Colorectal Research Center (A Sarveazad PhD), Department of Epidemiology and Biostatistics (A Tiyuri MSc), Iran University of Medical Sciences, Tehran, Iran (M Moradi MD); School of Computing, Mathematics and Engineering (Prof A Al-Jumaily PhD), Charles Sturt University, Wagga Wagga, NSW, Australia; Information and Communication Sciences and Technologies Pole, Mathematics, Algorithms and Decision Team (Prof A Al-Jumaily PhD), ENSTA Bretagne, Brest, France; Department of Parasitology (D Anvari PhD), Mazandaran University of Medical Sciences, Sari, Iran; Department of Parasitology (D Anvari PhD), Iranshahr University of Medical Sciences, Iranshahr, Iran; Social Determinants of Health Research Center (M Arab-Zozani PhD), Department of Epidemiology and Biostatistics (A Tiyuri MSc), Birjand University of Medical Sciences, Birjand, Iran; Department of Medical Laboratory Sciences (M Arkew MSc), Haramaya University, Haramaya, Ethiopia; Department of Cardiovascular, Endocrine-Metabolic Diseases and Aging (B Armocida MSc), National Institute of Health, Rome, Italy; Neurology Department (Prof A A Asadi-Pooya MD), Thomas Jefferson University, Philadelphia, PA, USA; Research Center for Biochemistry and Nutrition in Metabolic Diseases (Z Asemi PhD), Kashan University of Medical Sciences, Kashan, Iran; National Agency for Strategic Research in Medical Education (NASRME) (Prof S Asgary MSc), Ministry of Health and Medical Education, Tehran, Iran; Department of Immunology (S Athari PhD), Zanjan University of Medical Sciences, Zanjan, Iran; Department of Medical-Surgical Nursing (H Azami MSc), Hamadan University of Medical Sciences, Hamadan, Iran; Basic Health Sciences Institute (N Bagheri PhD), Community-Oriented Nursing Midwifery Research Center (M Heidari PhD), Department of Epidemiology and Biostatistics (A Mohammadian-Hafshejani PhD), Department of Health in Disasters and Emergencies (R Sheikhi BHlthSci), Shahrekord University of Medical Sciences, Shahrekord, Iran; School of Medicine (S Bagherieh BSc), Department of Environmental Health Engineering (A Fatehizadeh PhD), Department of Ophthalmology (A Forouhari MD), Emergency Department (A Forouhari MD), Isfahan University of Medical Sciences, Isfahan, Iran; Department of Translational Medicine (F Barone-Adesi PhD), University of Eastern Piedmont, Novara, Italy; Heidelberg Institute of Global Health (S Barteit PhD), Heidelberg University Hospital, Heidelberg, Germany; Center for Primary Care (S Basu PhD), Division of General Internal Medicine (Prof A Sheikh MD), Harvard University, Boston, MA, USA; School of Public Health (S Basu PhD), Department of Primary Care and Public Health (Prof A Majeed MD, Prof S Rawaf MD), The George Institute for Global Health (Prof S Yaya PhD), Imperial College London, London, UK; Medical Laboratory Science (M A Belete MSc), Department of Environmental Health (M Gebrehiwot PhD), Wollo University, Dessie, Ethiopia; Biological Sciences Department (L Belo PhD), Research Unit on Applied Molecular Biosciences (UCIBIO) (L Belo PhD), Institute for Research and Innovation in Health (Prof N Cruz-Martins MBiostat), Laboratory for Process Engineering, Environment, Biotechnology and Energy (LEPABE) (J Loureiro PhD), University of Porto, Porto, Portugal; School of Health Science (A Y Berhie MSc), College of Medicine and Health Sciences (H B Netsere MS), Bahir Dar University, Bahir Dar, Ethiopia; Social Determinants of Health Research Center (A Bijani PhD), Cellular and Molecular Biology Research Center (Prof S Mahjoub PhD), Department of Clinical Biochemistry (Prof S Mahjoub PhD), Babol University of Medical Sciences, Babol, Iran; Scientific-Tools.Org, Bergamo, Italy (B Bikbov MD); Institute for Health Metrics and Evaluation (K Burkart PhD, X Dai FMedSci, Prof L Dandona DPhil, Prof R Dandona MRCP, L S Flor MPH, H H Kyu PhD, Prof S S Lim PhD, T Mestrovic PhD, A H Mokdad PhD, Prof C J L Murray DPhil, Prof T Vos PhD, Prof S I Hay FMedSci), Department of Health Metrics Sciences, School of Medicine (K Burkart PhD, X Dai FMedSci, Prof R Dandona MRCP, L S Flor MPH, H H Kyu PhD, Prof S S Lim PhD, A Misganaw PhD, A H Mokdad PhD, Prof C J L Murray DPhil, Prof T Vos PhD, Prof S I Hay FMedSci), University of Washington, Seattle, WA, USA; Oncological Network (G Gorini MD), Institute for Cancer Research, Prevention and Clinical Network, Florence, Italy (G Carreras PhD); Department of Public Health (P Charalampous MSc), Erasmus University Medical Center, Rotterdam, Netherlands; Department of Medical Biochemistry (E Chekol Abebe MSc), Debre Tabor University, Debre Tabor, Ethiopia; Therapeutic and Diagnostic Technologies (Prof N Cruz-Martins MBiostat), Cooperativa de Ensino Superior Politécnico e Universitário (Polytechnic and University Higher Education Cooperative), Gandra, Portugal; Department of Research (H Kaur MPH, A Pandey PhD), Public Health Foundation of India, Gurugram, India (Prof L Dandona DPhil, Prof R Dandona MRCP, G Kumar PhD); Indian Council of Medical Research, New Delhi, India (Prof L Dandona DPhil); Department of Nursing (S M Degualem MBBS, A A Demlash MSc), Arba Minch University, Arba Minch, Ethiopia; Department of Neurosurgery (A K Demetriades MD), Global Health Governance Programme (J Patel), Centre for Medical Informatics (Prof A Sheikh MD), University of Edinburgh, Edinburgh, UK; Department of Neurosurgery (A K Demetriades MD), National Health Service (NHS) Scotland, Edinburgh, UK; Department of Surgical Nursing (A A Desta MSc), School of Nursing (H B Netsere MS), University of Gondar, Gondar, Ethiopia; Department of Epidemiology (M Dianatinasab MSc), Maastricht University, Maastricht, Netherlands; School of Health (S Doaei PhD), Department of Environmental Health Engineering (J Jaafari PhD), Gastrointestinal and Liver Diseases Research Center (Prof F Mansour-Ghanaei MD), Caspian Digestive Disease Research Center (Prof F Mansour-Ghanaei MD), Guilan University of Medical Sciences, Rasht, Iran; Research Center for Public Health and Nutrition (D E Effendi MA), National Research and Innovation Agency Republic of Indonesia (BRIN), Jakarta, Indonesia; Lincoln International Institute for Rural Health (L Engelbert Bain PhD), University of Lincoln, Lincoln, UK; Department of Public Health (F Esmaeilzadeh PhD), Maragheh University of Medical Sciences, Maragheh, Iran; Research Center on Public Health (P Ferrara MD), University of Milan Bicocca, Monza, Italy; Department of Nursing (G Fetensa MSc), Department of Public Health (M E Getachew MPH), Department of Midwifery (M Regasa MSc), Wollega University, Nekemte, Ethiopia; Institute of Public Health (F Fischer PhD), Department of Neurology (S Samadzadeh MD), Charité Universitätsmedizin Berlin (Charité Medical University Berlin), Berlin, Germany; Department of Medical Parasitology (M Foroutan PhD), Faculty of Medicine (M Foroutan PhD), Abadan University of Medical Sciences, Abadan, Iran; Institute of Applied Health Sciences (S Gaihre PhD), Aberdeen, UK; Department of Surgical Technology (N Galehdar PhD), Lorestan University of Medical Sciences,

Khorramabad, Iran; Department of Environmental Health Sciences (S Gallus DSc), Mario Negri Institute for Pharmacological Research, Milan, Italy; Department of Pharmacology (Prof R K Gautam PhD), Indore Institute of Pharmacy, Indore, India; Discipline of Population Health (T G Gebremeskel MPH), College of Medicine and Public Health (G R Naik PhD), Flinders University, Adelaide, SA, Australia; Department of Reproductive Health (T G Gebremeskel MPH), Aksum University, Aksum, Ethiopia; Department of Public Health (L Getacher MPH), Department of Pediatrics and Child Health (G B B Mulu MSc), Department of Nursing (N T Sharew MSc), Debre Berhan University, Debre Berhan, Ethiopia; E-Learning Center (M Ghasemi Nour MD), Clinical Research Development Unit (N Morovatdar MD), Applied Biomedical Research Center (A Sahebkar PhD), Biotechnology Research Center (A Sahebkar PhD), Mashhad University of Medical Sciences, Mashhad, Iran; Department of Genetics (P Goleij MSc), Sana Institute of Higher Education, Sari, Iran; Department of Nursing (M Golitaleb PhD), Arak University of Medical Sciences, Arak, Iran; Biorefining and Advanced Materials Research Center (V Gupta PhD), Scotland's Rural College (SRUC), Edinburgh, UK; Biology Department (M Hashemian PhD), Utica University, Utica, NY, USA; Independent Consultant, Tabriz, Iran (H Hassankhani PhD); Department of Public Health (D Z Heyi MPH, B Sahiledengle MPH), Madda Walabu University, Bale Robe, Ethiopia; Department of General Surgery and Surgical-Medical Specialties (Prof G Isola PhD), University of Catania, Catania, Italy; Institute of Molecular and Clinical Ophthalmology Basel, Basel, Switzerland (Prof J B Jonas MD); Department of Ophthalmology (Prof J B Jonas MD), Heidelberg University, Mannheim, Germany; Department of Family Medicine and Public Health (J J Jozwiak PhD), University of Opole, Opole, Poland; Institute of Family Medicine and Public Health (M Jürisson PhD), University of Tartu, Tartu, Estonia; School of Public Health (Z Kabir PhD), University College Cork, Cork, Ireland; Social Determinants of Health Research Center (L R Kalankesh PhD), Gonabad University of Medical Sciences, Gonabad, Iran; Institute for Prevention of Non-communicable Diseases (R Kalhor PhD), Health Services Management Department (R Kalhor PhD), Department of Food Hygiene and Safety (Prof R Mahmoudi PhD), Qazvin University of Medical Sciences, Qazvin, Iran; Surgery Research Unit (J H Kauppila MD), University of Oulu, Oulu, Finland; Department of Molecular Medicine and Surgery (J H Kauppila MD), Karolinska Institute, Stockholm, Sweden; International Research Center of Excellence (G A Kayode PhD), Institute of Human Virology Nigeria, Abuja, Nigeria; Julius Centre for Health Sciences and Primary Care (G A Kayode PhD), Utrecht University, Utrecht, Netherlands; Department of Healthcare Services Management (L Keikavoosi-Arani PhD), School of Medicine (M Shams-Beyranvand MSc), Alborz University of Medical Sciences, Karaj, Iran; Health Promotion Research Center (M Khammarnia PhD, H Okati-Aliabad PhD, F Shahraki-Sanavi PhD), Zahedan University of Medical Sciences, Zahedan, Iran; Family Medicine Department (M A Khan MSc), United Arab Emirates University, Al Ain, United Arab Emirates; Primary Care Department (M A Khan MSc), NHS North West London, London, UK; Faculty of Health and Wellbeing (K Khatab PhD), Sheffield Hallam University, Sheffield, UK; College of Arts and Sciences (K Khatab PhD), Ohio University, Zanesville, OH, USA; Social Determinants of Health Research Center (H Koohestani PhD), Saveh University of Medical Sciences, Saveh, Iran; Biomedical Research Networking Center for Mental Health Network (CIBERSAM) (A Koyanagi MD), San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain; Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain (A Koyanagi MD); Faculty of Health and Life Sciences (O P Kurmi PhD), Coventry University, Coventry, UK; Department of Medicine (O P Kurmi PhD), McMaster University, Hamilton, ON, Canada; Department of Clinical Sciences and Community Health (Prof C La Vecchia MD), University of Milan, Milan, Italy; Department of Public Health (Prof T Lallukka PhD), University of Helsinki, Helsinki, Finland; School of Health (J Loureiro PhD), Polytechnic Institute of Porto, Porto, Portugal; Environmental Health Research Center (Prof A Maleki PhD), Kurdistan University of Medical Sciences, Sanandaj, Iran; Department of Biochemistry (A Marjani PhD), Joint, Bone, Connective Tissue, Rheumatology Research Center (JBCRC) (M Moradzadeh PhD), Golestan University of Medical Sciences, Gorgan, Iran; Division of Infection, Immunity and Respiratory Medicine (A G Mathioudakis PhD), University of Manchester, Manchester, UK; North West Lung Centre (A G Mathioudakis PhD), Manchester University NHS Foundation Trust, Manchester, UK; Nutrition Health Research Center (F Mehri PhD), Iran University of Medical Sciences, Hamadan, Iran; International Dx Department (A A Mentis MD), BGI Genomics, Copenhagen, Denmark; University Centre Varazdin (T Mestrovic PhD), University North, Varazdin, Croatia; Department of Statistics and Econometrics (A Mirica PhD, A Otoiu PhD), Bucharest University of Economic Studies, Bucharest, Romania; National Data Management Center for Health (A Misganaw PhD), Ethiopian Public Health Institute, Addis Ababa, Ethiopia; Department of Public Health (H Mohammed MPH), Dire Dawa University, Dire Dawa, Ethiopia; Health Systems and Policy Research Unit (S Mohammed PhD), Ahmadu Bello University, Zaria, Nigeria; Department of Health Care Management (S Mohammed PhD), Technical University of Berlin, Berlin, Germany; School of Medicine (P Mokhtarzadehazar MD), Urmia University of Medical Sciences, Urmia, Iran (R Valizadeh PhD); Clinical Epidemiology and Public Health Research Unit (L Monasta DSc, L Ronfani PhD), Burlo Garofolo Institute for Maternal and Child Health, Trieste, Italy; Competence Center of Mortality-Follow-Up of the German National Cohort (R Westerman DSc), Federal Institute for Population Research, Wiesbaden, Germany (Prof U O Mueller MD); Center for Population and Health, Wiesbaden, Germany (Prof U O Mueller MD); Department of Surgery (F Mulita PhD), General University Hospital of Patras, Patras, Greece; School of Medicine (F Mulita PhD), University of Thessaly, Larissa, Greece; Department of Medical Microbiology and Immunology (S Muthupandian PhD), Mekelle University, Mekelle, Ethiopia; Saveetha Dental College (S Muthupandian PhD), Saveetha Dental College and Hospitals (M R Tovani-Palone PhD), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India; Department of Engineering (G R Naik PhD), Western Sydney University, Sydney, NSW, Australia; Department of Nursing Education and Research (A J J Nashwan MSc), Hamad Medical Corporation, Doha, Qatar; Department of Epidemiology (S Nejadghaderi MD), Non-Communicable Diseases Research Center (NCDRC), Tehran, Iran; Department of Gastroenterology (N M Noor MRCP), Cambridge University Hospitals, Cambridge, UK; Department of Applied Economics and Quantitative Analysis (Prof B Oancea PhD), University of Bucharest, Bucharest, Romania; Department of Medicine (A S Oguntade MSc), University College Hospital, Ibadan, Ibadan, Nigeria; National School of Public Health (A Padron-Monedero PhD), Institute of Health Carlos III, Madrid, Spain; Department of Epidemiology (R Pakzad PhD), Ilam University of Medical Sciences, Ilam, Iran; Vision and Eye Research Institute (Prof S Pardhan PhD), Anglia Ruskin University, Cambridge, UK; Department of Epidemiology and Community Health (R R Parikh MD), University of Minnesota School of Public Health, Minneapolis, MN, USA; School of Dentistry (J Patel), University of Leeds, Leeds, UK; Department of Neurology (U Pensato MD), IRCCS Humanitas Research Hospital, Milan, Italy; Centre for Primary Health Care and Equity (P Peprah MSc), University of New South Wales, Kensington, Australia; Mario Negri Institute for Pharmacological Research, Bergamo, Italy (N Perico MD, Prof G Remuzzi MD); School of Medicine (Prof D Poddighe PhD), Nazarbayev University, Astana, Kazakhstan; Clinical Academic Department of Pediatrics (Prof D Poddighe PhD), University Medical Center (UMC), Astana, Kazakhstan; University Medical Center Groningen (Prof M J Postma PhD), Interdisciplinary Centre Psychopathology and Emotion Regulation (ICPE) (N T Sharew MSc), University of Groningen, Groningen, Netherlands; Center of Excellence in Higher Education for Pharmaceutical Care Innovation (Prof M J Postma PhD), Universitas Padjadjaran (Padjadjaran University), Bandung, Indonesia; Department of Anesthesia (F Rahim PhD), Cihan University of Sulaimaniya, Sulaimaniya, Iraq; Department of Public Health (V Rahmanian PhD), Torbat Jam Faculty of Medical Sciences, Torbat Jam, Iran; Academic Public Health England (Prof S Rawaf MD), Public Health England, London, UK; Department of Epidemiology and Biostatistics (Prof M Rezaeian PhD), Rafsanjan University of Medical Sciences, Rafsanjan, Iran; Department of Public Health (A Riad DDS), Czech National Centre for Evidence-based Healthcare and Knowledge Translation (A Riad DDS), Masaryk University, Brno, Czech Republic;

Clinical and Epidemiological Research in Primary Care (GICEAP) (E Romero-Rodríguez PhD), Maimonides Biomedical Research Institute of Cordoba (IMIBIC), Cordoba, Spain; Department of Biostatistics and Epidemiology (K Roy Pramanik MSc), International Institute for Population Sciences, Mumbai, India; Department of Pediatric Neurology (S Sadeghian MD), Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran; Department of Polymer Technology (Prof M R Saeb PhD), Gdańsk University of Technology, Gdansk, Poland; Department of Neurology (S Samadzadeh MD), University of Southern Denmark, Odense, Denmark; Department of Medicine and Surgery (Y Sethi MBBS), Government Doon Medical College, Dehradun, India; Research Center for Environmental Determinants of Health (K Sharafi PhD), Kermanshah University of Medical Sciences, Kermanshah, Iran; Finnish Institute of Occupational Health, Helsinki, Finland (R Shiri PhD); Department of General Surgery (B Socea PhD), Carol Davila University of Medicine and Pharmacy, Bucharest, Romania; Department of Surgery (B Socea PhD), Sfântul Pantelimon Emergency Clinical Hospital Bucharest, Bucharest, Romania; Department of Medicine (Prof R Tabarés-Seisdedos PhD), University of Valencia, Valencia, Spain; Carlos III Health Institute (Prof R Tabarés-Seisdedos PhD), Biomedical Research Networking Center for Mental Health Network (CiberSAM), Madrid, Spain; Department of Biostatistics and Epidemiology (M Taheri Soodejani PhD), Shahid Sadoughi University of Medical Sciences, Yazd, Iran; Modestum LTD, Eastbourne, UK (M R Tovani-Palone PhD); Department Occupational Health and Safety (A R Tualeka PhD), Universitas Airlngga, Surabaya, Indonesia; Department of Cardiovascular Sciences (J Van den Eynde BSc), Katholieke Universiteit Leuven (University of Leuven), Leuven, Belgium; UKK Institute, Tampere, Finland (Prof T J Vasankari MD); Faculty of Medicine and Health Technology (Prof T J Vasankari MD), Tampere University, Tampere, Finland; Department of Mental Health and Psychiatry (M T Walde MSc), Haramaya University, Harar, Ethiopia; School of Population Health and Environmental Sciences (Y Wang PhD), King's College London, London, UK; Department of Orthopaedics (F Wei MD), Tangdu Hospital, Fourth Military Medical University, Xi'an, China; Department of Environmental Health and Epidemiology (V Yadav MD), National Institute for Research in Environmental Health, Bhopal, India; School of International Development and Global Studies (Prof S Yaya PhD), University of Ottawa, Ottawa, ON, Canada; Research and Development Department (I Zare BSc), Sina Medical Biochemistry Technologies, Shiraz, Iran; School of Public Health and Emergency Management (B Zhu PhD), Southern University of Science and Technology, Shenzhen, China; Department of Nursing (M Zoladl PhD), Yasuj University of Medical Sciences, Yasuj, Iran; National Institute for Health and Care Research-Biomedical Research Centre (Prof A Zumla PhD), University College London Hospitals, London, UK.

Contributors

Please see the appendix (p 168) for more detailed information about individual author contributions to the research, divided into the following categories: writing the first draft of the manuscript; 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.

Declaration of interests

AKD reports payment or honoraria for lectures, presentations, speakers bureaus; manuscript writing or educational events from speakers bureaus, Stryker, Integra, and Safe (orthopedics); leadership or fiduciary roles in board, society, committee, or advocacy groups, unpaid with the European Association of Neurosurgical Societies, the Board of Global Neuro Foundation, and the Steering Committee of AO Spine Knowledge Forum Degenerative, outside the submitted work. JJJ reports payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or educational events from Novartis and Adamed, outside the submitted work. JAL reports support for the present manuscript from Base Funding UIDB/00511/2020 of the Laboratory for Process Engineering, Environment, Biotechnology, and Energy, funded by national funds through The Foundation for Science and Technology and Ministry of Science, Technology, and Higher Education. A-FAM reports grants or contracts from MilkSafe (a novel pipeline to enrich formula milk using omics technologies), research cofinanced by the European Regional Development Fund of the EU and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call Research, Create, Innovate (project code T2EDK-02222), and from ELIDEK (Hellenic Foundation for Research and Innovation, MIMS-860); payment for expert testimony from serving as external peer-reviewer for Fondazione Cariplo, Italy; leadership or fiduciary roles in board, society, committee, or advocacy groups, paid or unpaid as an editorial board member for the *Systemic Reviews* journal, for the *Annals of Epidemiology* journal, and as Associate Editor for *Translational Psychiatry*; stocks in a family winery; and other financial or non-financial support from the BGI group as a scientific officer, outside the submitted work. MJP reports stock or stock options in Health Ecore, Zeist, NL, and PAG BV, outside the submitted work.

Data sharing

All data used in this analysis are available at http://ghdx.healthdata.org/gbd-results-tool.

Acknowledgments

This research was funded by the Australian National Health and Medical Research Council and the Bill & Melinda Gates Foundation. Murdoch Children's Research Institute researchers were supported by the Australian Victorian Government's Operational Infrastructure Support Program. Core work was supported by the Australian National Health and Medical Research Council Centre for Research Excellence for Driving Investment in Global Adolescent Health (GNT 1171981). PSA is supported by a NHMRC Investigator grant GNT 2008574. S Barteit acknowledges support from the Heidelberg Institute of Global Health, Faculty of Medicine, University Hospital, Heidelberg University, Heidelberg, Germany. JGB acknowledges support from the National Health and Medical Research Council of Australia (investigator grant 1173046). LB acknowledges support from Fundação para a Ciência e Tecnologia in the scope of the project UIDP/04378/2020 and UIDB/04378/2020 of The Research Unit on Applied Molecular Biosciences from the Universities of Porto and NOVA of Lisbon and project LA/P/0140/2020 of i4HB. KIC acknowledges support from the Centre of Research Excellence in Driving Global Investment in Adolescent Health funded by NHMRC APP1171981. AF acknowledges support from the Department of Environmental Health Engineering of Isfahan University of Medical Sciences, Isfahan, Iran. SG acknowledges support from the Institute of Applied Health Sciences, School of Medicine, Medical Sciences and Nutrition, University of Aberdeen, UK. RKG acknowledges support from Indore Institute of Pharmacy. JH acknowledges support from NHMRC investigator grant GNT2008600 and the Reckitt Global Hygiene Institute (RGHI); the views expressed are those of the authors and not necessarily those of RGHI. AGM acknowledges support from the NIHR Manchester Biomedical Research Centre and from an NIHR Clinical Lectureship in Respiratory Medicine. LM acknowledges support from the Italian Ministry of Health (Ricerca Corrente 34/2017), and payments made to the Institute for Maternal and Child Health IRCCS Burlo Garofolo. UOM acknowledges support from the German National Cohort Study Grant 01ER1801D. RRP acknowledges support from the University of Minnesota Doctoral Dissertation Fellowship. AR acknowledges support from the NPO Systemic Risk Institute number LX22NPO5101, funded by the European Union Next Generation EU (Ministry of Education, Youth, and Sports; NPO: EXCELES). AS acknowledges support from Health Data Research, UK. MRT-P acknowledges support from Saveetha Institute of Medical and Technical Sciences. JLW acknowledges support from an MRC Clinical Research Training Fellowship. AZ acknowledges support from The Pan-African Network on Emerging and Re-Emerging Infections supported by the EU and Developing Countries Clinical Trials Partnership, the EU Horizon 2020 Framework Programme, and from UK National Institute for Health and Care Research as a Senior Investigator Award and Mahathir Science Award winner, and The European and Developing Countries Clinical Trials Partnership (EU) Pascoal Mocumbi Prize Laureate. Researchers from Murdoch Children's Research Institute acknowledge support from the Victorian Government's Operational Infrastructure Support Program. We wish to acknowledge the extensive contributions to this paper by Prof George C Patton, who passed away in December, 2022

(https://doi.org/10.1016/S0140-6736(22)02592-2). Prof George C Patton was an unwavering advocate for adolescent health and the importance of data to inform actions that are responsive to adolescents' needs.

References

1 Hay SI. Maintaining progress for the most beautiful chart in the world. *Int Health* 2019; **11:** 344–48.

2 Burstein R, Henry NJ, Collison ML, et al. Mapping 123 million neonatal, infant and child deaths between 2000 and 2017. *Nature* 2019; **574:** 353–58.

3 Matthews KR, Ho V. The grand impact of the Gates Foundation. Sixty billion dollars and one famous person can affect the spending and research focus of public agencies. *EMBO Rep* 2008; **9:** 409–12.

4 Paulson KR, Kamath AM, Alam T, et al. Global, regional, and national progress towards Sustainable Development Goal 3.2 for neonatal and child health: all-cause and cause-specific mortality findings from the Global Burden of Disease Study 2019. *Lancet* 2021; **398:** 870–905.

5 Rao C, Adair T, Kinfu Y. Using historical vital statistics to predict the distribution of under-five mortality by cause. *Clin Med Res* 2011; **9:** 66–74.

6 Chopra M, Binkin NJ, Mason E, Wolfheim C. Integrated management of childhood illness: what have we learned and how can it be improved? *Arch Dis Child* 2012; **97:** 350–54.

7 Viner RM, Coffey C, Mathers C, et al. 50-year mortality trends in children and young people: a study of 50 low-income, middle-income, and high-income countries. *Lancet* 2011; **377:** 1162–74.

8 Patton GC, Azzopardi P. Missing in the middle: measuring a million deaths annually in children aged 5–14 years. *Lancet Glob Health* 2018; **6:** e1048–49.

9 Ward JL, Azzopardi PS, Francis KL, et al. Global, regional, and national mortality among young people aged 10–24 years, 1950–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2021; **398:** 1593–618.

10 Patton GC, Sawyer SM, Santelli JS, et al. Our future: a *Lancet* commission on adolescent health and wellbeing. *Lancet* 2016; **387:** 2423–78.

11 Azzopardi PS, Hearps SJC, Francis KL, et al. Progress in adolescent health and wellbeing: tracking 12 headline indicators for 195 countries and territories, 1990–2016. *Lancet* 2019; **393:** 1101–18.

12 Li Z, Li M, Patton GC, Lu C. Global development assistance for adolescent health from 2003 to 2015. *JAMA Netw Open* 2018; **1:** e181072.

13 Hui DS, Azhar IE, Madani TA, et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health. The latest 2019 novel coronavirus outbreak in Wuhan, China. *Int J Infect Dis* 2020; **91:** 264–66.

14 Ward JL, Harwood R, Smith C, et al. Risk factors for PICU admission and death among children and young people hospitalized with COVID-19 and PIMS-TS in England during the first pandemic year. *Nat Med* 2022; **28:** 193–200.

15 Banati P, Jones N, Youssef S. Intersecting vulnerabilities: the impacts of COVID-19 on the psycho-emotional lives of young people in low- and middle-income countries. *Eur J Dev Res* 2020; **32:** 1613–38.

16 Pai M, Kasaeva T, Swaminathan S. COVID-19's devastating effect on tuberculosis care: a path to recovery. *N Engl J Med* 2022; **386:** 1490–93.

17 Weiss DJ, Bertozzi-Villa A, Rumisha SF, et al. Indirect effects of the COVID-19 pandemic on malaria intervention coverage, morbidity, and mortality in Africa: a geospatial modelling analysis. *Lancet Infect Dis* 2021; **21:** 59–69.

18 Paremoer L, Nandi S, Serag H, Baum F. Covid-19 pandemic and the social determinants of health. *BMJ* 2021; **372:** n129.

19 Rashid SF, Theobald S, Ozano K. Towards a socially just model: balancing hunger and response to the COVID-19 pandemic in Bangladesh. *BMJ Glob Health* 2020; **5:** e002715.

20 UNAIDS. In danger: UNAIDS global AIDS update 2022. Geneva: Joint United Nations Programme on HIV/AIDS, 2022.

21 Ghebreyesus TA, Russell C. Opportunities in crisis for optimising child health and development. *Lancet* 2022; **399:** 1761–63.

22 Wang H, Abbas KM, Abbasifard M, et al. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950–2019: a comprehensive demographic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1160–203.

23 Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1223–49.

24 Institute for Health Metrics and Evaluation. Global Burden of Disease Study 2019 (GBD 2019) data input sources tool. https://ghdx.healthdata.org/gbd-2019/data-input-sources (accessed June 15, 2023).

25 Institute for Health Metrics and Evaluation. Global Burden of Disease Study 2019 (GBD 2019) code. https://ghdx.healthdata.org/gbd-2019/code (accessed June 15, 2023).

26 Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) cause list mapped to ICD codes. Seattle: Institute for Health Metrics and Evaluation, 2020.

27 Sawyer SM, Azzopardi PS, Wickremarathne D, Patton GC. The age of adolescence. *Lancet Child Adolesc Health* 2018; **2:** 223–28.

28 Sawyer SM, McNeil R, Francis KL, et al. The age of paediatrics. *Lancet Child Adolesc Health* 2019; **3:** 822–30.

29 Vos T, Lim SS, Abbafati C, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1204–22.

30 Ghys PD, Williams BG, Over M, Hallett TB, Godfrey-Faussett P. Epidemiological metrics and benchmarks for a transition in the HIV epidemic. *PLoS Med* 2018; **15:** e1002678.

31 WHO. Ending preventable child deaths from pneumonia and diarrhoea by 2025: the integrated global action plan for pneumonia and diarrhoea (GAPPD). 2013. https://www.who.int/publications/i/item/the-integrated-global-action-plan-for-prevention-and-control-of-pneumonia-and-diarrhoea-(gappd) (accessed Sept 13, 2022).

32 Campbell JC, Baty ML, Ghandour RM, Stockman JK, Francisco L, Wagman J. The intersection of intimate partner violence against women and HIV/AIDS: a review. *Int J Inj Contr Saf Promot* 2008; **15:** 221–31.

33 Kennedy E, Binder G, Humphries-Waa K, et al. Gender inequalities in health and wellbeing across the first two decades of life: an analysis of 40 low-income and middle-income countries in the Asia-Pacific region. *Lancet Glob Health* 2020; **8:** e1473–88.

34 Vassall A, Masiye F. Replenishing the global fund to fight AIDS, tuberculosis, and malaria. *BMJ* 2022; **378:** o2320.

35 Troeger C, Colombara DV, Rao PC, et al. Global disability-adjusted life-year estimates of long-term health burden and undernutrition attributable to diarrhoeal diseases in children younger than 5 years. *Lancet Glob Health* 2018; **6:** e255–69.

36 Reiner RC Jr, Wiens KE, Deshpande A, et al. Mapping geographical inequalities in childhood diarrhoeal morbidity and mortality in low-income and middle-income countries, 2000–17: analysis for the Global Burden of Disease Study 2017. *Lancet* 2020; **395:** 1779–801.

37 Perin J, Mulick A, Yeung D, et al. Global, regional, and national causes of under-5 mortality in 2000–19: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet Child Adolesc Health* 2022; **6:** 106–15.

38 Weiss DJ, Lucas TCD, Nguyen M, et al. Mapping the global prevalence, incidence, and mortality of *Plasmodium falciparum*, 2000–17: a spatial and temporal modelling study. *Lancet* 2019; **394:** 322–31.

39 Snow KJ, Cruz AT, Seddon JA, et al. Adolescent tuberculosis. *Lancet Child Adolesc Health* 2020; **4:** 68–79.

40 Patton GC, Coffey C, Cappa C, et al. Health of the world's adolescents: a synthesis of internationally comparable data. *Lancet* 2012; **379:** 1665–75.

41 Zhang J, Ma B, Han X, Ding S, Li Y. Global, regional, and national burdens of HIV and other sexually transmitted infections in adolescents and young adults aged 10–24 years from 1990 to 2019: a trend analysis based on the Global Burden of Disease Study 2019. *Lancet Child Adolesc Health* 2022; **6:** 763–76.

42 Diaz T, Strong KL, Cao B, et al. A call for standardised age-disaggregated health data. *Lancet Healthy Longev* 2021; **2:** e436–43.

43 UNICEF, WHO. Tracking progress towards universal coverage for reproductive, newborn and child health: the 2017 report. Washington, DC: United Nations Children's Fund and the World Health Organization, 2017.

44 Sheehan P, Sweeny K, Rasmussen B, et al. Building the foundations for sustainable development: a case for global investment in the capabilities of adolescents. *Lancet* 2017; **390:** 1792–806.

45 WHO. Global tuberculosis report 2022. Geneva: World Health Organisation, 2022.

46 WHO. World malaria report 2022. Geneva: World Health Organisation, 2022.

47 UNAIDS. Global data on HIV epidemiology and response. Geneva: Joint United Nations Programme on HIV/AIDS, 2022.

48 Berry G, Parsons A, Morgan M, Rickert J, Cho H. A review of methods to reduce the probability of the airborne spread of COVID-19 in ventilation systems and enclosed spaces. *Environ Res* 2022; **203:** 111765.

49 Upshaw TL, Brown C, Smith R, Perri M, Ziegler C, Pinto AD. Social determinants of COVID-19 incidence and outcomes: a rapid review. *PLoS One* 2021; **16:** e0248336.

50 Rader B, Scarpino SV, Nande A, et al. Crowding and the shape of COVID-19 epidemics. *Nat Med* 2020; **26:** 1829–34.

51 Lee KK, Bing R, Kiang J, et al. Adverse health effects associated with household air pollution: a systematic review, meta-analysis, and burden estimation study. *Lancet Glob Health* 2020; **8:** e1427–34.

52 Mora C, McKenzie T, Gaw IM, et al. Over half of known human pathogenic diseases can be aggravated by climate change. *Nat Clim Chang* 2022; **12:** 869–75.

53 Vollset SE, Goren E, Yuan C-W, et al. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *Lancet* 2020; **396:** 1285–306.

54 Watkins DA, Johnson CO, Colquhoun SM, et al. Global, regional, and national burden of rheumatic heart disease, 1990-2015. *N Engl J Med* 2017; **377:** 713–22.

55 Guthold R, Moller A-B, Azzopardi P, et al. The Global Action for Measurement of Adolescent health (GAMA) Initiative: rethinking adolescent metrics. *J Adolesc Health* 2019; **64:** 697–99.

56 Strong K, Requejo J, Agweyu A, et al. Child health accountability tracking-extending child health measurement. *Lancet Child Adolesc Health* 2020; **4:** 259–61.