Estimates of the global, regional, and national morbidity, mortality, and aetiologies of lower respiratory tract infections in 195 countries: a systematic analysis for the Global Burden of Disease Study 2015

GBD 2015 LRI Collaborators

Summary

Background The Global Burden of Diseases, Injuries, and Risk Factors (GBD) Study 2015 provides an up-to-date analysis of the burden of lower respiratory tract infections (LRIs) in 195 countries. This study assesses cases, deaths, and aetiologies spanning the past 25 years and shows how the burden of LRI has changed in people of all ages.

Methods We estimated LRI mortality by age, sex, geography, and year using a modelling platform shared across most causes of death in the GBD 2015 study called the Cause of Death Ensemble model. We modelled LRI morbidity, including incidence and prevalence, using a meta-regression platform called DisMod-MR. We estimated aetiologies for LRI using two different counterfactual approaches, the first for viral pathogens, which incorporates the aetiology-specific risk of LRI and the prevalence of the aetiology in LRI episodes, and the second for bacterial pathogens, which uses a vaccine-probe approach. We used the Socio-demographic Index, which is a summary indicator derived from measures of income per capita, educational attainment, and fertility, to assess trends in LRI-related mortality. The two leading risk factors for LRI disability-adjusted life-years (DALYs), childhood undernutrition and air pollution, were used in a decomposition analysis to establish the relative contribution of changes in LRI DALYs.

Findings In 2015, we estimated that LRIs caused 2·74 million deaths (95% uncertainty interval [UI] 2·50 million to 2·86 million) and 103·0 million DALYs (95% UI 96·1 million to 109·1 million). LRIs have a disproportionate effect on children younger than 5 years, responsible for 704 000 deaths (95% UI 651 000–763 000) and 60.6 million DALYs (95% UI 56·0–65·6). Between 2005 and 2015, the number of deaths due to LRI decreased by 36·9% (95% UI 31·6 to 42·0) in children younger than 5 years, and by 3·2% (95% UI –0·4 to 6·9) in all ages. Pneumococcal pneumonia caused 55·4% of LRI deaths in all ages, totalling 1 517 388 deaths (95% UI 857 940–2 183 791). Between 2005 and 2015, improvements in air pollution exposure were responsible for a 4·3% reduction in LRI DALYs and improvements in childhood undernutrition were responsible for an 8·9% reduction.

Interpretation LRIs are the leading infectious cause of death and the fifth-leading cause of death overall; they are the second-leading cause of DALYs. At the global level, the burden of LRIs has decreased dramatically in the last 10 years in children younger than 5 years, although the burden in people older than 70 years has increased in many regions. LRI remains a largely preventable disease and cause of death, and continued efforts to decrease indoor and ambient air pollution, improve childhood nutrition, and scale up the use of the pneumococcal conjugate vaccine in children and adults will be essential in reducing the global burden of LRI.

Funding Bill & Melinda Gates Foundation.

Copyright © The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY 4.0 license.
Here, we present results from the GBD study 2015, describing the burden of LRIs and four aetiologies (Haemophilus influenzae type B [Hib], Streptococcus pneumoniae [pneumococcal pneumonia], influenza, and respiratory syncytial virus [RSV]), covering deaths, episodes, disability-adjusted life-years (DALYs), risk factors contributing to the burden of LRIs, and the relationship between LRIs and social development for 195 countries from 1990 to 2015 for both sexes and by age.

Methods
Modelling overview
Details on the methods for GBD 2015 are available elsewhere.4 Here, we give a brief description of the methods and estimation strategy for LRIs, defined as acute-onset physician-diagnosed pneumonia or bronchiolitis. We measure LRI burden using three metrics: deaths, episodes, and DALYs. DALYs are the sum of years of life lost (YLLs) because of premature death and years lived with disability (YLDs). We estimated mortality and morbidity separately. Flowcharts and a detailed description for each step of the estimation process are provided in the appendix pp 2–3. Input data, including information on sources used, and code for each step of the estimation process are available on the Global Health Data Exchange. All estimates are produced by year and by age, for both sexes, and for all 195 countries. Each step of the GBD 2015 LRI estimation process, including data sources, is documented in accordance with the Guidelines for Accurate and Transparent Health Estimates Reporting.4

We saved 1000 draws from a posterior distribution of each parameter, and we repeated each analysis 1000 times using these draws to retain uncertainty of every step and input parameters. The results are given as mean values with 95% uncertainty intervals (UIs) showing the 2.5 and 97.5 percentiles of the distribution.

Mortality
The GBD Cause of Death database contains all available data from vital registration systems, surveillance systems, and verbal autopsies (summary in appendix p 4). We processed raw data to reconcile disparate coding schemes (such as the International Classification of Diseases 9 and 10), to redistribute poorly coded causes of death, and separate data by age and sex from tabulated cause lists.7

We estimated LRI mortality in the Cause of Death Ensemble model (CODEm) framework.5,8 CODEm is a spatiotemporal modelling platform that produces a wide range of submodels from cause of death data and space–time covariates. Covariates were selected independently for each submodel using an algorithm that captures the relationships between the covariates and LRI mortality and provides a variety of plausible models (for full list of covariates, see appendix p 5). We assessed our LRI cause of death models using in-sample and out-of-sample predictive performance.

The sum of all cause-specific mortality models must be equal to the all-cause mortality estimate.1 We corrected LRI mortality estimates and estimates for other causes of mortality by rescaling them according to the uncertainty around the cause-specific mortality rate. This process is called CoDCorrect and ensures internal consistency.
between causes of death and respects the all-cause mortality envelope.^

**Morbidity**

LRIs were defined as clinician-confirmed or radiologically confirmed pneumonia or bronchiolitis and were divided into moderate and severe or very severe episodes on the basis of WHO case definitions for pneumonia.^

Input data were derived from a systematic literature review of cross-sectional and cohort studies, hospital inpatient and outpatient data, health-care utilisation data (USA only), population-representative surveys, and excess mortality from the GBD 2015 cause of death estimates for LRI (appendix pp 6–7).

LRI morbidity (incidence, prevalence, and remission) was modelled using DisMod-MR version 2.1 (DisMod), a Bayesian, hierarchical, mixed-effects meta-regression platform.^

DisMod adjusts for variations in study methods between data sources and enforces consistency between data for the different parameters such as incidence and prevalence. Incidence, prevalence, remission, and excess mortality were related in a compartmental model of disease progression. Epidemiological data on LRI burden were analysed through a geographical cascade from a global level, at which fixed effects for covariates are established, to the most detailed geographic estimation level, which was either the national or subnational level. Model estimates from higher levels of the cascade were used as priors in analyses of lower levels. Random effects exist for each geographic estimation level. Geospatial priors, space–time covariates, random effects, and input data predicted incidence and prevalence of LRI episodes. Input data were adjusted in DisMod during the modelling process to meet our standard case definition using study-level binary covariates. These covariates described the source of the data and accounted for hospital-based, inpatient, and self-reported sources (appendix p 8).

DALYs are the sum of YLLs and YLDs and represent the cumulative burden of disease due to LRI.^

To estimate the YLDs from LRIs, we used a disability weight for each severity level (moderate and severe or very severe) and the proportion of cases that fall into each severity level (appendix p 7).

**Aetiologies**

We estimated LRI aetiologies separately from overall LRI mortality and morbidity using two distinct counterfactual modelling strategies to calculate population attributable fractions (PAFs) for influenza, RSV, Hib, and pneumococcal pneumonia. The PAF is the proportional reduction in LRI morbidity or mortality that would be observed if the exposure to the pathogen were zero. We did not attribute aetiologies to neonatal pneumonia cases or deaths because of an absence of reliable data in this age group, and we did not consider Hib in age groups older than 5 years for the same reason.

We used a vaccine probe design to estimate the PAF for pneumococcal pneumonia and Hib by first calculating the ratio of vaccine effectiveness against non-specific pneumonia to pathogen-specific pneumonia at the study level.^

We then adjusted this estimate by vaccine coverage and vaccine effectiveness to estimate country-specific and year-specific PAF values.^

We did not account for herd immunity in our estimates. Equations and more about these calculations are provided in the appendix (pp 9–10).

For Hib, we assumed that the vaccine efficacy against invasive Hib disease is the same as against Hib pneumonia. However, we did not make the same assumption for pneumococcal pneumonia because a study of pneumococcal conjugate vaccine (PCV) found that the vaccine efficacy against invasive pneumococcal disease might be significantly higher than against pneumococcal pneumonia.^

We used a ratio of efficacy against pneumococcal pneumonia to invasive pneumococcal disease from this study to adjust estimates of vaccine efficacy against invasive pneumococcal disease from the other studies. We used separate pneumococcal pneumonia and Hib age distributions, modelled in DisMod, to establish the PAF by age. Finally, geography and year PAFs were estimated using vaccine coverage modelled estimates.

Influenza and RSV were estimated by calculating an attributable fraction that relates the odds ratio (OR) of LRI given pathogen detection^

and proportion of LRI episodes that test positive for influenza or RSV.^

\[
PAF = \text{Proportion} \times \left(1 - \frac{1}{\text{OR}}\right)
\]

We conducted a systematic literature review of the proportion of LRI cases that test positive for influenza and RSV and used the meta-regression tool DisMod to estimate the proportion of people with LRI who are positive for influenza and RSV, separately, by location, year, age, and sex.

Different PAFs were measured for non-fatal and fatal LRI episodes. Fatal PAFs were adjusted using a scalar from the DisMod proportion models that represents the relative frequency of detection in inpatient versus non-inpatient sample populations. In the absence of aetiological data from fatal cases of LRI after death, we assumed that episodes of LRI requiring hospital admission were a reasonable proxy of severe and fatal episodes. Mortality is lower in patients with viral pneumonia than in those with pneumonia with bacterial causes. Therefore, we adjusted the fatal PAF estimates by establishing the ratio of case fatality in viral to bacterial causes of pneumonia from hospital data coded specifically to these causes, representing the relative fatality in people who were treated (appendix p 13).
Changes in burden with development
On the basis of methods used to construct the Human Development Index, GBD 2015 used the Socio-demographic Index (SDI), a summary measure of a country’s development based on lag-distributed income per capita, average educational attainment, and total fertility rate.\(^{22,23}\) We used the SDI to show how changes in under-5 LRI mortality and incidence are related to changes in development. We fitted a least-squares regression using a cubic spline of the relationship of SDI to LRI mortality and incidence for each year at the most detailed geographic locations.

Risk factor decomposition
Methods for risk factor attribution to LRI are described in detail elsewhere.\(^{22,23}\) Briefly, risk factors followed a PAF counterfactual approach in which the prevalence of exposure was modelled from scientific literature and population-representative surveys, and the relative risk of LRI given a risk exposure was from published meta-analyses. We used the two leading risk groups for LRI DALYs from GBD 2015\(^{22}\) air pollution (composed of household air pollution and ambient particulate matter\(^{26-27}\)) and childhood undernutrition (composed of underweight, wasted, and stunted\(^{28,29}\)), in a decomposition analysis of the change in LRI DALYs from 2005 to 2015. This period was chosen to show recent changes. The decomposition had four factors that contribute interdependently to LRI burden: undernutrition exposure, air pollution, population growth, and population ageing. The remaining changes were considered part of the unexplained causes of LRIs. A combinatorial process established the relative contribution of each of these four factors to the change in LRI DALYs.\(^{22,27}\)

Role of the funding source
The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
At the global level, under-5 LRI mortality occurred in 104·8 children per 100,000 (95% UI 97·0–113·6) and varied by region and country (table 1, figure 1A). According to our estimates, the highest under-5 LRI mortalities were in sub-Saharan Africa, in Somalia (546·8 deaths per 100,000, 95% UI 404·5–716·4) and Chad (511·3 deaths per 100,000, 361·9–693·1; table 1), and the lowest were in Finland in western Europe (0·65 deaths per 100 000, 0·43–0·88; figure 1A). The greatest overall number of under-5 LRI deaths occurred in India (140 649 deaths, 95% UI 122 930–160 758) because of its large population (table 1). The under-5 LRI mortality was nearly the same in males and females at the global level, but in south Asia, it was 1·2-times higher in girls than in boys (1·22 times in India and 1·24 times in Pakistan).

We calculated that, in 2015, LRIs caused 103·0 million DALYs (95% UI 96·1 million to 109·1 million) in all ages and 60·6 million DALYs (95% UI 56·0 million to 65·6 million) in children younger than 5 years (59% of LRI DALYs in all ages; table 1). We estimated that in 2015, 291·8 million episodes of LRI occurred (95% UI 276·3 million to 307·0 million), of which 101·8 million episodes were in children aged younger than 5 years (95% UI 90·0 million to 114·4 million; table 1).

Although nearly 60% of LRI DALYs were from children younger than 5 years, our findings suggest that LRI mortality was substantial across all ages, and in elderly people in particular. In adults aged 70 years or older, 1·27 million deaths (95% UI 1·15–1·34 million) were estimated to be caused by LRIs in 2015. In some countries, we estimated a much larger number of deaths due to LRIs in older adults (≥70 years) than in children younger than 5 years—eg, in China (172·3 per 100 000 [95% UI 150·3–196·4]) in older adults vs 29·2 per 100 000 [25·7–34·7] in children aged <5 years), the USA (235·2 per 100 000 [224·0–247·0] vs 2·7 per 100 000 [2·4–3·0]), and Japan (613·7 per 100 000 [588·4–639·2] vs 2·8 per 100 000 [2·4–3·2]).

The estimated global burden of LRIs decreased greatly between 2005 and 2015, particularly in children younger than 5 years (table 1, figure 1, 2). During this period, the global number of under-5 deaths due to LRI decreased by 36·9% (95% UI 31·6 to 42·0) from 1·11 million (95% UI 1·03 million to 1·20 million) to 0·70 3918 (651 385 to 763 039), with variation by region and SDI (table 1, figure 1C). However, the total number of LRI deaths decreased by 3·2% (95% UI –0·45 to 6·9; table 1, figure 1D) from 2·83 million (95% UI 2·63 million to 2·97 million) to 2·74 million (2·50 million to 2·86 million) because of a slower decrease in the LRI mortality rate in all ages (14·3% decrease) and population growth and ageing. The LRI mortality rate in all ages increased in many geographies, notably in high-SDI countries, where it increased 9·6% between 2005 and 2015, from 36·2 vs 39·7 per 100 000 (95% UI 35·4–37·1) to 39·7 per 100 000 (37·9–41·0).

Between 2005 and 2015, the fastest reduction in under-5 LRI mortality rate occurred in east and southeast Asia, central Europe, and tropical Latin America according to our estimates (>50% reduction; figure 1C). The fastest rate of improvement in under-5 LRI mortality occurred in Turkey (14% average annual decrease; figure 1C). The slowest decreases in under-5 mortality occurred in sub-Saharan Africa (2·1% annual decrease), and mortality increased in South Sudan (0·7% annual increase; figure 1C). We detected a relationship between LRI mortality and incidence and the SDI (figure 2). The LRI mortality rate decreased rapidly when transitioning from low to middle SDI, but the mortality rate in central Asia was much higher than expected on the basis of SDI (figure 2A). The relationship between incidence and SDI appeared to be more linear than for mortality and
|                     | Children younger than 5 years | All ages |
|---------------------|------------------------------|----------|
|                     | Deaths                       |          |
|                     | Total number                 | Number per 100 000 | Percent change 2005–15 | Episodes | Number per 100 000 | Percent change 2005–15 | DALT% |
|                     |                              |                       |                       |          |                       |                       |       |
| Global              | 702 919·9                    | (651 385·4 to 763 087·7) | -36·9 (101 759 to 114 446·8) | DALT% | 2 766 714·2           | (2 500 314·4 to 2 860 842·6) | 37·1 (33·9 to 38·8) |       |
| Central Europe      |                              |                       |                       |          |                       |                       |       |
| Europe, eastern     |                              |                       |                       |          |                       |                       |       |
| Europe, central     |                              |                       |                       |          |                       |                       |       |
| Albania             | 85 0                         | (55·9 to 123·3)       | -60·8 (-76·2 to -39·8) | 0·36     | (30·2 to 65·6)       | 0·07 (0·31 to 0·42)    | (0 to 0·01) |       |
| Armenia             | 101·4                        | (76·5 to 136·7)       | -51·4 (-64·6 to -33·9) | 0·30     | (26·0 to 35·3)       | 0·09 (0·07 to 0·12)    | (0·01 to 0·02) |       |
| Azerbaijan          | 164·2                        | (116·4 to 224·2)      | -48·9 (-64·2 to -27·7) | 1·42     | (1·01 to 1·93)       | -48·8 (-64·2 to -27·6) | (2·18 to 2·49) |       |
| Belarus             | 25·5                         | (17·6 to 37·5)        | -65·7 (-76·0 to -51·0) | 0·68     | (0·58 to 0·78)       | 0·02 (0·02 to 0·03)    | (0·04 to 0·05) |       |
| Croatia             | 7·5                          | (5·1 to 10·8)         | -56·7 (-64·5 to -43·4) | 0·33     | (0·20 to 0·27)       | 0·01 (-5·3 to -28·4)   | (2·78 to 3·00) |       |
| Czech Republic      | 20·6                         | (17·8 to 24·5)        | -55·5 (-63·6 to -42·2) | 0·16     | (0·14 to 0·18)       | 0 (0·01 to 0·01)      | (683·5 to 806·4) |       |
| Estonia             | 29·0                         | (2·0 to 4·0)          | -67·5 (-76·2 to -53·6) | 0·08     | (0·07 to 0·09)       | -66·4 (-80·0 to -53·6) | (1·02 to 1·11) |       |
| Georgia             | 7·2                          | (5·4 to 9·5)          | -70·3 (-78·1 to -59·9) | 0·32     | (0·29 to 0·39)       | -70·2 (-78·0 to -59·8) | (5·47 to 7·45) |       |
| Hungary             | 19·7                         | (12·8 to 27·8)        | -45·5 (-62·6 to -23·9) | 0·48     | (0·42 to 0·56)       | -44·3 (-60·7 to -23·2) | (2·10 to 2·27) |       |
| Kazakhstan          | 80·9                         | (58·7 to 104·8)       | -43·1 (-58·2 to -19·5) | 2·43     | (2·13 to 2·76)       | -43·0 (-59·1 to -19·5) | (2·58 to 3·62) |       |
| Kyrgyzstan          | 96·1                         | (80·7 to 115·4)       | -26·5 (-38·2 to -12·5) | 1·35     | (1·18 to 1·56)       | -26·5 (-38·1 to -12·5) | (1·20 to 1·68) |       |
| Latvia              | 52                           | (3·3 to 7·6)          | -64·7 (-76·4 to -47·9) | 0·13     | (0·11 to 0·15)       | -63·6 (-75·3 to -47·0) | (2·36 to 2·60) |       |
| Total number        | 2 766 714·2                  | (2 500 314·4 to 2 860 842·6) | -3·2 (-4·9 to -0·4) | 14·6 (11·6 to 19·4) | -19·7 (16·1 to 24·9) | -2·7 (0·01 to 0·02) | (0·01 to 0·02) |       |
| Percent change      |                             |                       |                       |          |                       |                       |       |
|                     |                              |                       |                       |          |                       |                       |       |
| (Table 1 continues on next page)
| Country          | Deaths | Number per 100000 | Percent change 2005–15 | Episodes | Number (x 10⁵) | Percent change 2005–15 | DALYs | Number (x 10⁵) | Percent change 2005–15 | Episodes | Number (x 10⁵) | Percent change 2005–15 | DALYs | Number (x 10⁵) | Percent change 2005–15 |
|------------------|---------|-------------------|------------------------|----------|----------------|------------------------|-------|----------------|------------------------|----------|----------------|------------------------|-------|----------------|------------------------|
| Lithuania        | 8.3     | (5.7 to 10.6)     | –62.2                  | 0.19     | (0.16 to 0.22) | 0.01                   | –64.3 | (5.40 to 6.36) | 583.5                  | 18.5     | (17.1 to 20.2) | –80                    | (17.0 to 15.5) | 0.14           | –21.6                  |
| Macedonia        | 15.6    | (9.8 to 22.5)     | –41.1                  | 0.17     | (0.14 to 0.19) | –40.6                  | 186.8 | (118.6 to 204) | 7.1                    | 7.4      | (5.7 to 9.8)  | –13                    | (13.6 to 15.6) | 0.48           | –31.5                  |
| Moldova          | 32.5    | (20.7 to 47.5)    | –47.7                  | 0.06     | (0.04 to 0.09) | –47.6                  | 752   | (653.5 to 809.6)| 17.8                   | (16.1 to 19.9)| –260           | (35.5 to           | (43.0 to 23.0)| 0.06           | –33.9                  |
| Mongolia         | 138.5   | (99.5 to 192.3)   | –44.5                  | 0.4      | (0.28 to 0.55) | –445                   | 6957  | (56.4 to 9.14) | 23.6                   | 1.41     | (1.29 to 1.53)| –3.5                   | (3.77 to 0.65) | –33.9          | –4.0                   |
| Montenegro       | 70      | (42 to 10.8)      | –69.5                  | 0.05     | (0.03 to 0.06)| –688                   | 590   | (48.5 to 72.2) | 9.4                    | –49      | (0.15 to 0.17)| –0.00                  | (0.10 to 0.01) | –32.2          | 0.00                   |
| Poland           | 7.8     | (4.7 to 9.45)     | –47.1                  | 0.06     | (0.04 to 0.08) | –460                   | 11861 | (10.6 to 7.2)  | 30.5                   | 192      | (5.3 to 34.2)| –66                    | (3.2 to 1.40) | 0.03           | 1.44                   |
| Romania          | 43.7    | (32.2 to 55.8)    | –66.6                  | 1.80     | (0.26 to 0.48) | –665                   | 51993 | (47.6 to 56.5)| 26.6                   | –394     | (7.0 to 47.1)| –3.15                  | (12.3 to 15.6)| –41.4          | 0.35                   |
| Russia           | 16.6    | (14.4 to 19.0)    | –40.8                  | 0.89     | (1.12 to 1.48) | –406                   | 40834 | (37.6 to 7.1)| 27.6                   | –149     | (4.7 to 20)| –2.5                   | (12.3 to 16.1)| –57.7          | –12.9                  |
| Serbia           | 7.5     | (5.8 to 9.6)      | –41.4                  | 0.49     | (0.03 to 0.04) | –41.0                   | 1341  | (88.6 to 137.0)| 46                    | 1.89    | (0.18 to 0.24)| –2.2                   | (24.7 to 2.1) | –4.7          | –8.2                   |
| Slovakia         | 27.9    | (21.8 to 34.9)    | –41.2                  | 0.35     | (0.03 to 0.02) | –40.6                   | 1881  | (15.8 to 7.2)| 33.6                   | –6.6     | (1.2 to 1.51)| –0.3                   | (0.26 to 0.34) | –4.1          | –18.1                  |
| Slovenia         | 1.9     | (1.2 to 2.5)      | –44.5                  | 0.09     | (0.08 to 0.11)| –42.0                   | 8094  | (700.3 to 92.5)| 39.2                   | 7.4      | (4.1 to 4.13)| 0.50                   | (0.47 to 0.52) | –11.7          | 0.08                   |
| Tajikistan       | 202.2   | (142.0 to 275.5)  | –30.3                  | 2.34     | (1.22 to 2.37)| –30.2                   | 35337 | (294.8 to 426.7)| 41.5                   | –210     | (24.6 to 56.0)| 5.11                   | (1.82 to 2.96) | –26.2          | 2.33                   |
| Turkmenistan     | 263.6   | (178.4 to 357.6)  | –50.0                  | 1.20     | (1.11 to 1.50)| –50.0                   | 1384  | (745.1 to 2.7)| 36.0                   | –45      | (2.56 to 3.07)| 2.80                   | (1.05 to 1.95) | –47.4          | 1.45                   |
| Ukraine          | 193.3   | (118.5 to 288.6)  | –52.2                  | 2.49     | (1.11 to 0.25)| –51.6                   | 69081 | (602.7 to 781.3)| 14.9      | 11.9      | (11.3 to 16.8)| –22.2                  | (32.4 to 8.88) | 3.11          | –33.6                  |
| Uzbekistan       | 589.9   | (440.7 to 779.5)  | –37.1                  | 5.07     | (3.79 to 6.69)| –37.1                   | 9269  | (7.0 to 5.1)| 31.0                   | –2.82    | (14.9 to 17.86)| 6.41                   | (5.11 to 8.06) | –33.3          | 0.16                   |
| **High income**  | **5.6** | **3.1 to 7.7**    | **–34.9**              | **2.43** | **1.6 to 1.9** | **–34.4**              | **486.40** | **470.46** | **312.20**             | **21.6** | **18.4 to 24.7**| **211.23**             | **203.63 to 218.10**| **51.07** | **9.0**                |

(Continued from previous page)
## Children younger than 5 years

| Country   | Total number | Number per 100000 | Percent change 2005–15 | Deaths | Number (x 10⁵) | Percent change 2005–15 | DALYs | Number (x 10⁵) | Percent change 2005–15 |
|-----------|--------------|-------------------|------------------------|--------|----------------|------------------------|-------|----------------|------------------------|
| Andorra   | 64           | (0.6 to 0.9)      | -50.1                  | 0      | 0              | 0                      | 47.8  | 335            | (2.3 to 6.6)           |
| Argentina | 5880         | (490 to 686)      | -32.0                  | 157    | 0.3            | 0                      | -31.7 | 31200         | (2833 to 3118)         |
| Australia | 341          | (27 to 41)        | -30.8                  | 2.2    | 0.4            | 0                      | -29.9 | 4505          | (3906 to 5209)         |
| Austria   | 67           | (53 to 84)        | -35.4                  | 1.7    | 0.1            | 0                      | -34.4 | 13157         | (1161 to 1501)         |
| Belgium   | 124          | (101 to 151)      | -24.0                  | 1.9    | 0.1            | 0                      | -23.5 | 6397          | (5165 to 7284)         |
| Brunei    | 51           | (41 to 62)        | 0.4                    | 0.15   | 0.0            | 0                      | 0.5   | 654           | (567 to 846)           |
| Canada    | 47           | (38 to 57)        | -13.6                  | 2.5    | 0.4            | 0                      | -12.9 | 87425         | (767 to 9963)          |
| Chile     | 945          | (74 to 114)       | -41.4                  | 8.1    | 0.9            | 0                      | -40.9 | 3396         | (3594 to 7904)         |
| Cyprus    | 15           | (12 to 18)        | -47.1                  | 0.41   | 0.1            | 0                      | -46.9 | 147           | (121 to 194)           |
| Denmark   | 51           | (40 to 66)        | -35.5                  | 1.7    | 0.1            | 0                      | -34.9 | 23802         | (1086 to 2707)         |
| Finland   | 19           | (13 to 26)        | -60.4                  | 0.7    | 0.9            | 0                      | -58.2 | 916           | (794 to 1055)          |
| France    | 455          | (33 to 60)        | -31.9                  | 1.2    | 0.4            | 0                      | -31.3 | 25009         | (2146 to 2909)         |
| Germany   | 426          | (33 to 53)        | -28.7                  | 1.3    | 0.1            | 0                      | -27.7 | 31528         | (2797 to 3559)         |
| Greece    | 126          | (9 to 20)         | -52.2                  | 2.5    | 0.1            | 0                      | -51.5 | 31530         | (2741 to 3574)         |
| Greenland | 87           | (66 to 111)       | -30.4                  | 1.8    | 0.1            | 0                      | -30.4 | 147           | (121 to 194)           |
| Iceland   | 68           | (50 to 88)        | -47.9                  | 2.4    | 0.1            | 0                      | -47.2 | 924           | (81 to 107)            |
| Ireland   | 85           | (69 to 105)       | -36.9                  | 2.4    | 0.1            | 0                      | -36.1 | 1652          | (1435 to 1891)         |
| Israel    | 183          | (148 to 231)      | -29.2                  | 2.2    | 0.2            | 0                      | -28.3 | 21402         | (1888 to 2413)         |
| Italy     | 307          | (22 to 39)        | -42.5                  | 1.2    | 0.3            | 0                      | -41.8 | 15172         | (133 to 150)           |

## All ages

| Country   | Total number | Number per 100000 | Percent change 2005–15 | Deaths | Number (x 10⁵) | Percent change 2005–15 | DALYs | Number (x 10⁵) | Percent change 2005–15 |
|-----------|--------------|-------------------|------------------------|--------|----------------|------------------------|-------|----------------|------------------------|
| Andorra   | 00           | (0 to 0)          | -50.1                  | 0      | 0              | 0                      | -47.8 | 335            | (2.3 to 6.6)           |
| Argentina | 5880         | (490 to 686)      | -32.0                  | 157    | 0.3            | 0                      | -31.7 | 31200         | (2833 to 3118)         |
| Australia | 341          | (27 to 41)        | -30.8                  | 2.2    | 0.4            | 0                      | -29.9 | 4505          | (3906 to 5209)         |
| Austria   | 67           | (53 to 84)        | -35.4                  | 1.7    | 0.1            | 0                      | -34.4 | 13157         | (1161 to 1501)         |
| Belgium   | 124          | (101 to 151)      | -24.0                  | 1.9    | 0.1            | 0                      | -23.5 | 6397          | (5165 to 7284)         |
| Brunei    | 51           | (41 to 62)        | 0.4                    | 0.15   | 0.0            | 0                      | 0.5   | 654           | (567 to 846)           |
| Canada    | 47           | (38 to 57)        | -13.6                  | 2.5    | 0.4            | 0                      | -12.9 | 87425         | (767 to 9963)          |
| Chile     | 945          | (74 to 114)       | -41.4                  | 8.1    | 0.9            | 0                      | -40.9 | 3396         | (3594 to 7904)         |
| Cyprus    | 15           | (12 to 18)        | -47.1                  | 0.41   | 0.1            | 0                      | -46.9 | 147           | (121 to 194)           |
| Denmark   | 51           | (40 to 66)        | -35.5                  | 1.7    | 0.1            | 0                      | -34.9 | 23802         | (1086 to 2707)         |
| Finland   | 19           | (13 to 26)        | -60.4                  | 0.7    | 0.9            | 0                      | -58.2 | 916           | (794 to 1055)          |
| France    | 455          | (33 to 60)        | -31.9                  | 1.2    | 0.4            | 0                      | -31.3 | 25009         | (2146 to 2909)         |
| Germany   | 426          | (33 to 53)        | -28.7                  | 1.3    | 0.1            | 0                      | -27.7 | 31528         | (2797 to 3559)         |
| Greece    | 126          | (9 to 20)         | -52.2                  | 2.5    | 0.1            | 0                      | -51.5 | 31530         | (2741 to 3574)         |
| Greenland | 87           | (66 to 111)       | -30.4                  | 1.8    | 0.1            | 0                      | -30.4 | 147           | (121 to 194)           |
| Iceland   | 68           | (50 to 88)        | -47.9                  | 2.4    | 0.1            | 0                      | -47.2 | 924           | (81 to 107)            |
| Ireland   | 85           | (69 to 105)       | -36.9                  | 2.4    | 0.1            | 0                      | -36.1 | 1652          | (1435 to 1891)         |
| Israel    | 183          | (148 to 231)      | -29.2                  | 2.2    | 0.2            | 0                      | -28.3 | 21402         | (1888 to 2413)         |
| Italy     | 307          | (22 to 39)        | -42.5                  | 1.2    | 0.3            | 0                      | -41.8 | 15172         | (133 to 150)           |

(Continued from previous page)
| Country       | Total number Death | Number per 100 000 Death | Percent change 2005–15 | Number per 100 000 Episode | Percent change | Number per 100 000 DALYs | Percent change 2005–15 | Number per 100 000 DALYs | Percent change 2005–15 |
|---------------|--------------------|--------------------------|------------------------|---------------------------|---------------|--------------------------|------------------------|--------------------------|------------------------|
| Japan         | 1497               | 2.8                      | -38.2                  | 2.26                      | 0.13          | -37.6                    | 156,576.6              | 122.0                    | 40.1                   |
| Luxembourg    | 0.7                | 25.4                     | -22.1                  | 0.01                      | -21.6         | 131.6                    | 190,156.6              | 236.6                    | 12.9                   |
| Malta         | 9.9                | 50                       | -30.8                  | 0.01                      | -30.5         | 126.1                    | 162,966.8              | 30.1                     | 0.01                   |
| Netherlands   | 17.6               | 20.0                     | -8.8                   | 0.02                      | -7.7          | 776.3                    | 6878.9                 | 45.3                     | 0.72                   |
| New Zealand   | 12.4               | 41                       | -18.1                  | 0.12                      | -17.7         | 725.3                    | 6211.8                 | 16.0                     | 0.64                   |
| Norway        | 47                 | 16                       | -33.1                  | 0.08                      | -32.4         | 2195.3                   | 1310.1                 | 42.5                     | -2.6                   |
| Portugal      | 113                | 25                       | -63.8                  | 0.15                      | -63.3         | 7053.4                   | 62966.6                | 65.3                     | 0.03                   |
| Singapore     | 31.1               | 5.8                      | -32.5                  | 0.20                      | -32.2         | 1252.5                   | 13899.8                | 81.0                     | 0.09                   |
| South Korea   | 369                | 17                       | -53.3                  | 0.82                      | -52.4         | 13583.1                  | 11924.6                | 51.4                     | 0.17                   |
| Spain         | 283                | 13                       | -48.8                  | 0.53                      | -47.9         | 14027.1                  | 12236.2                | 9.6                      | 0.90                   |
| Sweden        | 75                 | 23                       | -23.0                  | 0.12                      | -22.1         | 3290.2                   | 2905.6                 | 33.5                     | -2.9                   |
| Switzerland   | 90                 | 22                       | -14.3                  | 0.14                      | -12.9         | 185.6                    | 1613.9                 | 225.7                    | 0.17                   |
| UK            | 151                | 3.8                      | -19.0                  | 0.13                      | -18.7         | 39.304                   | 39.5                   | 13.6                     | 0.39                   |
| USA           | 528                | 27                       | -36.8                  | 0.47                      | -35.5         | 91996.2                  | 89094.3                | 28.4                     | 0.94                   |
| Uruguay       | 254                | 15.0                     | -45.2                  | 0.03                      | -44.7         | 18442.2                  | 1625.2                 | 18.9                     | 0.24                   |
| Latin America | 2147               | 44.1                     | -45.3                  | 0.01                      | -44.5         | 30.4                     | 26.5                   | 1.3                      | 0.04                   |
| Antigua and Barbuda | 2.1   | 285                      | -24.8                  | 0.00                      | -24.5         | 33.1                     | 28.8                   | 0.9                     | 0.01                   |

(Continued from previous page)

| Country       | Total number Death | Number per 100 000 Death | Percent change 2005–15 | Number per 100 000 Episode | Percent change | Number per 100 000 DALYs | Percent change 2005–15 | Number per 100 000 DALYs | Percent change 2005–15 |
|---------------|--------------------|--------------------------|------------------------|---------------------------|---------------|--------------------------|------------------------|--------------------------|------------------------|
| Antigua and Barbuda | 2.1   | 285                      | -24.8                  | 0.00                      | -24.5         | 30.4                     | 26.5                   | 1.3                      | 0.04                   |

(Table 1 continues on next page)
| Country       | Children younger than 5 years | All ages     |
|--------------|-------------------------------|--------------|
|               | Deaths | Episodes | DALYs | Deaths | Episodes | DALYs |
|               | Total number | Number per 100000 | Percent change 2005–15 | Number (x 10⁷) | Number per 100000 | Percent change 2005–15 |
| Barbados      | 48     | 28.0     | -29.3 | 0.03   | 0        | -29.0 | 2000 | 70.5 | 0.15 | 0.03 | 3.6 |
| Belize        | 156    | 13.0     | -28.3 | 0.07   | 0        | -29.1 | 1070 | 38.2 | 0.04 | 0.02 | 9.5 |
| Bermuda       | 0.2    | 0.10     | -45.0 | 0.01   | 0        | -43.3 | 161  | 30.1 | 0.03 | 0.02 | 9.5 |
| Bolivia       | 901    | 1.70     | -28.3 | 0.29   | 0.01     | -28.2 | 7502 | 15.6 | 0.05 | 0.04 | 12.7 |
| Brazil        | 4677   | 1.25     | -28.3 | 0.06   | 0        | -28.2 | 7502 | 15.6 | 0.05 | 0.04 | 12.7 |
| Colombia      | 1254   | 0.65     | -43.6 | 0.10   | 0        | -43.6 | 8230 | 16.9 | 0.07 | 0.06 | 14.7 |
| Costa Rica    | 365    | 0.10     | -45.0 | 0.03   | 0.00     | -45.0 | 607  | 12.6 | 0.09 | 0.08 | 15.0 |
| Cuba          | 668    | 0.13     | -33.3 | 0.06   | 0.00     | -33.3 | 710   | 15.6 | 0.05 | 0.04 | 14.7 |
| Dominican     | 3      | 0.10     | -37.8 | 0.01   | 0        | -37.8 | 284  | 5.9  | 0.03 | 0.03 | 11.4 |
| Dominican     | 536    | 0.13     | -43.6 | 0.10   | 0        | -43.6 | 6569 | 15.6 | 0.07 | 0.06 | 14.7 |
| El Salvador   | 156    | 0.13     | -50.0 | 0.06   | 0.00     | -50.0 | 2474 | 12.6 | 0.09 | 0.08 | 15.0 |
| Grenada       | 46     | 0.10     | -7.6  | 0.02   | 0        | -7.6  | 635  | 15.6 | 0.07 | 0.06 | 14.7 |
| Guatemala     | 29940  | 14.5     | -46.8 | 0.12   | 0.00     | -46.8 | 9940  | 14.5 | 0.07 | 0.06 | 14.7 |
| Guyana        | 33     | 0.10     | -44.6 | 0.10   | 0        | -44.6 | 2485 | 15.6 | 0.07 | 0.06 | 14.7 |
| Haiti         | 23842  | 12.6     | -39.7 | 0.06   | 0        | -39.7 | 6016 | 12.6 | 0.07 | 0.06 | 14.7 |

(Continued from previous page)
| Country                      | Deaths | Number (x 10⁵) | Percent change 2005-15 | Number (x 10⁵) | Percent change 2005-15 | Number (x 10⁹) | Percent change 2005-15 | DALYs | Number (x 10⁷) | Percent change 2005-15 | DALYs | Number (x 10⁴) | Percent change 2005-15 |
|------------------------------|--------|----------------|------------------------|----------------|------------------------|----------------|------------------------|-------|----------------|------------------------|-------|----------------|------------------------|
| Children younger than 5 years |        |                |                        |                |                        |                |                        |       |                |                        |       |                |                        |
| Honduras                     | 338.5  | (250 to 418)   | 0.92                   | (0.19 to 0.39) | 0.29                   | (1.02 to 1.46) | 1.28                   | 0.29  | (0.19 to 0.39) | 0.29                   | 0.29  | (0.19 to 0.39) | 0.29                   |
| Panama                       | 165.1  | (120 to 229)   | 0.02                   | (0.05 to 0.09) | 0.14                   | (0.01 to 0.2)  | 0.26                   | 0.02  | (0.05 to 0.09) | 0.14                   | 0.14  | (0.01 to 0.2)  | 0.26                   |
| Nicaragua                    | 53.9   | (52.9 to 54.9) | 0.29                   | (0.29 to 0.37) | 0.29                   | (0.29 to 0.37) | 0.29                   | 0.29  | (0.29 to 0.37) | 0.29                   | 0.29  | (0.29 to 0.37) | 0.29                   |
| Paraguay                     | 222.2  | (205 to 239)   | 0.02                   | (0.02 to 0.04) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Peru                         | 152.7  | (130 to 174)   | 0.02                   | (0.02 to 0.04) | 0.02                   | (0.02 to 0.04) | 0.02                   | 0.02  | (0.02 to 0.04) | 0.02                   | 0.02  | (0.02 to 0.04) | 0.02                   |
| Saint Lucia                  | 5.0    | (4.0 to 6.0)   | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Saint Vincent and the Grenadines | 3.3   | (2.1 to 4.5)   | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Suriname                     | 26.3   | (18 to 36)     | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| The Bahamas                  | 8.5    | (5.0 to 16)    | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Trinidad and Tobago          | 25.4   | (14 to 38)     | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Venezuela                    | 106.1  | (96 to 126)    | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| Virgin Islands               | 0.6    | (0.5 to 0.8)   | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |
| North Africa and Middle East | 49 797.9 | (41 345 to 60 086) | 0.00                   | (0.00 to 0.01) | 0.00                   | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   | 0.00  | (0.00 to 0.01) | 0.00                   |

(Continued from previous page)
### Children younger than 5 years

| Country     | Total number | Number per 100 000 | Percent change 2005-15 | Deaths | Number (x 10^3) | Percent change 2005-15 | Number (x 10^3) | DALYs |
|-------------|--------------|--------------------|-------------------------|--------|-----------------|-------------------------|-----------------|-------|
| Afghanistan | 3780         | (12727 to 260986) | -37·7                   | 927    | (796 to 10 82)  | -37·6                   | 25 847.5        | 793   |
| Algeria     | 9494         | (6029 to 13247)   | -19·5                   | 724    | (616 to 8 49)   | -19·0                   | 7777.3          | 19·6  |
| Bahrain     | 85           | (59 to 121)       | -49·2                   | 13      | (39 to 119)     | -48·0                   | 64884.4          | 7·24  |
| Egypt       | 79571        | (70228 to 133471) | -27·7                   | 18      | (6 to 21)       | -26·2                   | 23 821.7         | 25·7  |
| Iran        | 11614        | (1524 to 256)     | -54·1                   | 14      | (6 to 15)       | -53·6                   | 9733.7           | 12·3  |
| Iraq        | 26963        | (1872 to 36485)   | -35·5                   | 34      | (8 to 11)       | -33·2                   | 5969.8           | 16·4  |
| Jordan      | 2697         | (2088 to 3483)    | -13·6                   | 15      | (1 to 4)        | -13·3                   | 8073             | 10·7  |
| Kuwait      | 362          | (27 to 487)       | -6·0                    | 45      | (0 to 0·4)      | -6·8                    | 3053             | 7·05  |
| Lebanon     | 5           | (3 to 11)         | -5·8                    | 6       | (0·4 to 0·7)    | -4·4                    | 2434             | 5·8   |
| Libya       | 1008         | (666 to 1466)     | -43·6                   | 16      | (0 to 0·13)     | -43·2                   | 1006.3           | 7·05  |
| Morocco     | 9917         | (6730 to 14172)   | -47·8                   | 59      | (5 to 6)        | -47·6                   | 6638.4           | 25·1  |
| Oman        | 359          | (256 to 494)      | -16·6                   | 5       | (0 to 0·1)      | -11·1                   | 6638             | 14·8  |
| Palestine   | 1007         | (679 to 1441)     | -33·7                   | 10      | (0 to 0·13)     | -33·1                   | 6638             | 14·1  |
| Qatar       | 46           | (28 to 74)        | -56·9                   | 9       | (0 to 0·1)      | -9·1                    | 594              | 2·7   |
| Saudi Arabia| 1320         | (1066 to 1613)    | -43·1                   | 24      | (0 to 0·1)      | -42·2                   | 4056.6           | 29·6  |
| Sudan       | 86841        | (54807 to 16863)  | -35·9                   | 15      | (0 to 0·14)     | -35·8                   | 15 005.7         | 37·2  |
| Syria       | 725          | (272 to 980)      | -36·5                   | 3       | (3 to 4·2)      | -36·3                   | 2670             | 14·3  |

### All ages

| Country     | Total number | Number per 100 000 | Percent change 2005-15 | Deaths | Number (x 10^3) | Percent change 2005-15 | Number (x 10^3) | DALYs |
|-------------|--------------|--------------------|-------------------------|--------|-----------------|-------------------------|-----------------|-------|
| Afghanistan | 3800         | (12797 to 260986) | -37·7                   | 927    | (796 to 10 82)  | -37·6                   | 25 847.5        | 793   |
| Algeria     | 9494         | (6029 to 13247)   | -19·5                   | 724    | (616 to 8 49)   | -19·0                   | 7777.3          | 19·6  |
| Bahrain     | 85           | (59 to 121)       | -49·2                   | 13      | (39 to 119)     | -48·0                   | 64884.4          | 7·24  |
| Egypt       | 79571        | (70228 to 133471) | -27·7                   | 18      | (6 to 21)       | -26·2                   | 23 821.7         | 25·7  |
| Iran        | 11614        | (1524 to 256)     | -54·1                   | 14      | (6 to 15)       | -53·6                   | 9733.7           | 12·3  |
| Iraq        | 26963        | (1872 to 36485)   | -35·5                   | 34      | (8 to 11)       | -33·2                   | 5969.8           | 16·4  |
| Jordan      | 2697         | (2088 to 3483)    | -13·6                   | 15      | (1 to 4)        | -13·3                   | 8073             | 10·7  |
| Kuwait      | 362          | (27 to 487)       | -6·0                    | 45      | (0 to 0·4)      | -6·8                    | 3053             | 7·05  |
| Lebanon     | 5           | (3 to 11)         | -5·8                    | 6       | (0·4 to 0·7)    | -4·4                    | 2434             | 5·8   |
| Libya       | 1008         | (666 to 1466)     | -43·6                   | 16      | (0 to 0·13)     | -43·2                   | 1006.3           | 16·0  |
| Morocco     | 9917         | (6730 to 14172)   | -47·8                   | 59      | (5 to 6)        | -47·6                   | 6638.4           | 25·1  |
| Oman        | 359          | (256 to 494)      | -16·6                   | 5       | (0 to 0·1)      | -11·1                   | 6638             | 14·8  |
| Palestine   | 1007         | (679 to 1441)     | -33·7                   | 10      | (0 to 0·13)     | -33·1                   | 6638             | 14·1  |
| Qatar       | 46           | (28 to 74)        | -56·9                   | 9       | (0 to 0·1)      | -9·1                    | 594              | 2·7   |
| Saudi Arabia| 1320         | (1066 to 1613)    | -43·1                   | 24      | (0 to 0·1)      | -42·2                   | 4056.6           | 29·6  |
| Sudan       | 86841        | (54807 to 16863)  | -35·9                   | 15      | (0 to 0·14)     | -35·8                   | 15 005.7         | 37·2  |
| Syria       | 725          | (272 to 980)      | -36·5                   | 3       | (3 to 4·2)      | -36·3                   | 2670             | 14·3  |

(Continued from previous page)
| Region       | Death 2005–15 | Number per 100,000 (x10⁵) | Percent change 2005–15 | Episode 2005–15 | Number (x10⁵) | Percent change 2005–15 | DALYs 2005–15 | Number (x10⁵) | Percent change 2005–15 | DALYs 2005–15 |
|--------------|---------------|---------------------------|------------------------|-----------------|---------------|------------------------|----------------|---------------|------------------------|----------------|
| Tunisia      | 110.7         | (764 10 549 6)           | –13.6                  | 11.3            | (811 10 549 6) | –5.60 to –10.5         | 0.95           | (011 10 549 6) | 0.70 to 0.13          | 0.13           |
| Turkey       | 984.5         | (624 40 549 6)           | –24.4                  | 15.4            | (1011 10 549 6)| –8.43 to –6.64        | 11.69          | (013 10 549 6)| –5.13 to –3.52        | 0.87           |
| United Arab Emirates | 10.2 | (510 10 549 6) | –24.4                  | 2.1             | (1035 10 549 6)| 0.01 to 0.02         | 0.41           | (049 10 549 6)| –21.2                  | 0.07           |
| Yemen        | 402.9         | (2765 20 549 6)          | –34.4                  | 100.2           | (6910 10 549 6)| –5.87 to 0.31         | 12.28          | (1059 10 549 6)| –21.4                  | 3.47           |
| South Asia   | 205886.6      | (183132 10 549 6)        | –45.0                  | 122.9           | (1059 10 549 6)| –5.14 to –27.4        | 384.32         | (429 10 549 6)| –5.14 to –27.4        | 317            |
| Bangladesh   | 21249         | (170717 10 549 6)        | –256                   | 139.1           | (999 10 549 6)| –6.65 to –7.89        | 27.27          | (1930 10 549 6)| –18.1                  | 0.36           |
| Bhutan       | 43.6          | (27110 61 549 6)         | –56.0                  | 66.0            | (1012 10 549 6)| –5.0 to –4.26         | 0.13           | (1616 10 549 6)| 0.02 to 0.06          | –0.77          |
| India        | 1406493       | (1239199 10 549 6)       | –45.5                  | 113.2           | (1099 10 549 6)| –5.93 to –3.79        | 279.76         | (3109 10 549 6)| 121.15                  | 3.60           |
| Nepal        | 43627         | (34816 10 549 6)         | –62.9                  | 135.4           | (12210 10 549 6)| –7.04 to –5.37        | 5.49           | (13230 10 549 6)| –6.29                  | 3.76           |
| Pakistan     | 391580        | (295232 10 549 6)        | –22.0                  | 157.7           | (1189 10 549 6)| –6.95 to –4.25        | 53.90          | (2059 10 549 6)| –21.9                  | 3.37           |
| Southeast Asia, East Asia, and Oceania | 68893.1 | (61004 10 549 6) | –56.3                  | 46.9            | (416 10 549 6) | –5.17 to –4.99        | 118.59         | (10343 10 549 6)| –5.62                  | 59.38          |
| American Samoa | 15             | (11 10 549 6)            | –39.4                  | 13.3            | (916 10 549 6) | –5.68 to –18.8        | 0.02           | (002 10 549 6)| 0.02 to 0.02          | –3.85          |
| Cambodia     | 21359         | (152340 10 549 6)        | –63.5                  | 139.6           | (884 10 549 6)| –7.30 to –51.2        | 2.39           | (3230 10 549 6)| 1.84 to 1.38          | –6.34          |
| China        | 242470        | (213338 10 549 6)        | –61.2                  | 29.2            | (2570 10 549 6)| –6.61 to –54.4        | 36.98          | (32430 10 549 6)| 20.92                  | 4.14           |
| Federated States of Micronesia | 35             | (20 10 549 6)            | –48.6                  | 29.0            | (16 10 549 6)  | –6.99 to –14.1        | 0.03           | (003 10 549 6)| –4.83                  | –0.03          |
| Fiji         | 945           | (485 10 549 6)           | –24.5                  | 107.5           | (563 10 549 6) | –6.01 to –35.5        | 0.21           | (017 10 549 6)| 0.08 to 0.08          | –2.44          |

(Continued from previous page)
### Children younger than 5 years

| Country                     | Deaths 2005–15 (per 100,000) | Number (x 10⁵) | Percent change 2005–15 | Deaths 2015–16 (per 100,000) | Number (x 10⁵) | Percent change 2015–16 | Deaths Total number per 100,000 | Number (x 10⁵) | Percent change 2005–15 | Deaths Total number per 100,000 | Number (x 10⁵) | Percent change 2005–15 |
|-----------------------------|-----------------------------|----------------|------------------------|-----------------------------|----------------|------------------------|-------------------------------|----------------|------------------------|-------------------------------|----------------|------------------------|
| Guam                        | 54                          | 38.4          | 0.03                   | 42                          | 58.3          | 34.3                   | 0.12                          | 0.02           | -20.2                  | 0.11                        | 0.02           | -20.2                  |
| Indonesia                   | 1525.0                      | 61.5          | 13.75                  | 162                         | 41.66.2       | 16.2                   | -23.5                         | 0.06            | 19.4                   | 0.14                        | 14.54          | -17.6                  |
| Laos                        | 2384.5                      | 285.2         | 2.05                   | 506                         | 242.3         | 62.4                   | -37.1                         | 2.58            | 2.53                   | -46.1                       | 1.79            | -23.5                  |
| Marshall Islands            | 51                          | 539           | 0.02                   | -57.6                       | 247           | 34.2                   | -142                          | 0.06            | 0.01                   | 1.55                        | 0.04            | 30.0                   |
| Mauritius                   | 115                         | 16.1          | 0.01                   | 66.3                        | 37.9           | 25.8                   | 44.4                          | 0.06            | 0.07                   | 5.56                        | 0.02            | 5.56                   |
| Myanmar                     | 771.0                       | 164.3         | 0.01                   | 547                         | 473.0         | 18.8                   | -104                          | 0.05            | 39.8                   | 1.04                        | 0.01            | 39.8                   |
| Northern Mariana Islands    | 9.0                         | 11.5          | 0.02                   | -58.8                       | 10.2           | 28.8                   | 46.2                          | 0.06            | 0.07                   | 18.7                        | 0.02            | 18.7                   |
| Papua New Guinea            | 217.2                       | 215.0         | 0.01                   | -52.4                       | 215.0         | 215.0                  | -134                          | 7.20            | 19.0                   | 48.8                        | 48.8            | 48.8                   |
| Philippines                 | 924.2                       | 814.0         | 0.01                   | -48.4                       | 549.15        | 54.5                   | 148                           | 46.9            | 19.0                   | 46.9                        | 19.0            | 46.9                   |
| Solomon Islands             | 51.4                        | 61.2          | 0.01                   | -37.7                       | 73.6           | 40.6                   | -1.7                          | 0.49            | 1.0                   | 0.49                        | 0.01            | 1.0                   |

(Continued from previous page)
| Country | Children younger than 5 years | All ages |
|---------|-------------------------------|----------|
| Sri Lanka | 156.9 (112.5 to 228.7) | 442.4 (359.7 to 534.2) |
| Taiwan (province of China) | 30.9 (18.0 to 49.1) | 11.2 (5.6 to 18.8) |
| Thailand | 292.1 (202.7 to 411.8) | 59.3 (39.8 to 79.4) |
| Timor-Leste | 30.8 (13.5 to 55.4) | 2.7 (1.3 to 3.9) |
| Tonga | 4.8 (2.7 to 8.1) | 0.2 (0.0 to 0.3) |
| Vanuatu | 3.4 (2.0 to 5.4) | 0.2 (0.0 to 0.4) |
| Vietnam | 321.8 (24.7 to 42.4) | 0.1 (0.0 to 0.3) |
| Sub-Saharan Africa | 215.1 (101.9 to 343.2) | 73.8 (44.7 to 110.1) |
| Angola | 1161.2 (743.9 to 1707.9) | 8.5 (5.3 to 14.5) |
| Benin | 402.6 (290.2 to 528.2) | 8.4 (5.8 to 11.2) |
| Botswana | 114.6 (64.4 to 182.1) | 0.1 (0.0 to 0.2) |
| Burkina Faso | 1007.3 (700.8 to 1439.9) | 9.0 (6.7 to 11.4) |
| Burundi | 526.2 (323.6 to 761.9) | 0.2 (0.0 to 0.3) |
| Cameroon | 954.0 (637.4 to 1354.4) | 8.5 (6.2 to 11.4) |
| Cape Verde | 301.8 (221.2 to 400.2) | 0.2 (0.0 to 0.3) |
| Central African Republic | 322.2 (208.4 to 453.1) | 0.1 (0.0 to 0.2) |

(Continued from previous page)

Notes:
1. Percent change 2005–15 refers to the percentage change in DALYs from 2005 to 2015.
2. DALYs are disability-adjusted life years, a measure of the burden of disease.
3. The values in parentheses are 95% confidence intervals.

www.thelancet.com/infection Vol 17 November 2017
| Country/Region | Deaths younger than 5 years | Percent change 2005–15 | Episodes (x10⁵) | Percent change 2005–15 | DALYs (x10⁵) | Percent change 2005–15 | All ages | Deaths | Percent change 2005–15 | Episodes (x10⁵) | DALYs (x10⁵) | Percent change 2005–15 |
|---------------|-----------------------------|------------------------|-----------------|------------------------|--------------|------------------------|-----------------|-------|------------------------|-----------------|--------------|------------------------|
| Chad          | 13 589·9 (960·2 to 18 424·0) | 12·5 (–40·9 to 2·8)    | 7·17            | 11·6 (8·25 to 15·78)   | 11·8 (–20·7 to 59·5) | 32 109·8 (23·17 to 45·07) | 19 668·5 (144·9 to 25 521·5) | 13·9 (11·93 to 14·18) | 15·6 (9·97 to 17·61) | 13·0 (0·50 to 0·66)     | 3·7 (0·23 to 0·31) | –35·3 (–73·3 to 19·12) |
| Comoros       | 163·7 (97·5 to 261·4)        | –3·5 (–58·9 to 7·3)    | 0·22            | 0·14                   | –3·2 (–58·7 to 7·1) | 4·46 (32·6 to 60·2) | 5·63 (42·1 to 76·1) | 5·7 (33·3 to 34·2)     | –0·5 (0·59 to 0·60)    | 0·55 (0·23 to 0·21)     | –20·7 (–47·0 to 19·2) |
| Congo         | 932·8 (576·1 to 1398·2)      | –27·2 (–54·4 to 13·1)  | 1·03            | 0·8                    | –2·1 (–54·3 to 13·1) | 32·50 (23·17 to 45·07) | 70·2 (51·0 to 97·3) | 35 (2·16 to 2·68)      | 3·53 (1·02 to 1·91)    | –1·17 (–27·0 to 17·1)  | –0·3 (–1·5 to 0·9)     |
| (Kinshasa)    |                            |                        |                 |                        |              |                       |                  |                  |                        |                  |              |                        |
| Côte’d’Ivoire| 936·3 (682·1 to 12 702·1)    | –7·4 (–33·2 to 31·2)   | 5·07            | 8·06                   | –4·7 (–33·1 to 31·0) | 20·42 (15·32 to 27·82) | 90·0 (67·5 to 122·8) | 4·4 (8·77 to 14·74)    | 12·26 (13·15 to 14·07) | –1·6 (–26·0 to 31·6)   | –0·8 (–1·9 to 0·3)     |
| Democratic    | 38 357·4 (183·5 to 383·2)    | –82                   | 32·20           | 32·25                  | –1·8 (–40·7 to 35·9) | 23·52 (15·14 to 32·14) | 95·07 (69·3 to 122·8) | 3·7 (5·59 to 6·50)     | 6·67 (5·64 to 7·67)    | –1·8 (–28·5 to 38·2)   | –0·8 (–25·5 to 33·4)   |
| Republic of   | 5 373·9 (56·1 to 101·4)      | –61·6                 | 1·06            | 0·2                    | –1·6 (–61·6 to –9·3) | 68·61 (43·72 to 1008·9) | 75·1 (49·1 to 113·3) | 8·6 (0·57 to 0·66)     | 0·61 (0·32 to 0·32)    | –5·5 (–49·4 to 10·5)   | –6·2 (–37·1 to 42·7)   |
| Ethiopia      | 2 579·0 (75·1 to 101·4)      | –54·1                 | 25·38           | 22·31                  | –4·0 (–70·0 to –31·7) | 53·82 (42·87 to 74·4) | 74·56 (43·10 to 78·1) | 8·6 (0·38 to 0·67)     | 6·09 (0·57 to 0·56)    | 0·61 (0·18 to 0·22)    | –3·6 (–1·6 to –2·13)  |
| Gabon         | 2 110 (136·1 to 306·8)       | –29·6                 | 0·40            | 0·2                    | –2·9 (–51·7 to 3·9)  | 13·99 (8·20 to 173·00) | 49·7 (11·1 to 2·16)  | 2·4 (0·29 to 0·54)     | 0·4 (0·11 to 0·16)     | –1·8 (–37·0 to 18·9)   | –0·4 (–39·7 to 0·4)    |
| Ghana         | 4 623·3 (80·4 to 156·5)       | –23·8                 | 6·35            | 4·02                   | –2·3 (–45·6 to 5·8)  | 19·05 (14·99 to 28·34) | 6·95 (8·55 to 16·81) | 3·7 (5·85 to 11·32)    | 15·68 (14·51 to 16·81) | –5·7 (–63·4 to 33·4)   | –0·2 (–3·3 to 7·9)     |
| Guinea        | 7 135·2 (261·5 to 465·4)     | –20·2                 | 3·48            | 6·12                   | –2·0 (–42·4 to 7·6)  | 13·57 (10·43 to 17·80) | 10·37 (8·33 to 13·80) | 3·2 (6·28 to 10·11)    | 8·09 (2·92 to 1·10)    | –8·2 (–33·4 to 29·9)   | –0·9 (–15·4 to 12·5)   |
| Guinea-      | 1 150·3 (798·5 to 1605·7)    | –13·8                 | 0·45            | 0·98                   | –1·3 (–42·0 to 25·6) | 2·22 (1·37 to 3·31) | 1·05 (0·96 to 1·15) | 1·3 (0·91 to 1·98)     | 2·28 (0·97 to 1·29)    | –7·2 (–35·0 to 27·9)   | –0·7 (–11·3 to 2·4)    |
| Bissau        |                            |                        |                 |                        |              |                       |                  |                  |                        |                  |              |                        |
| Kenya         | 11 999·1 (160·7 to 14 866·0) | 164·2                 | 12·68           | 10·33                  | –15·8 (–26·7 to 3·2) | 26·84 (18·86 to 36·27) | 5·81 (4·95 to 6·57) | 3·6 (2·84 to 7·67)     | 3·08 (1·42 to 4·72)    | –7·0 (–16·3 to 4·2)    | –0·6 (–13·6 to 9·2)    |
| Lesotho       | 680·6 (471·5 to 942·7)        | –26·9                 | 0·41            | 0·35                   | –2·8 (–48·4 to 2·9)  | 21·94 (14·98 to 31·68) | 7·02 (7·20 to 14·78) | 8·6 (2·10 to 3·75)     | 1·28 (0·47 to 1·14)    | –3·0 (–7·5 to 14·6)    | –0·4 (–10·0 to 6·2)    |
| Liberia       | 1 499·6 (105·2 to 20 065·2)  | –30·5                 | 1·21            | 1·29                   | –3·0 (–52·3 to –2·2) | 32·23 (24·04 to 41·77) | 7·15 (5·33 to 9·26) | –6·9 (3·01 to 2·63)    | –2·87 (3·12 to 3·23)   | –2·01 (–41·3 to 6·4)   | –0·9 (–8·9 to 9·3)     |

(Table 1 continues on next page)
| Country          | Children younger than 5 years | All ages          |
|------------------|--------------------------------|-------------------|
|                  | Deaths                         | Deaths            |
|                  | Total number per 100 000       | Number (x 10^5)   |
|                  | Percent change 2005–15         | Number (x 10^5)   |
|                  |                                 | Percent change 2005–15 |
|                  |                                 | DALYs             |
|                  |                                 | Number (x 10^5)   |
|                  |                                 | Percent change 2005–15 |
|                  |                                 | DALYs             |
| Madagascar       | 209.4 (5261.9 to 11 031.9)     | 17 759.4 (12 659.9 to 23 847.2) |
|                  | -10.1 (-40.5 to 34.7)          | -101 (-40.3 to 34.7) |
|                  | 7.57 (6.50 to 8.77)            | 6.71 (4.63 to 9.55) |
|                  | -10.1 (-40.3 to 34.7)          | -101 (-40.3 to 34.7) |
| Malawi           | 274.5 (57 711.7 to 11 070.3)   | 14 233.9 (10 768.6 to 18 529.2) |
|                  | -10.0 (-37.7 to 24.3)          | -101 (-37.6 to 24.4) |
|                  | 6.10 (5.26 to 6.98)            | 6.96 (4.91 to 9.5) |
|                  | -10.0 (-37.6 to 24.4)          | -101 (-37.6 to 24.4) |
| Mali             | 190.0 (824.8 to 864.0)         | 856.47 (657 81 to 1 146 270) |
|                  | -12.6 (-40.0 to 26.1)          | -12.6 (-39.7 to 26.2) |
|                  | 4.58 (3.96 to 5.34)            | 5.28 (3.69 to 7.41) |
|                  | -12.6 (-39.7 to 26.2)          | -12.6 (-39.7 to 26.2) |
| Mauritania       | 144.0 (85 48 to 1161.0)        | 23 018.8 (1683.4 to 3127.0) |
|                  | -5.1 (-51.4 to 6.2)            | -5.1 (-51.2 to 6.2) |
|                  | 1.05 (0.90 to 1.23)            | 0.76 (0.56 to 0.99) |
|                  | -5.1 (-51.2 to 6.2)            | -5.1 (-51.2 to 6.2) |
| Mozambique       | 158.9 (465 15 to 909 8)        | 21 201.5 (11 530.9 to 37 598.8) |
|                  | -35.2 (-55.0 to -9.8)          | -35.2 (-55.0 to -9.7) |
|                  | 6.36 (5.51 to 7.28)            | 5.64 (3.97 to 7.82) |
|                  | -35.2 (-55.0 to -9.7)          | -35.2 (-55.0 to -9.7) |
| Namibia          | 90.8 (187 11 to 449 0)         | 32 228.8 (898.3 to 1953.5) |
|                  | -11.0 (-47.6 to 42.9)          | -11.0 (-46.7 to 42.7) |
|                  | 0.47 (0.40 to 0.54)            | 0.26 (0.16 to 0.39) |
|                  | -11.0 (-46.7 to 42.7)          | -11.0 (-46.7 to 42.7) |
| Niger            | 344.5 (1002 4 to 19 340.4)     | 22 000.2 (16 957.4 to 28 386.2) |
|                  | -16.9 (-43.1 to 16.7)          | -16.9 (-43.2 to 16.5) |
|                  | 6.43 (5.53 to 7.40)            | 12.07 (8.57 to 16.55) |
|                  | -16.9 (-43.2 to 16.5)          | -16.9 (-43.2 to 16.5) |
| Nigeria          | 209.4 (47 564.4 to 80 812.9)   | 12 901.8 (8 541.6 to 18 385.2) |
|                  | -23.4 (-46.8 to 9.3)           | -23.4 (-46.7 to 9.3) |
|                  | 50.12 (43.56 to 57.15)         | 51.19 (37.64 to 69.39) |
|                  | -23.4 (-46.7 to 9.3)           | -23.4 (-46.7 to 9.3) |
| Rwanda           | 237.7 (2804.7 to 56 450.0)     | 818.13 (62 181.2 to 11 024.6) |
|                  | -39.6 (-58.4 to -12.2)         | -39.6 (-58.3 to -12.3) |
|                  | 3.25 (2.80 to 3.76)            | 3.5 (2.41 to 4.84) |
|                  | -39.6 (-58.3 to -12.3)         | -39.6 (-58.3 to -12.3) |
| São Tomé and Príncipe | 115.3 (82 2 to 161 8)     | 129.2 (85 4 to 179 9) |
|                  | -45.2 (-60.4 to -22.7)         | -45.2 (-60.2 to -22.7) |
|                  | 0.05 (0.04 to 0.05)            | 0.03 (0.02 to 0.04) |
|                  | -45.2 (-60.2 to -22.7)         | -45.2 (-60.2 to -22.7) |
| Senegal          | 130.0 (100 9 to 1764.1)        | 87 977.2 (63 296.0 to 12 395.3) |
|                  | -31.4 (-51.3 to -6.0)          | -31.4 (-51.1 to -6.2) |
|                  | 3.63 (2.22 to 4.07)            | 3.06 (2.24 to 3.9) |
|                  | -31.4 (-51.1 to -6.2)          | -31.4 (-51.1 to -6.2) |
| Sierra Leone     | 356.5 (2458.7 to 50 654.6)     | 668.53 (502 54 to 849 8) |
|                  | -26.7 (-49.5 to 3.8)           | -26.6 (-49.4 to 3.7) |
|                  | 1.96 (1.67 to 2.30)            | 3.1 (2.11 to 4.34) |
|                  | -26.7 (-49.5 to 3.8)           | -26.6 (-49.4 to 3.7) |

(Note 1 continues on next page)
### Table 1: Episodes, DALYs, and deaths attributable to lower respiratory tract infections in 2015, by country

| Country     | Children younger than 5 years |  |  |  |  | All ages |  |  |  |  |
|-------------|--------------------------------|---|---|---|---|---------|---|---|---|---|
|             | Deaths                         | Episodes | DALYs | Deaths | Episodes | DALYs |
|             | Total number | Number per 100 000 | Percent change 2005–15 | Number | Percent change 2005–15 | Number | Percent change 2005–15 | Total number | Number per 100 000 | Percent change 2005–15 | Number | Percent change 2005–15 | Number | Percent change 2005–15 |
| Somalia     | 11116.1          | 546.9 | (2.8 to 50.0) | (7.0 to 49.5) | 17021.0 | 156.9 | (2.8 to 50.0) | (7.0 to 49.5) | 12116.0 | 244.5 | (2.8 to 50.0) | (7.0 to 49.5) | 11170 | 227.2 | (2.8 to 53.6) | (7.0 to 53.6) |
| South Africa | 3306.8           | 62.1  | (-63.5 to 7.2) | 2.85 | -63.4 | 35.12 | 65.4 | (-14.5 to 14.5) | (34.0 to 74.2) | 30300 | 4.4 | (-25.8 to -3.5) | (34.0 to 74.2) | 34 | 10.68 | (-44.1 to -26.3) | (9.27 to 36.84) |
| South Sudan  | 7656.5           | 399.5 | (-6.1 to 6.9) | 6.57 | 47.5 | 13757.3 | 112.0 | 55.3 | (10.13 to 12.05) | (5.67 to 12.23) | 39843 | 0.0 | 51.7 | (2.4 to 157.4) | (2.4 to 157.4) |
| Swaziland   | 303.4            | 173.3 | (-46.6 to 0.30) | 0.26 | -46.5 | 1062.8 | 82.5 | -17.6 | (0.79 to 0.91) | (0.34 to 0.74) | 119 | 0.0 | -30.8 | (-53.1 to 0.2) | (-53.1 to 0.2) |
| Tanzania    | 17712.5          | 190.4 | (-26.3 to 14.12) | 15.22 | -26.2 | 38574.2 | 72.3 | -16 | (32.02 to 21.1) | (16.22 to 21.1) | 28222 | 2.2 | 16.2 | (16.22 to 21.1) | (16.22 to 21.1) |
| The Gambia  | 457.3            | 91.6 | (-19.8 to 0.0) | 0.39 | -19.1 | 5333.9 | 73.0 | -25.7 | (5.48 to 7.05) | (2.27 to 7.05) | 5995 | 0.0 | -90 | (-191.3 to -90) | (-191.3 to -90) |
| Togo        | 2229.8           | 192.5 | (-19.2 to 2.53) | 1.92 | -19.1 | 32933.9 | 73.0 | 56.3 | (2.12 to 7.05) | (2.12 to 7.05) | 5995 | 0.0 | -90 | (-191.3 to -90) | (-191.3 to -90) |
| Uganda      | 12596.9          | 26.9 | (1.0 to 16.56) | 10.27 | -6.0 | 10997.1 | 66.4 | (-23.3 to 28.4) | (2.37 to 28.4) | 18861 | 8.1 | 77 | (13.39 to 17.1) | (13.39 to 17.1) |
| Zambia      | 5076.6           | 17.6 | (-31.3 to 4.44) | 4.36 | -31.2 | 13140.0 | 80.9 | -8.7 | (9.69 to 10.53) | (6.29 to 10.53) | 8067 | 0.0 | 200 | (-10.4 to 8.1) | (-10.4 to 8.1) |
| Zimbabwe    | 2836.8           | 11.0 | (-26.4 to 3.24) | 2.49 | -26.4 | 10709.5 | 68.8 | -29.0 | (3.41 to 4.68) | (3.41 to 4.68) | 15661 | 0.0 | 78 | (-28.3 to 38.3) | (-28.3 to 38.3) |

Data are n or % (95% uncertainty interval). Modelled number of deaths, episodes, and DALYs for each country in children younger than 5 years and for all ages (not age standardised). The percent change in deaths and DALYs is the change in the absolute number between 2005 and 2015. Data are from GBD 2015 estimates for both sexes. DALYs=disability-adjusted life-years.

(Continued from previous page)
(Figure 1 continues on next page)
Figure 1: Global distribution of LRI mortality
LRI mortality rate per 100,000 people in children younger than 5 years (A) and all ages (B) in 2015. Percent change in LRI deaths per 100,000 people between 2005 and 2015 in children younger than 5 years (C) and in all ages (D). LRI—lower respiratory tract infection. ATG—Antigua and Barbuda. VCT—Saint Vincent and the Grenadines. FSM—Federated States of Micronesia. LCA—Saint Lucia. TTO—Trinidad and Tobago. TLS—Timor-Leste.
Figure 2: LRI burden by Global Burden of Diseases Study region plotted against SDI
Under-5 LRI mortality rate per 100,000 person-years is shown in (A) and LRI incidence per child-year is shown in (B). Region codes are Global (●), East Asia (□), Southeast Asia (▲), Oceania (○), Central Asia (△), Central Europe (◆), Eastern Europe (★), High-income Asia Pacific (♦), Australasia (◆), Western Europe (□), Southern Latin America (▲), High-income North America (△), Caribbean (◆), Andean Latin America (○), Central Latin America (♦), Tropical Latin America (★), North Africa and Middle East (●), South Asia (□), Central sub-Saharan Africa (▲), Eastern sub-Saharan Africa (○), Southern sub-Saharan Africa (♦), and Western sub-Saharan Africa (◆).

SDI (figure 2B). Despite reductions in LRI mortality, LRI incidence has decreased at a slower rate than mortality in children younger than 5 years (8.8% [95% UI 6.6–11.1%] from 0–18 episodes per child-year [95% UI 0–16–0–20] in 2005 to 0–15 episodes per child-year [95% UI 0–13–0–17] in 2015, and in all ages [5.5%, 4.4–6.6] from 0–042 [95% UI 0–039–0–044] in 2005 to 0–040 [0–037–0–042] in 2015. LRI deaths were attributed to four aetiologies in GBD 2015.7

We estimated that the bacterial causes of LRIIs, pneumococcal pneumonia and Hib, together accounted for 64.1% of LRI deaths in children younger than 5 years (table 2). Pneumococcal pneumonia was the most common aetiology, leading to an estimated 392,965 deaths (95% UI 228,367–532,281) or 55.8% (95% UI 32.5–75.0%) of LRI deaths in children younger than 5 years, and 1,517,388 deaths (857,940–2,183,791), or 55.4% (31.5–79.1) of LRI deaths in all ages. Syria had the highest percentage of under-5 LRI deaths due to pneumococcal pneumonia (70.6%, 95% UI 43.4–91.8). Pneumococcal pneumonia was also responsible for a substantial number of deaths in the elderly population worldwide: we estimated that in 2015, pneumococcal pneumonia killed 693,041 people aged 70 years and older (95% UI 295,084–1,116,257). The pneumococcal pneumonia PAF in children younger than 5 years was unchanged globally between 2005 and 2015, but decreased in high-SDI regions (figure 3). During the same period, the attributable fraction of LRI deaths in children younger than 5 years due to Hib decreased by 38.6% (95% UI 34.5–43.3), from 13.4% (0.8–24.7) in 2005 to 8.3% (0.5 to 15.9) in 2015 (figure 3). Hib was a major cause of under-5 LRI mortality in India where we estimated that it was responsible for 14.9% (0.9–27.4) of LRI deaths (table 2). Hib was not attributed to any LRI deaths in people older than 5 years.

We estimated that RSV was responsible for 36,363 deaths (20,355–61,545), and influenza was responsible for 10,151 (5,731–16,790) in children younger than 5 years, together accounting for 6.6% of LRI deaths in this age group (table 2). The burdens of RSV were highest in central and eastern Europe and in central Asia, where it accounted for more than 10% of under-5 LRI mortality in 2015 in each of these regions (figure 3); the highest RSV burden was 12.3% (95% UI 6.6–21.7%) in Macedonia. Influenza was not frequently associated with under-5 LRI mortality but was responsible for more than 7% of deaths in all ages in central and eastern Europe and central Asia. The highest attributable fraction due to influenza was in central Asia and central and eastern Europe. The viral aetiologies, RSV and influenza, were more often associated with non-fatal episodes of LRI, largely because of the adjustment for the lower case fatality ratio in viral causes of LRI than bacterial aetiologies. In all ages, 15.4% (95% UI 13.0–18.4%) of incidence was attributable to RSV and 10.4% (8.7–11.9%) to influenza. Between 2005 and 2015, the influenza PAF increased globally in all ages (5.6% increase, 95% UI 0.0–11.0%), and by more than 15% in North Africa, the Middle East, and south Asia.

We estimated that the leading risk factors for LRI DALYs in 2015 were childhood wasting (responsible for 44.6% [95% UI 31.7–52.8] of DALYs worldwide), household air pollution (35.8%, 24.8–45.9), and ambient particulate matter (27.5%, 20.8–34.7). Suboptimal breastfeeding was the third-leading risk factor for under-5 DALYs globally and the leading risk factor for under-5 DALYs in high SDI locations. Other risk factors for LRI, such as smoking, alcohol use, and zinc deficiency, were responsible for less than 10% of LRI DALYs globally.
Articles

A decomposition of the change in attributable DALYs between 2005 and 2015 by country is shown in figure 4, which includes the two leading risk factors for LRI DALYs, childhood undernutrition and air pollution (indoor and ambient). At the global level, we estimated that LRI DALYs have decreased 8-9% because of reduced prevalence of childhood undernutrition and decreased 4-3% because of improvements in air pollution exposure. We estimated that LRI attributable to childhood undernutrition have decreased in many countries in sub-Saharan Africa during this period, particularly in Kenya (37-2% decrease), but the number of DALYs in Kenya have only marginally decreased overall, mainly because of population growth during this period, particularly in Kenya (37·2% decrease). DALYs due to LRI have increased by an estimated 18-9% between 2005 and 2015 (data not shown). The increase in LRI DALYs in this age group was highest in low-SDI regions where the number of DALYs increased by 25-0%. All LRI models and results for GBD 2015 can be explored further online using the Institute for Health Metrics and Evaluation visualisations.

Table 2: Number of deaths and PAFs of LRI-related deaths in children aged 5 years or younger, by aetiology, in top ten countries with highest under-5 LRI mortality burden.

Aetiological attributable fractions are based on a counterfactual modelling strategy and do not necessarily sum to 100% in a given location. LRI=lower respiratory tract infection. PAF=population attributable fraction. Data are n or % (95% uncertainty interval). The number of deaths in children younger than 5 years are shown for each aetiology at the global level and for each of the ten countries with the highest LRI mortality burden.

| Aetiology                         | Global | India | Nigeria | Pakistan | Democratic Republic of the Congo | Ethiopia | China | Bangladesh | Afghanistan | Tanzania | Indonesia |
|-----------------------------------|--------|-------|---------|----------|----------------------------------|----------|-------|------------|------------|----------|-----------|
| Pneumococcal pneumonia            | 215·7  | 237·8 | 54·2    | 50·2     | 39·8                             | 3·4      | 13·8  | 19·7       | 2·2        | 2·9      | 3·8       |
| Haemophilus influenza type b       | 37·8   | 1·8   | 1·0      | 1·9       | 0·4                               | 1·0      | 6·0   | 3·4        | 0·4        | 0·4      | 7·4       |
| Respiratory syncytial virus        | 2·0    | 0·3   | 0·4      | 0·5       | 0·3                               | 0·4      | 0·5   | 0·5        | 0·5        | 0·5      | 0·5       |
| Influenza                          | 83·0   | 0·7   | 57·0     | 0·5       | 0·3                               | 0·4      | 55·0  | 0·4        | 0·4        | 0·4      | 59·5      |
| LRI deaths unattributed, %         | 55·4   | 20·7  | 14·8     | 2·4       | 1·0                               | 0·5      | 47·4  | 1·1        | 0·5        | 0·5      | 47·7      |

Data are n or % (95% uncertainty interval). The number of deaths in children younger than 5 years are shown for each aetiology at the global level and for each of the ten countries with the highest LRI mortality burden.

Some solutions to prevent LRI deaths do not require major advances in technology. Measures to protect, prevent, and treat LRIs are highlighted in the Global Action Plan for Pneumonia and Diarrhoea. For the Institute for Health Metrics and Evaluation visualisations see http://www.healthdata.org/gbd/data-visualizations

Discussion

The GBD 2015 study estimated that LRIs were the fifth-leading cause of death (of 249 causes) and the leading infectious cause, responsible for 2·74 million deaths (95% UI 2·50 million to 2·86 million). LRIs were the leading cause of death (of 249 causes) and the leading infectious cause, responsible for 2·74 million deaths (95% UI 2·50 million to 2·86 million). LRIs were the leading cause of death (of 249 causes) and the leading infectious cause, responsible for 2·74 million deaths (95% UI 2·50 million to 2·86 million).

For the Institute for Health Metrics and Evaluation visualisations see http://www.healthdata.org/gbd/data-visualizations

www.thelancet.com/infection Vol 17 November 2017

1153
Although such interventions were not estimated in GBD 2015, improved access to health care and emphasis on appropriate treatment have probably played a crucial role in reducing LRI mortality, with proper treatment reducing mortality by 20–42%. How much of the decrease in mortality is due to proper adherence and implementation of the WHO Integrated Management of Childhood Illness recommendations is unclear, because data on its uptake are scarce. These recommendations, which are based on symptom-based screening criteria such as fast breathing or lower chest wall indrawing, have been updated several times, and their application varies substantially. Divergence from these criteria might lead to inappropriate treatment and misuse of antibiotics. Our results suggest that most severe LRIs have bacterial causes, whereas pneumococcal pneumonia and Hib have effective Gavi-supported vaccines, emphasising that combined appropriate case management and vaccine use might prevent many episodes of LRI and reduce dependence on antibiotics.

In 2015, approximately 65% of children younger than 5 years received the Hib vaccine and 40% received the PCV. At the global level, the PAF of Hib on LRI deaths decreased 37·8% between 2005 and 2015, reflecting the expanded use and introduction of the vaccine during this time, particularly in countries that received support from Gavi. Despite the growing use of PCV, pneumococcal pneumonia mortality has not decreased significantly at the global level and has decreased more slowly than Hib, in part because the PAF for pneumococcal pneumonia depends on the PAF for Hib; as Hib decreases, we assume that pneumococcal pneumonia must increase to account for overall LRI aetiological attribution.

The expanded use of PCV might have several indirect effects on LRI burden. PCV might prevent influenza and RSV mortality, because up to half of severe viral infections are complicated by pneumococcal pneumonia. Further, PCV might induce large indirect (herd) vaccine effects that protect unvaccinated populations, such as adults and elderly people. Amid debate about quantifying the effect of indirect vaccine effectiveness for adults in populations with infant vaccine use, our findings highlight the burden of LRI in the elderly population, including nearly 700 000 deaths in people aged older than 70 years due to pneumococcal pneumonia. Expanding access to the vaccine in adults might substantially reduce the burden of LRI.

Our results suggest that LRIs were the second-leading cause of DALYs globally in 2015 after ischaemic heart disease. Our results also suggest that decreases in under-5 undernutrition have substantially reduced LRI DALYs, and are responsible for nearly 9% of the decline during this period. The greatest reduction in LRI DALYs due to childhood undernutrition between 2005 and 2015 occurred in east and southeast Asia. This finding is notable because improved childhood nutrition will have effects beyond reducing LRI DALYs and is also likely to reduce the burden of disease caused by diarrhoea and measles. Emphasis on sustainable agriculture, supplementary nutritional programmes, and equitable distribution of food through the Sustainable Development Goals will be necessary for continued reductions in the global burden of LRI.

![Figure 3: Attributable fraction of LRI mortality in children younger than 5 years in 2015](https://example.com/figure3.png)

**Figure 3: Attributable fraction of LRI mortality in children younger than 5 years in 2015**

Aetiologies for each GBD region are ordered by the global ranking. Numbers show the population attributable fraction in 2015, and colours show the percent change from 2005 to 2015. LRI—lower respiratory tract infection.
Household solid fuel use as a risk factor for LRI has decreased since 2005, particularly in Latin America and southeast Asia, which are undergoing rapid urbanisation and economic development. Economic development that shifts energy requirements away from household burning of biomass might reduce exposure to indoor air pollution at the expense of outdoor and ambient particulate matter from large-scale energy production facilities like coal-burning power plants.\(^4\) Providing affordable clean energy options in low sociodemographic areas of the world is covered by the Sustainable Development Goals, but achieving this aim will be a challenge and the risk of LRIs might depend on its success.\(^3\)

Our estimates of LRI mortality, morbidity, and aetiology attribution are limited by data availability and especially the sparsity of data in sub-Saharan Africa, the region with the greatest LRI burden and need for high-quality data (appendix pp 5, 7, and 14–15). Only extremely scarce verbal autopsy data are available for large populations and the data that are available in Africa and south Asia might be of low quality, as measured by indices such as completeness, detail, internal consistency, and timeliness. Better surveillance systems, including standard reporting mechanisms and case definitions, in Africa and south and southeast Asia would substantially reduce a major source of uncertainty in the LRI mortality estimates.\(^4\) Assessing a systematic bias in morbidity or mortality estimates is difficult because of data quantity and quality. The predictive modelling approaches used in GBD 2015 rely on covariates and shared information across space and time to fill in these areas and the data gaps are reflected in the uncertainty intervals in the estimates (table 1).
Even with the application and expanded use of PCR diagnostic techniques, data on the aetiology of pneumonia remain sparse, particularly in areas with high disease burden. This scarcity of data is largely due to the difficulty of obtaining appropriate samples for testing, particularly in children, the relatively high cost of PCR, and challenges in culturing and diagnosing many pathogens that cause respiratory infections.45,46 Studies that have attempted to elucidate the aetiology of childhood pneumonia, frequently using nasopharyngeal swabs or lung aspirates, have had poor success in identifying an obvious aetiologial agent.45,47 Atypical pathogens, including nosocomial infections such as Staphylococcus aureus, or intracellular pathogens like Mycoplasma pneumoniae, might be important aetiologies for LRIs and are not included in GBD 2015.48,49 Such
Figure 4: Risk factor decomposition of the change in attributable DALYs in all ages between 2005 and 2015 (A) Southeast Asia, east Asia, and Oceania; (B) north Africa and Middle East; (C) south Asia; (D) central Europe, eastern Europe, and central Asia; (E) sub-Saharan Africa; (F) Latin America and Caribbean; and (G) high-income WHO regions. Black dots show the overall percentage change in LRI DALYs and colours show contribution of different factors to the rate of change. Bars to the left of zero show a reduction in attribution and bars to the right show an increase. LRI=lower respiratory infection. DALY=disability-adjusted life-year.
omissions might limit the ability to attribute LRI episodes and deaths to pathogens because our analysis is not able to show whether the unattributed LRI episodes and deaths are due to the four aetiologies included in GBD 2015 or other pathogens. Results from the Pneumonia Etiology Research for Child Health Project,9 a seven-site case-control study in sub-Saharan Africa and south Asia, were not available for inclusion in GBD 2015 but might provide evidence on LRI aetiologies such as additional pathogens, the relative contribution of each aetiology, and viral–bacterial coinfections.

The attributable fraction strategy for Hib and pneumococcal pneumonia assumes that the vaccine efficacy against invasive disease is the same as for pneumonia. A study by Bonten and colleagues18 using a urine antigen test in elderly adults suggests that the vaccine efficacy of PCV13 might be up to a third higher against invasive pneumococcal disease than against pneumococcal pneumonia.18 We have adjusted our estimates of vaccine effectiveness from other studies using this ratio but recognise the uncertainty around the application of a single study in elderly adults to all other studies and decided to use a flat distribution centred on the mean ratio from the study to reflect this uncertainty. Application of this diagnostic test is unsuitable for children and is complicated by the frequent nasopharyngeal carriage rate in children, perhaps up to 90% in low-income settings.43,52 We do not account for serotype replacement or changes in serotype prevalence due to the introduction of PCV, which might be an important factor in the burden of pneumococcal pneumonia and the effectiveness of the vaccine at the population level.29

Only four randomised controlled trials on Hib vaccine efficacy have been done in children younger than 5 years. Despite a plausible disease burden in older children and adults, we decided to apply the attributable fraction of LRI episodes and deaths due to Hib pneumonia to the under-5 age group only. The lower bound of the Hib PAF estimates is below zero (not statistically significant) at the global level, reflecting in part the scarcity of reliable data on Hib vaccine efficacy.

The attribution of the viral pathogens to LRI mortality was based on the relative case fatality of bacterial to viral aetiologies, and cases of LRI admitted to hospital might not be representative of cases not admitted to hospital. Efforts to improve surveillance, such as the African Network for Influenza Surveillance and Epidemiology,11 are essential in tracking the burden of influenza and other LRI aetiologies and for appropriate and timely response to epidemics. We excluded data describing pandemic H1N1 influenza to avoid biasing global and temporal trends in influenza burden, but doing so might have led to lower estimates of influenza burden, particularly since 2008.

The GBD 2015 estimates of LRI mortality and burden are generally similar to the GBD 2013 estimates.10 Global under-5 mortality was lower in GBD 2015 than GBD 2013, primarily because of decreased estimates in Nigeria (appendix pp 18–21). Nigeria is a high-population, high-burden country with sparse data and estimates in this high-burden country are influenced by regional trends and covariates; limitations shared by much of sub-Saharan Africa. In fact, only a single datapoint informed cause of death models in this country. Mortality and morbidity were different between GBD versions in China and India (appendix pp 18–21), which reflects in part that these countries are now modelled subnationally (data not shown), allowing for greater accuracy and precision in geographic disparities. Disparities in LRI burden by wealth, geography, and other subpopulation characteristics might be missed when national-level estimates are presented. The GBD study will be produced annually starting with GBD 2016, and future iterations will feature finer spatial resolution, including mapping the burden of LRI on a 5 × 5 km level, which will enable tracking of the burden at a very fine resolution.

Our estimates of pneumonia mortality in children younger than 5 years differ from those produced by the WHO Department of Evidence, Information and Research and the Maternal and Child Epidemiology Estimation (MCEE) group. The GBD 2015 estimates for under-5 mortality due to LRI in 2015 (704 000 deaths, 95% UI 651 000–763 000) were much lower than those from the MCEE (920 000 deaths).42,53 The difference in total under-5 deaths was greatest for Nigeria and India (appendix p 25).

Despite substantial reductions in under-5 LRI mortality in many countries, the burden remains high, particularly in areas of low sociodemographic development, and has increased in some populations, particularly elderly people. Estimates of the global burden of LRI will be improved by more high-quality data on mortality, morbidity, and aetiologies, especially in sub-Saharan Africa where the burden is highest and data are most scarce. The creation and expansion of civil registration systems in Africa and south Asia are gaining momentum, and such data will not only improve global comparative mortality assessments such as the GBD study, but also increase the evidence for guiding decision about local policy.42,55 Improvements in diagnostics for LRI aetiologies, including those appropriate for children younger than 5 years to better understand the unique contribution of each aetiology to the LRI burden, will help guide targeted interventions such as vaccination. Continuing to emphasise the importance of appropriate case management, to expand the use of PCV, and to reduce childhood undernutrition and exposure to air pollution will accelerate the reduction in LRI disease burden.

GBD 2015 LRI Collaborators
Christopher Troeger, Mohammad Forouzanfar, Puja C Rao, Ibrahim Khalil, Alexandria Brown, Scott Swartz, Nancy Fullman, Jonathan Mosser, Robert L Thompson, Robert C Reiner Jr, Amanuel Abajobir, Noore Alam, Mulubirhan Assefa Alemayehu, Azmeraw T Amare, Carl Abelardo Antonio, Hamid Asayesh,
Europide Avokpaoh, Aleksandra Barac, Muktak A Beshir, Dube Jara Boneya, Michael Brauer, Laila Dandona, Joseph R A Fitchett, Tevelde Gebehietwot, Gessessew Bugga Halu, Peter J Hotze, Amir Kasaean, Tawikh Gou, Niranjan Kissoon, Luke Knibbs, Anil Kumar, Rajesh Kumar Rai, Hassan Magdy Abd El Razek, Muktak S K Mohammed, Katie Nielson, Ilyal Oren, Abdalla Osman, George Patton, Mostafa Qorbani, Haro Share Rbna, Benn Sartorius, Muloje Savic, Mika Shigematsu, Banya Sykes, Soumya Swaminathan, Roman Topor-Madry, Kingsley Ukwaia, Andrea Werdecker, Naohiro Yonemoto, Maysaa El Sayed Zaki, Stephen S Lim, Mohsen Naghavi, Theo Vos, Simon I Hay, Christopher J I Murray, Ali H Mokdad.

Joint senior authors.

Affiliations
Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA (C Troeger MPH, M Forouzanfar MBBS, P C Rao MPH, I Khalid MD, A Brown MSC, S Swartz MS, N Fullman MPH, J Mosser MD, R L Thompson PhD, C J L Murray DPhil, M Naghavi PhD, T Vos PhD, S S Lim PhD, M Ngihavi PhD, T Vos PhD, S I Hay FMedSci, C J L Murray DPhil, A H Mokdad PhD, L Dandona MD); University of Oxford, Oxford, UK (S I Hay FMedSci); University of Queensland, Brisbane, QLD, Australia (A Abajo MPH, J Knibbs PhD); Queensland Health Australia, Brisbane, QLD, Australia (N Alam MA); University of British Columbia, Vancouver, BC, Canada (M Brauer ScD, N Kissoon MBBS); Mekelle University, Mekelle, Ethiopia (M A Alemayohu MPH, G Hailu MSc); University of Adelaide, Adelaide, SA, Australia (A T Amare MPH, MSc); University of the Philippines Manila, Manila, Philippines (C A Antonio MD); Qom University of Medical Sciences, Qom, Iran (H A Ayashey PhD); Africare Benin, Cotonou, Benin (E Avokpaoh MD, MPH); University of Belgrade, Belgrade, Serbia (B Baraz PhD); Jimma University, Jimma, Ethiopia (M A Beshir MPH, T T Gerbehietwot MPH); Debre Markos University, Debre Markos, Ethiopia (D Bonye MPH); Public Health Foundation of India, Gurugram, India (R Dandona PhD, G A Kumar PhD); Harvard University, Boston, MA, USA (J R A Fitchett MBBS); Baylor University, Atlanta, GA, USA (P J Hotze PhD); Tehran University of Medical Sciences, Tehran, Iran (A Kasaean PhD); Executive Board of the Health Ministers’ Council for Cooperation Council States, Riyadh, Saudi Arabia (T Khoja FRCPG); Society for Health and Demographic Surveillance, Kolkata, India (R K Rai MPH); Mansoura University, Mansoura, Egypt (H Magdy Abd El Razek MBBC, M El Sayed Zaki MD); MizanTepi University, Tepi, Ethiopia (M S K Mohammed MS); University of Washington, Seattle, WA, USA (K Nielsen MD); University of Arizona, Tucson, AZ, USA (E Oren PhD); Public Health Institute Sudan, Khartoum, Sudan (A Osman MD); University of Melbourne, Melbourne, VIC, Australia (G Patton MD); Alboz University of Medical Sciences, Baghestan, Iran (M Qorbani PhD); Harzama University, Dire Dawa, Ethiopia (H S Roba MPH); University of KwaZulu Natal, Durban, South Africa (B Sartorius PhD); Norwegian Institute of Public Health, Oslo, Norway (M Savic PhD); National Institute of Infectious Diseases Japan, Tokyo, Japan (M Shigematsu PhD); University of California Irvine, Irvine, CA, USA (B Sykes PhD); Indian Council of Medical Research, New Delhi, India (S Swaminathan MD); Jagiellonian University Medical College, Krakow, Poland (R Topor-Madry PhD); Federal Teaching Hospital, Abakaliki, Nigeria (K Ukwaia MD); Federal Institute for Population Research, Wiesbaden, Germany (A Werdecker PhD); Kyoto University, Kyoto, Japan (N Yonemoto MPH).

Contributors
CT, PCR, and IK prepared the first draft. CT, MF, and AB constructed the figures and tables. MF, CJLM, AHM, ACR, and SIH provided overall guidance. PCR managed the project. CT, PCR, and IK finalised the manuscript based on comments from other authors and reviewer feedback. CT and PCR managed the appendix. All other authors provided data or developed models for indicators, reviewed results, initiated modelling infrastructure, and reviewed or contributed to the report.

Declarations of interests
SIH is funded by grants from the Bill & Melinda Gates Foundation (OPP1060203, OPP1093011, OPP1124245, and OPP1159934). All other authors declare no competing interests.

References
1. GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2015; 385: 117–71.
2. Bhutta ZA, Das JK, Walker N, et al. Interventions to address deaths from childhood pneumonia and diarrhoea equitably: what works and at what cost? Lancet 2013; 381: 1417–29.
3. UN Department of Economic and Social Affairs. Sustainable Development Goal 3: ensure healthy lives and promote well-being for all at all ages. 2017; https://sustainabledevelopment.un.org/sdg3 (accessed Oct 10, 2016).
4. GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1545–620.
5. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, years lived with disability, and years spent in ill-health for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1459–544.
6. Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate andTransparent Health Estimates Reporting: The GATHER statement. Lancet 2016; 388: e19–e23.
7. Naghavi M, Makela S, Foreman K, O’Brien J, Pournamale F, Lozano R. Algorithms for enhancing public health utility of national causes-of-death data. Popul Health Metr 2010; 8: 9.
8. Foreman KJ, Lozano R, Lopez AD, Murray CJ. Modelling causes of death: an integrated approach using CEDERN. Popul Health Metr 2012; 10: 1.
9. WHO Department of Child and Adolescent Health and Development. Handbook: integrated management of childhood illness, Geneva: World Health Organization, 2005. http://apps.who.int/iris/bitstream/10665/42939/1/9241546441.pdf (accessed Nov 7, 2016).
10. Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 31 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2015; 386: 743–800.
11. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380: 2163–96.
12. GBD 2015 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1603–38.
13. Feikin DR, Scott JA, Gessner UD. Use of vaccines as probes to define disease burden. Lancet 2014; 383: 1762–70.
14. O’Brien KL, Wolfson LJ, Watt JP, et al. Burden of disease caused by Streptococcus pneumoniae in children younger than 5 years: global estimates. Lancet 2009; 374: 893–902.
15. Watt JP, Wolfson LJ, O’Brien KL, et al. Burden of disease caused by Haemophilus influenzae type b in children younger than 5 years: global estimates. Lancet 2009; 374: 903–11.
16. Swinger G, Fransman D, Hussey G. Conjugate vaccines for preventing Haemophilus influenzae type B infections. Cochrane Database Syst Rev 2009; 4: CD004977.
17. Lucero MG, Dulalia VE, Nihos LT, et al. Pneumococcal conjugate vaccines for preventing vaccine-type invasive pneumococcal disease and X-ray defined lobar pneumonia in children less than 2 years of age. Cochrane Database Syst Rev 2009; 4: CD004977.
18. Bontem MJ, Hjuijs SM, Bolkenhaas M, et al. Polysaccharide conjugate vaccine against pneumococcal pneumonia in adults. N Engl J Med 2015; 372: 1114–25.
19. Shi T, McLean K, Campbell H, Nair H. Aetiological role of common respiratory viruses in acute lower respiratory infections in children under five years: a systematic review and meta-analysis. J Glob Health 2015; 5: 010048.
20. Miettinen OS. Proportion of disease caused or prevented by a given exposure, trait or intervention. Am J Epidemiol 1974; 99: 325–32.
Articles

21 United Nations Development Programme. Human development report 2015: work for human development. New York, NY: United Nations, 2016. http://hdr.undp.org/sites/default/files/2015_human_development_report.pdf (accessed Nov 10, 2016).

22 GBD 2015 Risk Factors Collaborators. Global, regional and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1659–724.

23 Mokdad AH, Forouzanfar MH, Dassu F, et al. Global burden of diseases, injuries, and risk factors for young people’s health during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2016; 387: 2383–401.

24 Dherani M, Pope D, Mascarenhas M, Smith KR, Weber M, Bruce N. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. Bull World Health Organ 2008; 86: 390–398C.

25 Mehta S, Shin H, Burnett R, North T, Cohen AJ. Ambient particulate air pollution and acute lower respiratory infections: a systematic review and implications for estimating the global burden of disease. Air Qual Atmos Health 2013; 6: 69–83.

26 Olofin I, McDonald CM, Ezzati M, et al. Associations of suboptimal growth with all-cause and cause-specific mortality in children in the first five years: a pooled analysis of ten prospective studies. PLoS One 2013; 8: e64636.

27 Das Gupta P. Standardization and decomposition of rates: a user’s manual. Washington DC: US Bureau of the Census; 1993.

28 WHO. The United Nations Children’s Fund (UNICEF). Ending preventable child deaths from pneumonia and diarrhoea by 2025: the integrated Global Action Plan for Pneumonia and Diarrhoea (GAPPD). Geneva: World Health Organization, 2013. http://apps.who.int/iris/bitstream/10665/79200/1/9789241505239_eng.pdf?ua=1 (accessed Nov 7, 2016).

29 Izadnegahdar R, Cohen AL, Klugman KP, Qazi SA. Childhood pneumonia in developing countries. Lancet Respir Med 2013; 1: 574–84.

30 Soffi S, Ahmed S, Fox MP, et al. Effectiveness of community case management of severe pneumonia with oral amoxicillin in children aged 2–59 months in Matari district, rural Pakistan: a cluster-randomised controlled trial. Lancet 2012; 379: 279–37.

31 Sazawal S, Black RE. Effect of pneumonia case management in mortality in neonates, infants, and preschool children: a meta-analysis of community-based trials. Lancet Infect Dis 2003; 3: 547–56.

32 Graham SM, English M, Hazir T, Enarson P, Duke T. Challenges to improving case management of childhood pneumonia at health facilities in resource-limited settings. Bull World Health Organ 2008; 86: 349–55.

33 Crowther-Gibson P, Cohen C, Klugman KP, de Gouveia L, von Gottberg A. Risk factors for multidrug-resistant invasive pneumococcal disease in South Africa, a setting with high HIV prevalence, in the prevaccine era from 2003 to 2008. Antimicrob Agents Chemother 2012; 56: 5088–95.

34 Kim I, McGee L, Tomczyk S, Beall B. Biological and epidemiological features of antibiotic-resistant Streptococcus pneumoniae in pre- and post-conjugate vaccine eras: a United States perspective. Clin Microbiol Rev 2016; 29: 525–52.

35 WHO. Immunization coverage. Geneva: World Health Organization, 2016. http://www.who.int/mediacentre/factsheets/ [accessed Nov 2, 2016].

36 No authors listed. Progress introducing Haemophilus influenzae type b vaccine in low-income countries, 2004–2008. Wkly Epidemiol Rec 2008; 83: 61–67.

37 Madhi SA, Kwannda L, Cutland C, Klugman KP. The impact of a 9-valent pneumococcal conjugate vaccine on the public health burden of pneumonia in HIV-infected and -uninfected children. Clin Infect Dis 2005; 40: 1511–18.

38 Rodgers GL, Klugman KP. Surveillance of the impact of pneumococcal conjugate vaccines in developing countries. Hum Vaccin Immunother 2016; 12: 417–20.

39 Prato R, Fortunato F, Martellini D. Pneumococcal pneumonia prevention among adults: is the herd effect of pneumococcal conjugate vaccination in children as good a way as the active immunization of the elderly? Curr Med Res Opin 2016; 32: 543–54.

40 Stevens GA, Finucane MM, Paciorek CJ, et al. Trends in mild, moderate, and severe stunting and underweight, and progress towards MDG 1 in 141 developing countries: a systematic analysis of population representative data. Lancet 2012; 380: 824–34.

41 Jackson S, Mathews KH, Pulanic D, et al. Risk factors for severe acute lower respiratory infections in children: a systematic review and meta-analysis. Coot Med J 2013; 54: 110–21.

42 UN Department of Economic and Social Affairs. Sustainable Development Goal 2: end hunger, achieve food security and improved nutrition and promote sustainable agriculture. 2017. https://sustainabledevelopment.un.org/sdg2 (accessed Oct 7, 2016).

43 Kurmi OP, Lam K BH, Ayres JG. Indoor air pollution and the lung in low- and medium-income countries. Eur Respir J 2012; 40: 239–54.

44 Mikkelsen L, Phillips DE, AbouZahr C, et al. A global assessment of civil registration and vital statistics systems: monitoring data quality and progress. Lancet 2015; 386: 1395–406.

45 Scott JA, Brooks WA, Peris JS, Holtzman D, Mulholland EK. Pneumonia research to reduce childhood mortality in the developing world. J Clin Invest 2008; 118: 1291–1300.

46 Templeton KE, Scheltinga SA, van den Eeden WC, Graafelman AW, van den Broek PJ, Claas EC. Improved diagnosis of the etiology of community-acquired pneumonia with real-time polymerase chain reaction. Clin Infect Dis 2005; 41: 345–51.

47 Resti M, Moronnda M, Cortimigia M, et al. Community-acquired bacteremic pneumococcal pneumonia in children: diagnosis and serotyping by real-time polymerase chain reaction using blood samples. Clin Infect Dis 2010; 51: 1042–49.

48 Arnold FW, Summersgill J, Lassore AS, et al. A worldwide perspective of atypical pathogens in community-acquired pneumonia. Am J Respir Crit Care Med 2007; 175: 1086–93.

49 Cilloniz C, Martin-Leeches I, Garcia-Vidal C, San Jose A, Torres A. Microbial etiology of pneumonia: epidemiology, diagnosis and resistance patterns. Int J Mol Sci 2016; 17: E2120.

50 Levine OS, O’Brien KL, Deloria-Knoll M, et al. The Pneumonia Etiology Research for Child Health Project: a 21st century childhood pneumonia etiology study. Clin Infect Dis 2012; 54 (suppl 2): S93–101.

51 Dowell SF, Garman RL, Liu G, Levine OS, Yang YH. Evaluation of Binax NOW, an assay for the detection of pneumococcal antigens in urine samples, performed among pediatric patients. Clin Infect Dis 2001; 32: 824–25.

52 Hill PC, Akisanay A, Sankareh K, et al. Nasopharyngeal carriage of Streptococcus pneumoniae in Gambian villagers. Clin Infect Dis 2006; 43: 673–79.

53 Radin JM, Katz MA, Tempa S, et al. Influenza surveillance in 15 countries in Africa, 2006–2010. J Infect Dis 2012; 206 (suppl 1): S14–21.

54 Johns Hopkins Bloomberg School of Public Health. Maternal and child epidemiology estimation. http://www.jhsph.edu/research/centers-and-institutes/institute-for-international-programs/current-projects/maternal-child-epidemiology-estimation/ (accessed Aug 25, 2016).

55 WHO. Estimates for 2000–2015. Geneva: World Health Organization. http://www.who.int/healthinfo/global_burden_disease/estimates/en/index3.html (accessed Aug 25, 2016).

56 AbouZahr C, de Savigny D, Mikkelsen L, et al. Civil registration and vital statistics: progress in the data revolution for counting and accountability. Lancet 2015; 386: 1173–85.