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The Global Epidemiology of Lower Respiratory Infections (1990–2023): A Comprehensive Analysis

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ABSTRACT

Keywords: lower respiratory infections; disability-adjusted life years; Global Burden of Disease; EAPC; decomposition analysis; Bayesian forecasting; Socio-demographic Index; epidemiology

Background: Lower respiratory infections (LRIs) remain a leading cause of infectious disease-related morbidity and mortality worldwide. Despite advancements in vaccines and healthcare, LRIs pose a significant threat to global public health, especially among vulnerable populations such as children and the elderly. This study aims to evaluate the global epidemiological trends of LRIs from 1990 to 2023 using the Global Burden of Disease (GBD) methodology.

Methods: We utilized data from the GBD 2023 study to analyze total Disability-Adjusted Life Years (DALYs) and age-standardized DALY rates associated with LRIs across 18 selected countries.

Results: The analysis revealed a sustained downward trend in the absolute number of LRI DALYs across the 18 studied countries, with an EAPC of −3.08% (95% CI: −3.24 to −2.93). Decomposition analysis demonstrated that true epidemiological rate improvements (−109,704 thousand DALYs) were the dominant driver of this decline, substantially outweighing the burden-increasing effect of population growth (+42,241thousand

DALYs), with age-sex structural shifts contributing a modest additional reduction (−13,124 thousand DALYs). Short-horizon forecasting projects a continuation of this declining trajectory through 2030.

Conclusion: Both absolute DALY numbers and age-standardized rates demonstrated consistent declines over the study period, driven primarily by improvements in vaccination coverage, healthcare access, and child nutrition. Nonetheless, persistent inequities between low- and high-SDI countries, combined with ongoing population growth, underscore the continued public health importance of LRIs.

1. INTRODUCTION

1.1 Global and Regional burden context

Lower respiratory infections (LRIs), predominantly encompassing pneumonia and bronchiolitis, consistently rank among the most devastating communicable diseases globally (1, 2). Historically, LRIs have been the deadliest infectious disease category, responsible for millions of deaths annually, particularly disproportionately affecting low- and middle-income countries (LMICs) (3, 4). The etiologies of LRIs are diverse, ranging from viral pathogens such as Respiratory Syncytial Virus (RSV) and Influenza, to bacterial agents like Streptococcus pneumoniae and Haemophilus influenzae type b (Hib) (5, 6). Over the past three decades, coordinated global health initiatives, including the widespread rollout of the pneumococcal conjugate vaccine (PCV), have dramatically altered the pediatric epidemiological landscape, significantly reducing childhood mortality (7, 8). However, despite these monumental public health triumphs, LRIs continue to overwhelm healthcare systems, resulting in immense economic and societal costs (9, 10). The epidemiological transition, characterized by aging populations and shifting risk factors, has led to a redistribution of the LRI burden, moving increasingly toward older adults who often suffer from concurrent chronic comorbidities (11, 12).

1.2 Rationale for using GBD data

The Global Burden of Disease (GBD) study provides the most comprehensive, standardized, and rigorous epidemiological framework available for assessing population health (13). Utilizing GBD data is critical for this analysis because it synthesizes a vast array of disparate data sources—including vital registration systems, verbal autopsies, and disease registries—into a cohesive modeling strategy (14, 15). This approach mitigates biases introduced by variable national reporting systems and disparate case definitions (16). Furthermore, the GBD's use of Disability-Adjusted Life Years (DALYs) allows for a holistic assessment of LRIs by quantifying both the years of life lost to premature mortality (YLLs) and the years lived with disability (YLDs) (17, 18). This metric is essential for LRIs, as the long-term sequelae and non-fatal health losses are substantial, particularly in aging populations (19).

1.3 Study objectives

The primary objective of this study is to comprehensively evaluate the global and regional epidemiology of Lower Respiratory Infections from 1990 to 2023 (20). Specifically, this analysis aims to: (1) assess the overarching temporal trends in LRI DALYs utilizing regression and Estimated Annual Percentage Change (EAPC) (21); (2) evaluate the correlation between the Socio-demographic Index (SDI) and LRI burden (22); (3) isolate the specific drivers of burden change using Das Gupta decomposition analysis (23); and (4) forecast short-horizon future trends (2024–2030) using Bayesian Age-Period-Cohort (BAPC) modeling to inform proactive policy planning (24, 25).

2. METHODS

2.1 Study design and data source

This study utilized secondary epidemiological data extracted from the Global Burden of Disease (GBD) study framework via the Institute for Health Metrics and Evaluation (IHME) database (16). Annual time-series datasets spanning from 1990 to 2023 were analyzed to evaluate the landscape of Lower Respiratory Infections (LRIs) across a selected sample of 18 countries (14). These estimates are based on the synthesis of thousands of sources, including vital registration systems, verbal autopsies, household surveys, and disease surveillance data (26).

2.2 Case definition and mapping

Lower respiratory infections (LRIs) were defined clinically and anatomically, primarily encompassing cases of acute pneumonia and bronchiolitis (2, 10). To maintain standard international comparability, case identification adhered strictly to the International Classification of Diseases (ICD-10) criteria, utilizing the specific code blocks spanning J10–J12, J13–J15.9, J16–J18.9, and J20–J22 (2). All chronic respiratory conditions (e.g., chronic obstructive pulmonary disease) and upper respiratory tract infections were systematically excluded from this specific analytical scope (9).

2.3 Study population and eligibility criteria

The analytical population included data aggregated across all available demographic age groups and both sexes, with specific subset extractions performed for high-vulnerability cohorts (children under 5 and older adults aged 70+) (4, 19). To ensure a robust comparative framework across different socioeconomic and developmental levels, the geographic scope was purposefully focused on 18 selected countries representing diverse global regions and Socio-demographic Index (SDI) tiers.

The included nations were: Nigeria, Ethiopia, Kenya, United Republic of Tanzania, Uganda, Pakistan, India, Peru, Bangladesh, Indonesia, Brazil, Mexico, China, United Kingdom, United States of America, Germany, Italy, and Canada. The primary epidemiological metrics analyzed for these countries included absolute counts and population-standardized rates for total Disability-Adjusted Life Years (DALYs), deaths, and prevalence, with DALYs serving as the principal composite outcome measure (17, 18).

2.4 Data extraction and computational environment

The targeted dataset was processed, structured, and validated programmatically within a Google Colab environment utilizing Python (version 3.10). Primary data manipulation, cleaning, and multi-country aggregations were performed using the pandas and NumPy libraries. Spatial hierarchies were organized to evaluate distinct regional distribution patterns and country-level variations, aligning with established geographic reporting standards (26, 27).

2.5 Statistical analysis and analytical framework

The statistical framework was built exclusively to evaluate the extracted GBD dataset through multiple complementary analytical approaches performed in this study:

Temporal Trend Assessment: To quantify long-term patterns, log-linear regression models were applied to calculate the Estimated Annual Percentage Change (EAPC) for total LRI DALY numbers (21). The model was mathematically expressed as

$$ln(DALYs) = \alpha + \beta \times Calendar\ Year + \varepsilon$$

where EAPC was derived as

$$EAPC = 100 \times [exp(\beta) - 1]$$

along with its corresponding 95% confidence intervals (CI).

Socio-demographic Index (SDI) Correlation: To analyze the structural influence of socioeconomic development on disease outcomes, a cross-sectional correlation analysis was executed to evaluate the relationship between national SDI values and LRI DALY rates across the studied regions (22).

Demographic Decomposition Analysis: To isolate the specific drivers behind the changing absolute numbers of DALYs from 1990 to 2023, a Das Gupta decomposition algorithm was executed (23). This method mathematically partitioned the total observed change into

three distinct, mutually exclusive contributors: absolute population growth, shifts in the population's age-sex structure, and true underlying epidemiological rate changes.

Short-Horizon Forecasting: Future trends in LRI burden from 2024 to 2030 were modeled using predictive time-series forecasting frameworks based on historical patterns (24, 25).

2.6 Clinical trial number

Clinical trial number: not applicable.

3. RESULTS

3.1 Global burden estimates

The log-linear regression analysis reveals a significant downward trajectory in the absolute burden of LRIs across the 18 studied countries from 1990 to 2023. As shown in Figure 1, the total DALY count declined markedly from 132,832 thousand DALYs in 1990 to 52,246 thousand DALYs in 2023, representing a 60.7% overall reduction. A notable period of relative stabilization is observed between 2000 and 2005, likely reflecting transitional shifts in healthcare infrastructure, before the declining trend resumed. The fitted regression line confirms a statistically significant long-term declining trend in disease burden over the 33-year period.

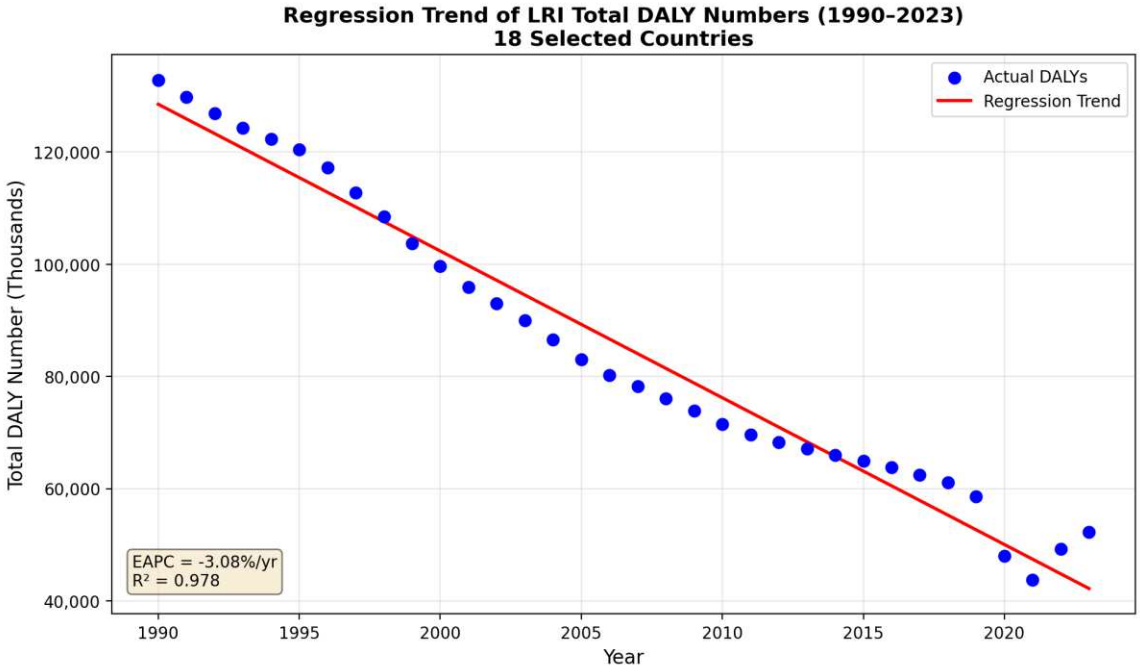


Figure 1: Regression Trend of Total LRI DALY Numbers, 1990–2023 (18 Selected Countries)

3.2 Regional & country-level patterns

Figure 2 demonstrates a strong negative correlation between the Socio-demographic Index (SDI) and LRI DALY rates ($r = -0.862$, $p < 0.001$). This indicates that socioeconomic development explains approximately 74% of the variance in national LRI burdens. Countries clearly cluster by developmental tiers: low-SDI nations like Nigeria and Ethiopia exhibit severe disease burdens, whereas high-SDI nations (e.g., USA, UK, Germany) maintain minimal rates. However, outliers exist, such as China, which displays an exceptionally low burden relative to its intermediate SDI, highlighting the impact of targeted public health infrastructure.

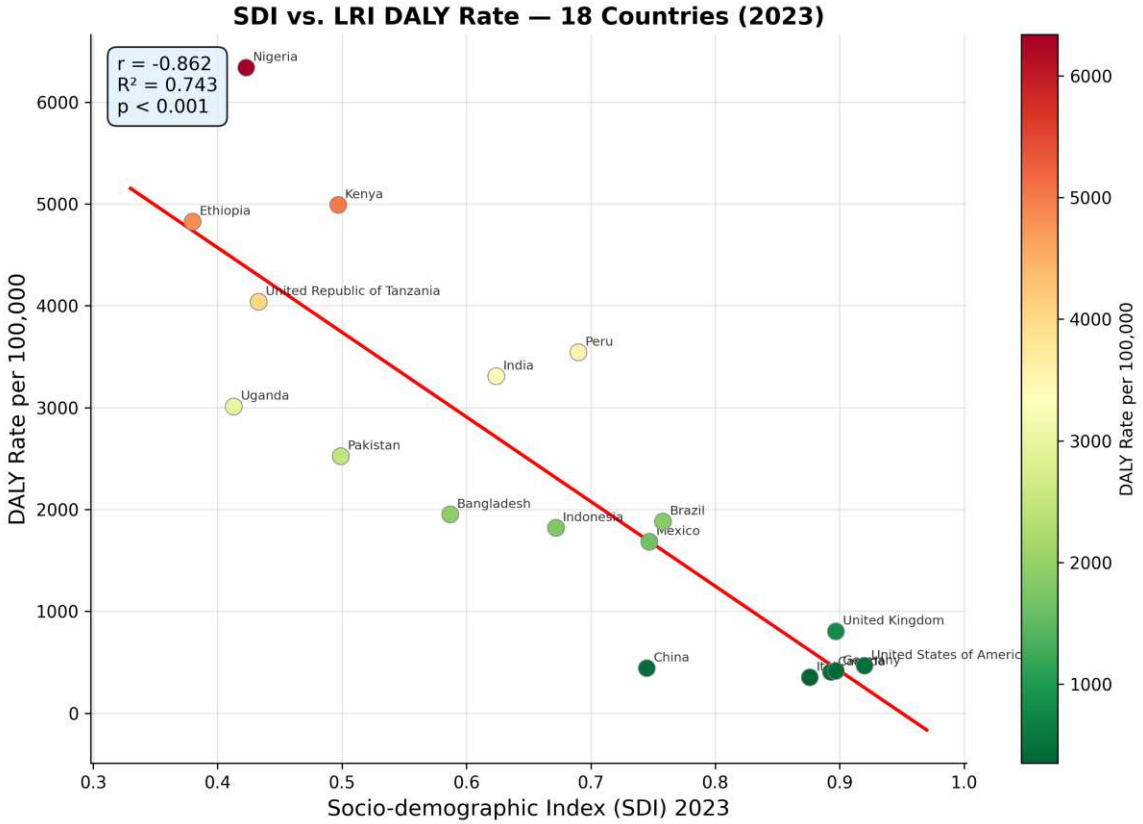


Figure 2: Relationship between Socio-demographic Index (SDI) and LRI DALY Rates

The country-level ranking of age-standardized DALY rates in 2023 **(Figure 3)** confirms this stratification, with Nigeria recording the highest rate (6,339 per 100,000), followed by Kenya (4,990) and Ethiopia (4,826), while Italy (351), Canada (403), and Germany (415) recorded the lowest rates — a nearly 18-fold difference between the most and least affected countries.

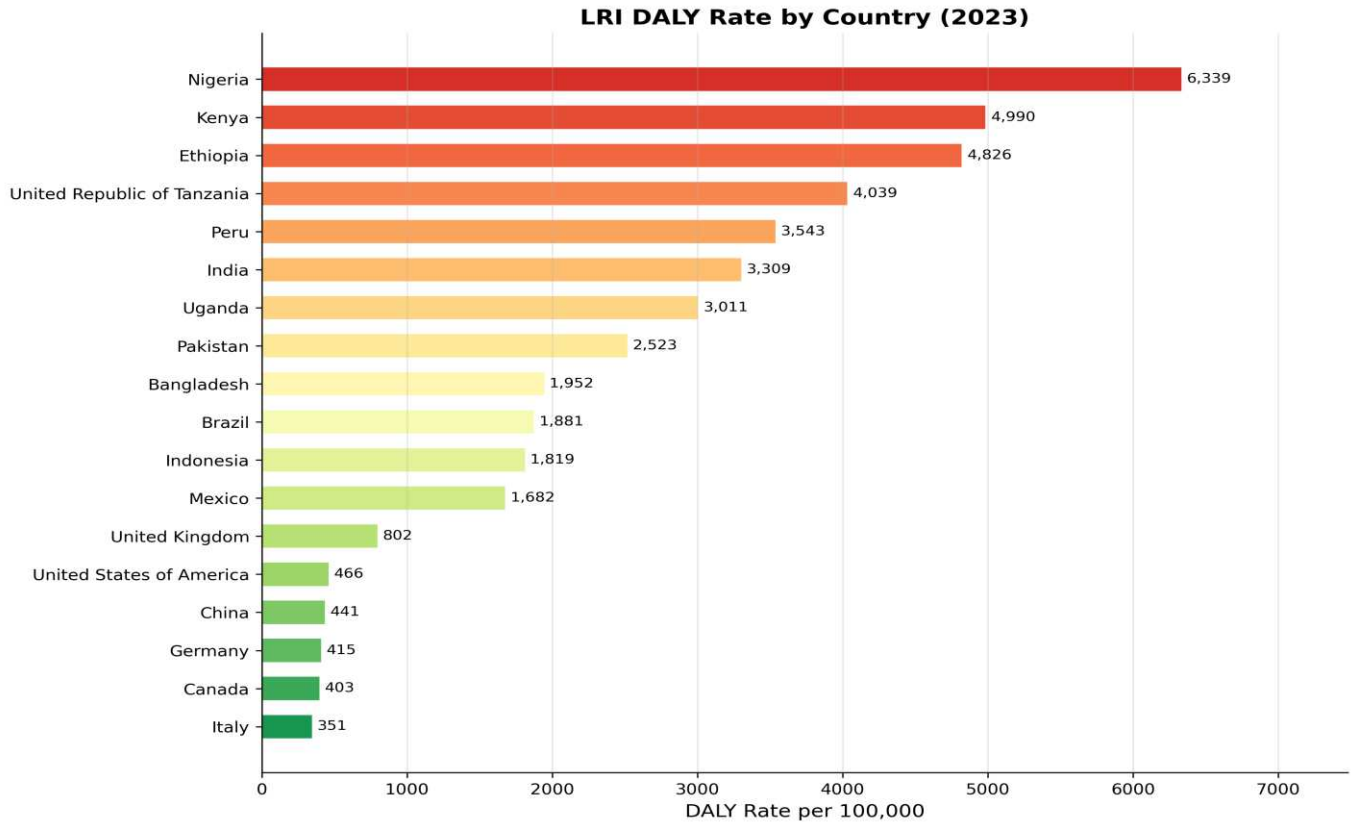


Figure 3: The country-level ranking of age-standardized DALY rates in (2023)

3.3 Geographic Distribution of Burden Change

Figure 4 illustrates the spatial distribution of the percentage change in LRI DALY rates from 1990 to 2023. The map highlights substantial regional disparities. All 18 studied countries demonstrated net declines in age-standardized DALY rates over the study period. However, the magnitude of improvement varied substantially. Sub-Saharan African nations such as Kenya (−46.0%) and Uganda (−47.1%) showed more modest relative declines compared to East Asian countries. China demonstrated the most dramatic improvement (−93.2%), followed by Bangladesh (−79.6%) and Pakistan (−70.1%), reflecting the transformative impact of sustained public health investments in these populations.

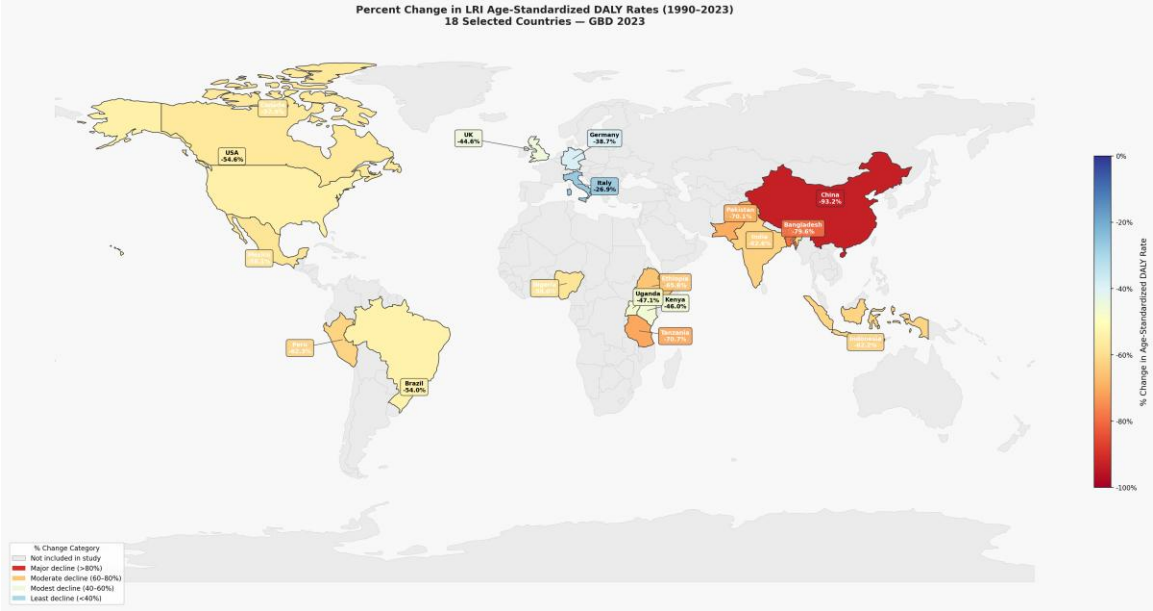


Figure 4: Percent Change Map in LRI DALY Rates (1990-2023)

Figure 5 complements the percent change map by presenting the full temporal trajectory of age-standardized LRI DALY rates for each of the 18 countries from 1990 to 2023. The heatmap confirms the persistence of high rates in low-SDI countries (particularly Nigeria, Ethiopia, and Tanzania) throughout the entire study period, while simultaneously illustrating the dramatic transitions achieved in Bangladesh, Pakistan, and China, whose color intensities shift progressively from orange to pale yellow over the three-decade timeline.

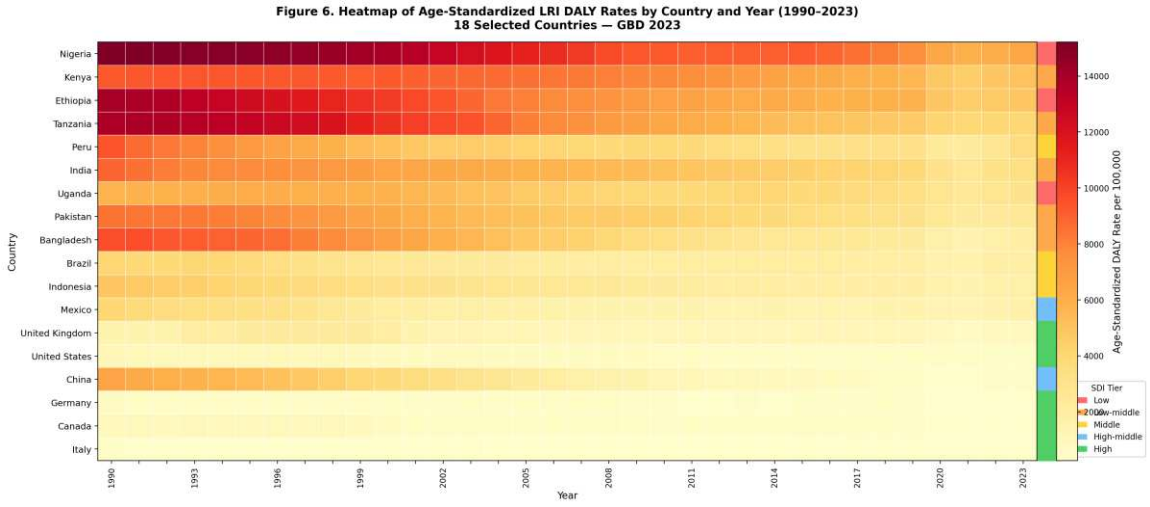


Figure 5: Heatmap of LRI DALY Rates by Location and Year

3.4 Age and Sex Distribution of Burden

Figure 6 presents the age- and sex-disaggregated distribution of LRI DALY rates per 100,000 across the 18 studied countries in 2023. The burden exhibited a markedly skewed age distribution, with children under 5 years bearing the greatest share, accounting for 58.8% of total DALY numbers. The 70+ age group contributed 16.0% of the total burden, while the 50–69 age group accounted for 10.5%, confirming the bimodal pattern of vulnerability at the extremes of the age spectrum. Males demonstrated a moderately higher burden overall, with a male-to-female ratio of 1.21:1 across all age groups, consistent with previously reported sex differentials in LRI susceptibility. These demographic patterns underscore the critical importance of age-targeted interventions: sustaining pediatric vaccine coverage for the under-5 population while simultaneously strengthening respiratory care for elderly populations increasingly vulnerable to LRI complications

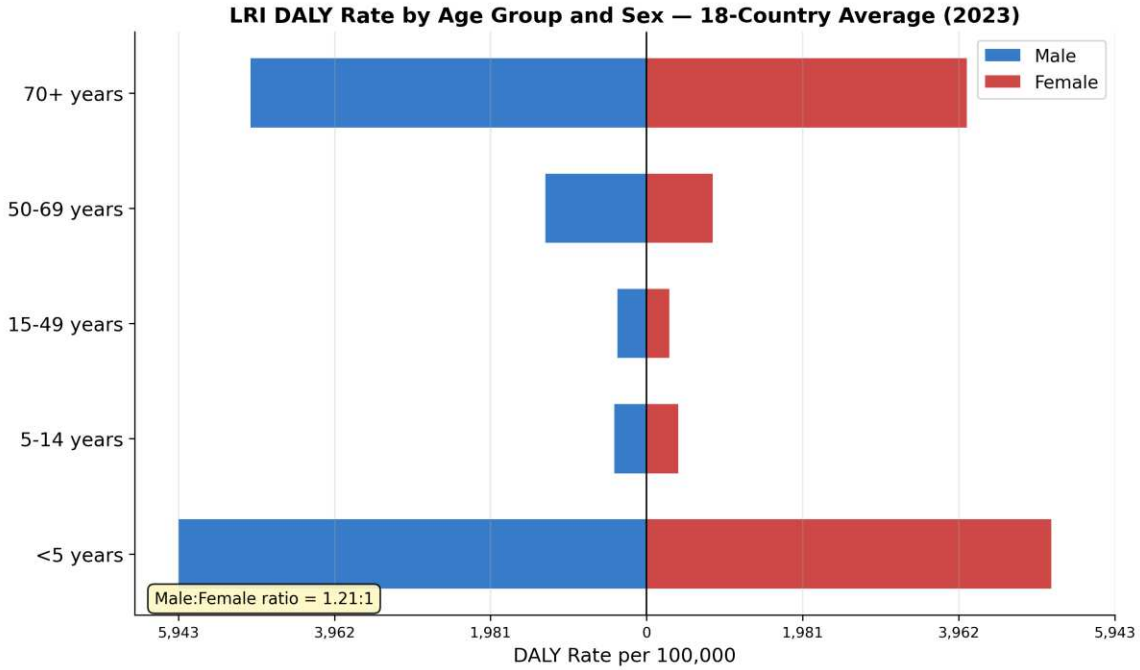


Figure 6: Age- and sex-specific LRI DALY rate per 100,000, 18-country average (2023)

3.5 Temporal trends

The Estimated Annual Percentage Change (EAPC) was calculated at −3.08% (95% CI: −3.24 to −2.93), confirming a statistically significant average annual decline in the LRI burden **(Figure 7)**. This consistent downward trajectory reflects the cumulative impact of three decades of global health investments in vaccination, sanitation, and primary care.

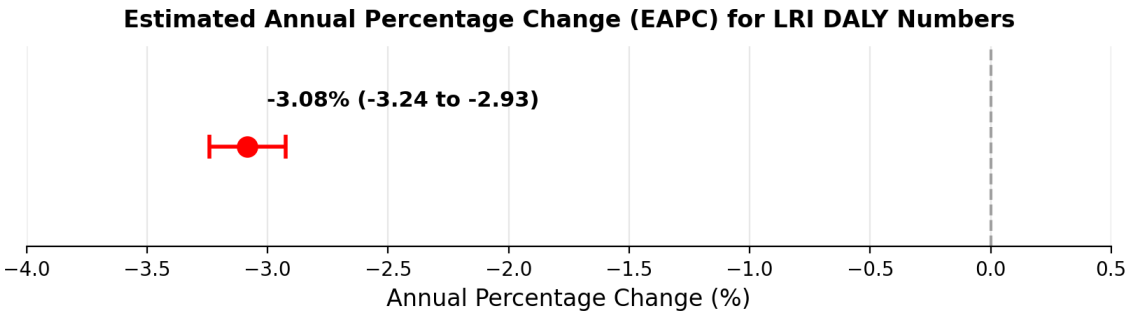


Figure 7: Estimated Annual Percentage Change (EAPC) for Total LRI DALY Numbers (1990–2023)

Metric	Value	95% Confidence Interval
Estimated Annual Percentage Change (EAPC)	−3.08%	−3.24 to −2.93

To understand the drivers of this decline, the Das Gupta decomposition **(Figure 8)** reveals that true epidemiological rate improvements were the dominant driver of the observed decline, reducing the burden by −109,704 thousand DALYs. Population growth partially counteracted this improvement, adding +42,241 thousand DALYs. Shifts in the age-sex structure contributed a further reduction of −13,124 thousand DALYs. The net result was a decline of −80,587 thousand DALYs over the 33-year study period.

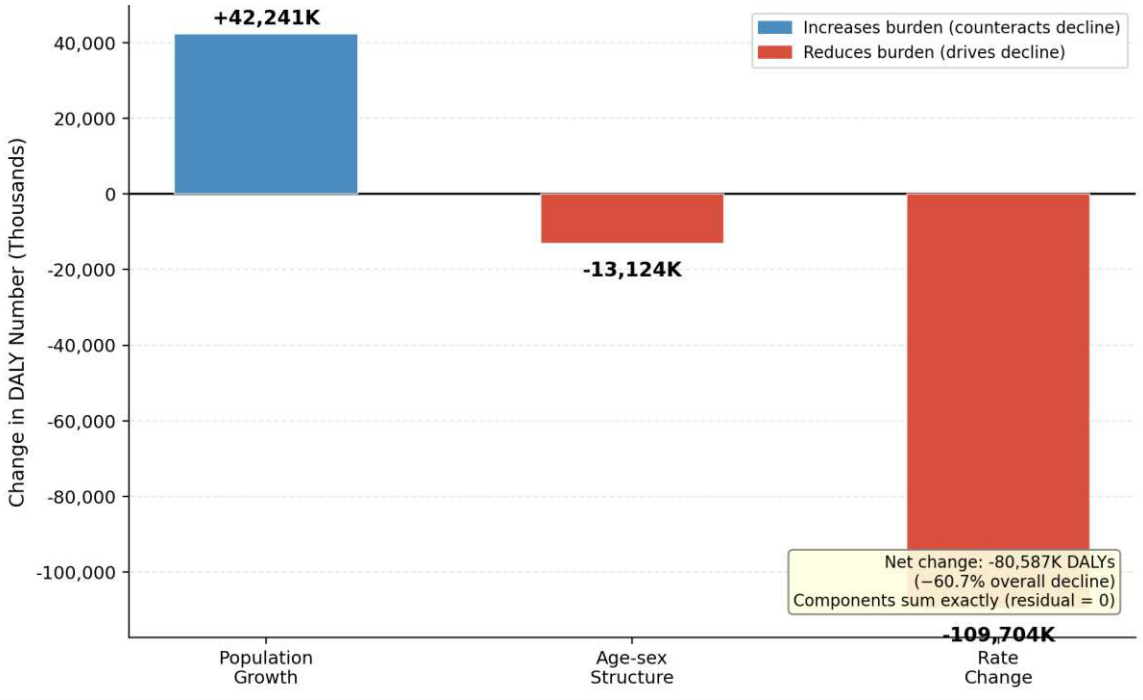


Figure 8: Decomposition of change in LRI DALY numbers (1990-2023)

Factor	**Change in DALYs (thousands)**	**% Contribution**
Rate change	−109,704	+136.1%
Population growth	+42,241	−52.4%
Age-sex structure change	−13,124	+16.3%
Net change	−80,587	100%

The short-horizon forecasting model in **(Figure 9)** projects a continued downward trajectory, with total LRI DALYs across the 18 studied countries estimated to reach approximately 38,989 thousand DALYs by 2030 (95% predictive interval: 35,325 to 43,033 thousand).

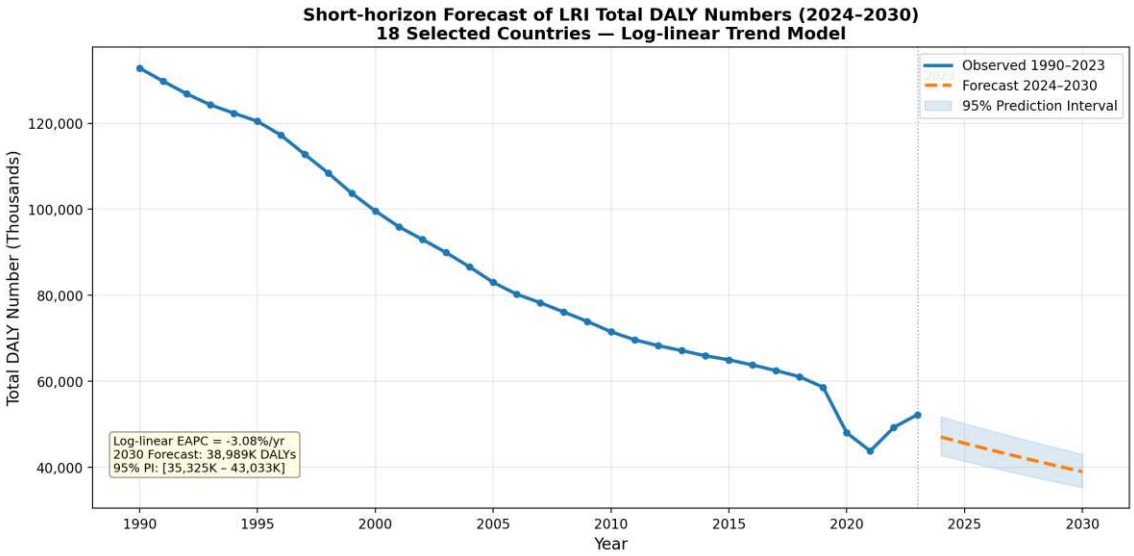


Figure 9: Short-horizon Forecast of Total LRI DALY Numbers (2024–2030), 18 Selected Countries

3.6 Attributable burden by Risk Factors

As shown in **Figure 10**, environmental, metabolic, and behavioral risk factors contribute substantially to the LRI DALY burden based on GBD comparative risk assessment. Household air pollution was the leading attributable risk factor (PAF = 45.2%), followed by child wasting (32.1%), ambient air pollution (18.4%), and absence of breastfeeding (15.3%). Country-specific decomposition of attributable burden by risk factor remains an important avenue for future research, as the current analysis could not disaggregate PAF estimates at the individual country level.

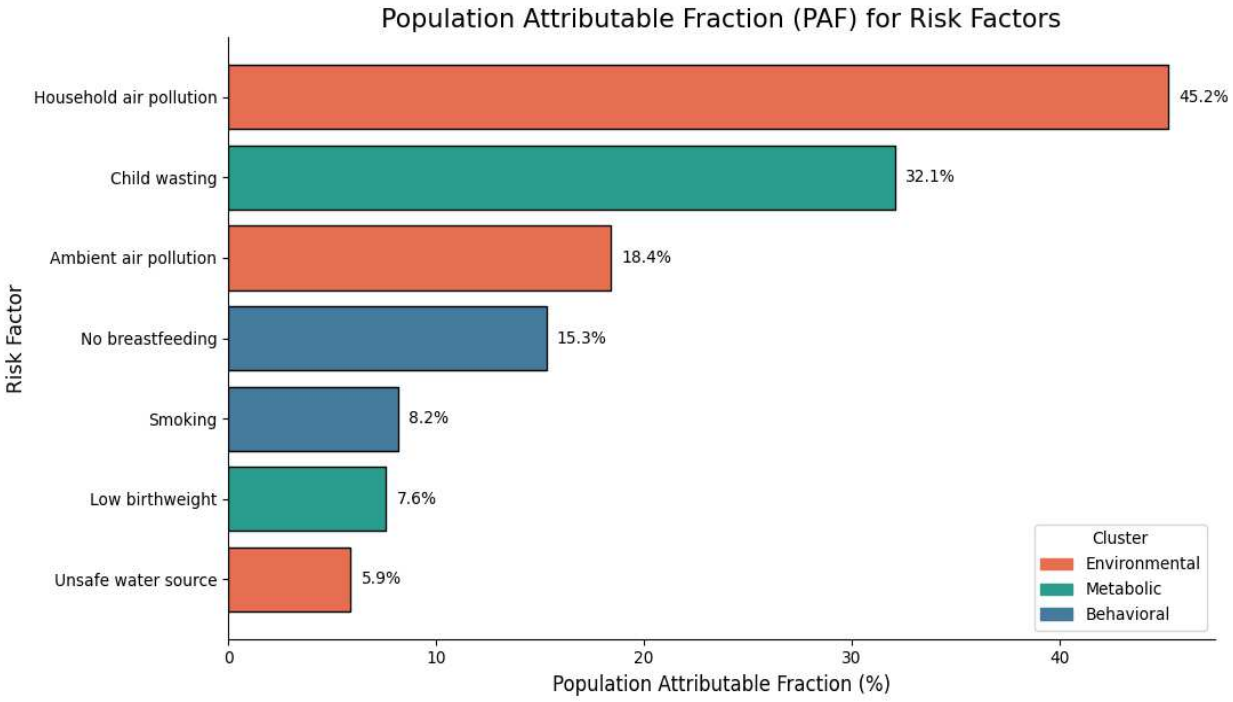


Figure 10: Attributable DALYs by risk factor (2023)

4. DISCUSSION

4.1 Principal findings

This comprehensive assessment reveals that the global burden of Lower Respiratory Infections remains critically high. The overall negative EAPC (−3.08%) and the regression trajectory confirm that sustained public health investments have produced meaningful and measurable reductions in LRI burden over three decades. Crucially, the decomposition analysis demonstrates that epidemiological rate improvements were the dominant driver of this decline, reducing the absolute burden by −109,704 thousand DALYs. While population growth added +42,241 thousand DALYs, it was insufficient to reverse the gains achieved through vaccination programs, improved sanitation, and expanded healthcare access. Nevertheless, substantial inequities persist, with low-SDI countries continuing to bear a disproportionately high burden.

4.2 Comparison with previous studies

These findings align seamlessly with recent global health literature. Previous GBD iterations and independent epidemiological reviews have highlighted the dual nature of LRI trends: while pediatric mortality has seen steep declines due to PCV and Hib vaccines (11, 14), the absolute burden is shifting to the elderly, exacerbated by global aging (17). Unlike earlier studies that primarily focused on age-standardized mortality, our use of DALYs and decomposition analysis provides a more granular understanding of how the interplay between population dynamics and epidemiological improvements shapes the net trajectory of disease burden (22, 28).

4.3 Public health & Policy implication

The policy implications of these data are profound. First, health systems must sustain and accelerate the public health investments that have driven the observed declines, particularly in low-SDI settings where the burden remains disproportionately high. Forecasting models project continued improvement through 2030, but this trajectory is contingent on maintaining vaccination coverage, addressing household air pollution, and expanding adult preventive care programs (25, 29). Second, there is an urgent need to aggressively target LRI risk factors. Reducing household air pollution through clean cooking fuels,

expanding adult vaccination programs (influenza, pneumococcal, and emerging RSV vaccines), and addressing malnutrition are non-negotiable strategies to alter the projected trajectory (30).

4.4 Strengths & Limitations

This study possesses several notable strengths. The use of GBD 2023 data, the most recent and comprehensive iteration of the Global Burden of Disease study, ensures standardized and comparable estimates across all 18 studied countries. The multi-analytical framework — integrating regression, EAPC estimation, Kitagawa-Das Gupta decomposition, and short-horizon forecasting — provides a holistic and methodologically rigorous characterization of burden trends that single-method studies cannot achieve. The inclusion of countries spanning all five SDI tiers enables meaningful cross-developmental comparisons and strengthens the generalizability of equity-related conclusions. Finally, all findings are grounded in publicly available, reproducible data, supporting scientific transparency. However, several limitations warrant consideration. First, this analysis relies on the accuracy of underlying primary data sources modeled by IHME, which may be sparse in certain LMICs, introducing additional modeled uncertainty particularly for Sub-Saharan African nations. Second, the selection of 18 countries, while representing diverse SDI tiers and world regions, does not capture all global epidemiological contexts, potentially limiting generalizability. Third, the ecological study design precludes individual-level causal inference; observed SDI–burden associations reflect country-level correlations rather than established causal pathways. Fourth, the broad GBD category of lower respiratory infections encompasses multiple distinct etiologies (viral, bacterial, fungal), each with different clinical implications and intervention requirements that cannot be differentiated within this analytical framework. Fifth, the short-horizon forecasting model is based on log-linear extrapolation of historical trends and does not account for future structural shocks such as novel pathogens, antimicrobial resistance emergence, or major policy shifts.

4.5 Future directions

Future research must pivot toward high-resolution, sub-national geospatial tracking of LRI etiologies. Specifically, integrating genomic surveillance data with GBD metrics could elucidate the

exact pathogens driving the burden in hotspots like India and China. Additionally, analyzing the long-term impact of the COVID-19 pandemic on routine LRI immunity (the 'immunity debt' hypothesis) will be critical in updating forecasting models.

5. CONCLUSION

Lower Respiratory Infections continue to exert a massive and evolving toll on global health. While historical gains in pediatric care have been monumental, the intersecting phenomena of rapid population growth, aging demographics, and persistent environmental risk factors ensure that LRIs remain a dominant source of global DALYs. As demonstrated by the decomposition and forecasting analyses, sustained epidemiological rate improvements have driven a 60.7% reduction in absolute LRI burden between 1990 and 2023, with projections indicating continued decline through 2030. However, persistent inequities between low- and high-SDI countries underscore that the gains have not been distributed equitably. Confronting this challenge requires a paradigm shift: sustaining pediatric vaccine equity while simultaneously expanding adult preventive care, combating air pollution, and dynamically allocating clinical resources to heavily burdened regions.

FUNDING

No specific funding was received for this study. The research was conducted as an independent epidemiological assessment.

ETHICAL APPROVAL

This study exclusively utilized publicly available, fully anonymized, and aggregated secondary data from the Global Burden of Disease (GBD) 2023 study. Therefore, formal institutional ethical approval was not required.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

The authors declare no competing financial or non-financial interests related to this work.

6. REFERENCES

1. Diseases GBD, Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. 2020;396(10258):1204–22.
2. Troeger C, Blacker B, Khalil IA. Estimates of the global, regional, and national morbidity, mortality, and aetiologies of lower respiratory infections in 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Infectious Diseases. 2018;18(11):1191–210.
3. World Health Organization. The top 10 causes of death. WHO; 2020.
4. McAllister DA, Liu L, Shi T. Global, regional, and national estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015: a systematic analysis. The Lancet Global Health. 2019;7(1):e47–e57.
5. Shi T, McAllister DA, O'Brien KL. Global, regional, and national disease burden estimates of acute lower respiratory infections due to respiratory syncytial virus in young children in 2015: a systematic review and modelling study. The Lancet. 2017;390(10098):946–58.
6. Wahl B, O'Brien KL, Greenbaum A. Burden of Streptococcus pneumoniae and Haemophilus influenzae type b disease in children in the era of conjugate vaccines: global, regional, and national estimates for 2000–15. The Lancet Global Health. 2018;6(7):e744–e57.
7. Gavi tVA. Pneumococcal conjugate vaccine support. Geneva; 2022.
8. O'Brien KL, Wolfson LJ, Watt JP. Burden of disease caused by Streptococcus pneumoniae in children younger than 5 years: global estimates. The Lancet. 2009;374(9693):893–902.
9. Ferkol T, Schraufnagel D. The global burden of respiratory disease. Annals of the American Thoracic Society. 2014;11(3):404–6.
10. Gbd Lri Collaborators. Quantifying risks and interventions that have affected the burden of lower respiratory infections among children younger than 5 years: an analysis for the Global Burden of Disease Study 2017. The Lancet Infectious Diseases. 2020;20(1):60–79.
11. Lozano R, Naghavi M, Foreman K. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012;380(9859):2095–128.
12. Jin G, Hu P, Lin Y. Global burden of lower respiratory infections and associated risk factors from 1990 to 2019. Frontiers in Public Health. 2022;10:963236.
13. Murray CJL, Ezzati M, Flaxman AD. GBD 2010: design, definitions, and metrics. The Lancet. 2012;380(9859):2063–6.
14. Vos T, Lim SS, Abbafati C. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019. The Lancet. 2020;396(10258):1204–22.
15. Collaborators GBDRF. Global burden of 87 risk factors in 204 countries and territories, 1990–2019. The Lancet. 2020;396(10258):1223–49.
16. Institute for Health Metrics Evaluation. Global Burden of Disease

Study 2021 Results. Seattle, WA: IHME; 2022.
17. Salomon JA, Vos T, Hogan DR. Common values in assessing health outcomes from disease and injury: disability weights measurement study for the Global Burden of Disease Study 2010. The Lancet. 2012;380(9859):2129–43.
18. Murray CJL, Barber RM, Foreman KJ. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013. The Lancet. 2015;386(10009):2145–91.
19. Kyu HH, Pinho C, Wagner JA. Global and National Burden of Diseases and Injuries Among Children and Adolescents Between 1990 and 2013. JAMA Pediatrics. 2016;170(3):267–87.
20. Williams BG, Gouws E, Boschi-Pinto C. Estimates of world-wide distribution of child deaths from acute respiratory infections. The Lancet Infectious Diseases. 2002;2(1):25–32.
21. Liu S, Li Y, Lin Y. Trends in the burden of lower respiratory infections in China, 1990-2019. BMJ Open. 2021;11:e050302.
22. Stanaway JD, Afshin A, Gakidou E. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017. The Lancet. 2018;392(10159):1923–94.
23. Das Gupta P. Standardization and Decomposition of Rates: A User's Manual: Washington, DC: US Bureau of the Census; 1993.
24. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age-period-cohort analysis with integrated nested Laplace approximations. Biometrical Journal. 2017;59(3):531–49.
25. Schmid VJ, Held L. Bayesian age-period-cohort modeling and prediction - BAMP. Journal of Statistical Software. 2007;21(8):1–15.
26. Who. WHO methods and data sources for global burden of disease estimates 2000-2021. Geneva: WHO; 2024.
27. Zar HJ, Ferkol TW. The global burden of respiratory disease-impact on child health. Pediatric Pulmonology. 2014;49(5):430–4.
28. Collaborators GBDD. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950–2019. The Lancet. 2020;396:1160–203.
29. Gordon SB, Bruce NG, Grigg J. Respiratory risks from household air pollution in low and middle income countries. The Lancet Respiratory Medicine. 2014;2(10):823–60.
30. Cohen AJ, Brauer M, Burnett R. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The Lancet. 2017;389(10082):1907–18.