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The Burden of Lower Respiratory Infections and the Risk Factors across Regions in Ethiopia: Global Burden of Diseases Study 1990-2019

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2
3 71 **Abstract**

4
5 72 **Objective:** This analysis is to present the burden and trends of morbidity and mortality due to
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7 73 LRIs, their contributing risk factors, and the disparity across administrative regions and cities from
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9 74 1990 to 2019.

11
12 75 **Design:** This analysis is part of a collaborative and comparable systematic Global Burden of
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14 76 Disease (GBD 2019) study.

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17 77 **Study setting:** The study includes nine region states and two chartered cities of Ethiopia

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19 78 **Outcome Measures:** We calculated incidence, death, and years of life lost (YLLs) due to LRIs
20
21 79 and contributing risk factors using all accessible data sources. We calculated 95% uncertainty
22
23 80 intervals (UI) for the point estimates.

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26 81 **Results:** In 2019, LRIs incidence, death, and YLLs among all age groups were 8313.7 (95% UI:
27
28 82 7757.6–8918), 59.4 (49.8–71.4) and 2404.5 (2059.4–2833.3) per 100000 people, respectively.
29
30 83 From 1990, the corresponding decline rates were 39%, 61%, and 76%, respectively. Children
31
32 84 under the age of five years account for 20% of episodes, 42% of mortalities, and 70% of the YLL
33
34 85 of the total burden of LRIs in 2019. The mortality rate was significantly higher in predominantly
35
36 86 pastoralist regions–Benishangul-Gumuz 101.8 (84.0–121.7) and Afar 103.7 (86.6–122.6). The
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38 87 Somali region showed the least decline in mortality rates. More than three-fourths of under-five
39
40 88 child deaths due to LRIs were attributed to malnutrition. Household air pollution from solid fuel
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42 89 attributed to nearly half of the risk factors for all age mortalities due to LRIs in the country.

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45 90 **Conclusion:** In Ethiopia, LRIs have reduced significantly across the regions over the years (except
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47 91 in elders), however are still the third leading cause of mortality, disproportionately affecting
48
49 92 children younger than five years old, and predominantly pastoralist regions. Interventions need to
50
51 93 consider leading risk factors, targeted age groups and pastoralist and cross-border communities.

52
53 94 **Keywords:** *Lower respiratory infections, regions, chartered cities, Ethiopia*

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3 95 ***What is already known on this topic***
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5 96 Lower respiratory infections (LRIs) remain a significant contributor to Ethiopia's morbidity and
6
7 97 mortality. LRIs are one of the leading causes of under-five mortality and are expected to increase
8
9 98 because of the current conflict, internal displacements, health care service interruption and the
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11 99 COVID-19 pandemic. This work is among the first to present a comprehensive analysis of LRIs
12
13
14 100 effect on morbidity and mortality, and their risk factors across all the regional states of Ethiopia
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17 101 over an extended time period to support health decision making at subnational levels.
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19 102 ***What this study adds***
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21 103 This is the first collaborative effort to provide the effects of LRIs and its risk factors on morbidity
22
23 104 and mortality for Ethiopia's nine regions and two chartered cities from 1990 to 2019. This analysis
24
25 105 highlights substantial decline morbidities and mortalities caused by LRIs over the last three
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27 106 decades, as well as the disparities between regions and chartered cities, and the opportunity to
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29 107 reduce LRIs burden of premature mortality by addressing specific geographic locations, risk
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31 108 factors and age-groups with cost-effective interventions.
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35 109 ***How this study might affect research, practice or policy***
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37 110 The results identify regions and segments of the population highly affected by LRIs , and the
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39 111 leading risk factors contributing to premature mortalities. These could be potential priorities for
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41 112 action against LRIs that would reduce premature mortality. There is a need to enhance strategies
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43 113 addressing predominantly pastoralist regions and cross-border communities and for quality health-
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45 114 care services in underserved areas. Although morbidity and mortality have shown improvements
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47 115 over the past three decades, LRIs burden is still high in parts of Ethiopia.
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117 INTRODUCTION

118 Lower Respiratory Infections (LRIs) have been a predominant health problem worldwide, causing
119 more than 2.3 million deaths in 2016 alone, amounting to a mortality rate of 32.2 per 100,000
120 people (1). LRIs comprise diseases of the lower airways such as pneumonia, bronchitis, and
121 bronchiolitis, among others (2). Nearly all (99%) of LRI deaths occur in low and middle income
122 countries and highly affect children under the age of 5 years (3). In sub-Sahara African countries,
123 the mortality rate is 66.4 per 100,000 people, which is four times the mortality rate in East Asia
124 and twice the global average (2).

125 Ethiopia ranked in the top three African countries in the number of under-five child deaths from
126 LRIs (4). To prevent child death from LRIs and other diseases in early life, Ethiopia has been
127 implementing the “Integrated management of childhood illness” program since 1997 which was
128 scaled up to the national level in 2007 (5). LRIs, and pneumonia in particular, have been among
129 the top three leading causes of childhood mortality in the country (6). Among LRIs’ aetiologies,
130 *S. pneumonia* contributed to more deaths than the other LRIs aetiologies combined (3). In 2011,
131 the country introduced 10-valent pneumococcal conjugate vaccine (PCV 10) into its national
132 immunization program to reduce the burden of Streptococcal pneumonia (7).

133 Morbidity and mortality from LRIs are attributable to multiple underlying factors. Malnutrition is
134 one of the main underlying risk factors (8, 9). The other main attributable factor are poor living
135 conditions that include household crowding, parental smoking, high use of household solid
136 fuel/biomass consumption, poor ventilation, and lack of hand-washing facilities (10-12). In
137 addition, bottle feeding also contributes to the burden of LRIs in children (13).

138 The flagship Ethiopian Health Extension Program (HEP) has been the backbone of the country’s
139 health system strategies to reduce the burden of LRIs and other diseases through preventive and

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3 140 health promotion activities at the community level. The HEP has also improved broader access to
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5 141 health care, availability of essential antibiotics, and immunization mainly to the rural population
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8 142 since 2004 (14). In 2010, the country also introduced the “integrated community case
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10 143 management” (ICCM) approach to treat pneumonia through trained health cadres of health
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12 144 extension workers (HEWs) implementing HEP (15).

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15 145 Currently, Ethiopia is implementing its Health Sector Transformation Plan-2 (HSTP-2) which is
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17 146 adapted from the Sustainable Development Goals. Some of the aims include increasing the
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19 147 proportion of under-five children with pneumonia who received antibiotics from 48% to 69% and
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21 148 improving full vaccination coverage from 44% to 69% between 2020 and 2025 (16). Commitment
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23 149 to international goals such as The Global Action Plan for the Prevention and Control of Pneumonia
24
25 150 and Diarrhoea by 2025 could be reached if enough investment is made in high LRI burden
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27 151 countries like Ethiopia (17).

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30 152 As Ethiopia is a country of stark contrasts in socioeconomic, epidemiological, and geographical
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32 153 variations, estimating disease burden at the regional level could provide valid and reliable
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34 154 information to inform policy decisions, including efficient resource allocation to match the burden
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36 155 in the subnational states. Hence, this paper presents the 2019 Global Burden of Diseases, Injuries,
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38 156 and Risk Factors study (GBD) results on the burden, trends and regional variations of LRIs in
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40 157 Ethiopia from 1990 to 2019.

44 45 158 **METHODS**

46 47 48 49 159 **Study Setting**

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52 160 Ethiopia is the second-most populous country in Africa next to Nigeria, with an estimated
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54 161 population of 112 million in 2019 (18). More than half of the country's population is under 20, and

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3 162 over 80% of the population resides in rural areas (19). The country is subdivided into ten regional
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5 163 states (Afar, Amhara, Benishangul-Gumuz, Gambella, Harari, Oromia, Somali, Sidama, Southern
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7 164 Nations and Nationalities and Peoples (SNNP), and Tigray) and two chartered cities (Addis Ababa
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9
10 165 and Dire Dawa). During this study, Sidama was a zonal administration under the SNNP region.
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12 166 Oromia, Amhara, and SNNP are the highly populated regions. In this study, we classified the
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14 167 regions into urban (Addis Ababa, Dire Dawa, and Harari), agrarian (Oromia, Amhara, SNNP,
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16 168 Tigray), and pastoralist (Benishangul-Gumuz, Afar, Gambella, and Somali). The healthcare
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18 169 system of the country is a three-tiered system consisting of primary, secondary, and tertiary levels
19
20 170 of healthcare delivery units with 21,154 functioning health facilities and 159,545 health workforce
21
22 171 in 2019 (16). The primary health care unit (PHCU) consists of health posts (staffed by HEWs),
23
24 172 health centres, and primary hospitals. The secondary level of care consists of general hospitals and
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26 173 the tertiary level of care includes national referral hospitals which provide specialized services
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31 174 (16).

34 175 **Data Sources and Analysis**

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36
37 176 The analysis and findings of LRIs presented in this paper were produced by the Ethiopia
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39 177 Subnational Burden of Disease Initiative, a collaborative endeavour between the National Data
40
41 178 Management Center for Health (NDMC) at the Ethiopian Public Health Institute (EPHI) and the
42
43 179 Institute for Health Metrics and Evaluation (IHME), as part of GBD. The details of the
44
45 180 methodology were described elsewhere (20). In brief, woreda (district) level geographic boundary
46
47 181 mapping of regions and cities was used because woredas were relatively stable government
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49 182 structures (compared to lower or higher level administrative structures) during political or
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51 183 government changes and through the three census years (1984, 1994, and 2007). First, the analysis
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53 184 was estimated by mapping population and demography at the district level by time and region.
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3 185 Then, the data sources were mapped by regions before processing the data in the GBD analysis
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5 186 based on GBD protocol. EPHI, in collaboration with IHME, gathered all accessible data sources
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7 187 by location for Ethiopia and all regions and cities that included census, demographic surveillance,
8
9 188 household surveys, diseases registry, health service utilization, disease notification, and other data
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11 189 for this analysis. A comprehensive description of data sources, quality, and modelling for GBD
12
13 190 2019 has been reported on the following online portal: ([http://ghdx.healthdata.org/gbd-2019/data-](http://ghdx.healthdata.org/gbd-2019/data-input-sources)
14
15 191 [input-sources](http://ghdx.healthdata.org/gbd-2019/data-input-sources)).

192 **GBD Methods and Tools**

193 The GBD details are reported elsewhere (21). Diseases and injuries within the GBD were
194 organized into levels: Level 1 being the broadest causes of death and disability to Level 4 being
195 the most specific. Within the three Level 1 causes (communicable, maternal, neonatal, and
196 nutritional diseases; non-communicable diseases; and injuries), there were 174 Level 3 causes.
197 The GBD 2019 study has estimated the burden of disease, including LRIs, for Ethiopia's national
198 and subnational states. LRIs comprise diseases of the lower airways such as pneumonia, bronchitis,
199 and bronchiolitis, among others (2). LRI mortality was estimated by age, sex, geography, and year
200 using a modelling platform called the Cause of Death Ensemble model. LRI morbidity, including
201 incidence, was modelled using a meta-regression platform known as DisMod-MR, a Bayesian,
202 hierarchical, mixed-effects meta-regression platform (22). Years of life lost (YLLs) were
203 computed by multiplying cause-specific deaths by the life expectancy at the age of death (23, 24).
204 Population risk assessments over time and among risks were estimated using the comparative risk
205 assessment approach developed for the GBD study (25, 26). The GBD risk factors were
206 categorized as follows: Level 1 risk factors are behavioural, environmental, occupational, and

207 metabolic; Level 2 risk factors include 20 clusters of risks; Level 3 consists of 52 clusters of risks;
208 and Level 4 contains 69 specific risk factors (21).

209 **Presentation of results**

210 We present the burden of LRIs in Ethiopia and its regional states using incidence, deaths, and
211 YLLs categorized by sex, age groups, and year. We used numbers, rates, and percent change for
212 the quantification of the burden. We also estimated the risk factors contributing to LRIs in Ethiopia
213 and the percent change between 1990 and 2019. We reported GBD causes and risk factors using
214 level 3 classifications, with 95% Uncertainty Intervals (UI). Additional tables and figures are
215 attached in the supplementary appendix.

216 **Patient and public involvement**

217 Patients and the public were not involved in this study.

218 **RESULTS**

219 **Morbidity Due to LRIs**

220 In 2019, an estimated 6,628,673.6 (95% UI: 6,108,786.2–7,230,986.3) new cases of LRIs occurred
221 in Ethiopia resulting in an age-standardized incidence rate of 8313.7 per 100,000 people (7757.6–
222 8918). Out of the total LRI episodes, 22% (1,448,680.0 new cases [1,150,089.8–1,799,704.4]) of
223 new cases occurred among children younger than 5 years, yielding an annual incidence rate of
224 8685.0 per 100,000 children (6895.1–10,789.8). In adults older than 70 years, there were 725,273.3
225 (640,315.4–837,746.3) new cases of LRIs with an annual incidence of 38,394.4 per 100,000 people
226 (33,896.9–44,348.5) (Appendix Table 1 and Table 2).

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3 227 Compared to national estimates, a significantly lower age-standardized incidence rate of LRIs per
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5 228 100,000 people was observed in the chartered cities (6788.1 [6285.1–7339.1] in Addis Ababa,
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7 229 7148.8 [6634.6–7750.7] in Dire Dawa), and in Harari region (7190.5 [6684.1–7718.6]). The
8
9 230 highest rates of age-standardized incidence per 100,000 people were observed in Afar (9350.2
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11 231 [8648.8–10,157.4]), Somali (9220.0 [8515.9–10,046.4]), and Benishangul-Gumuz (9054.6
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13 232 [8394.2–9766.0]) although not significant compared to the national estimate (Figure 1; Figure 2;
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15 233 Appendix Table 2).

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18 234 In children younger than 5 years, the lowest incidence rates were observed in Addis Ababa (4927.2
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20 235 [3812.5–6231.8]), Harari (6821.6 [5373.5–8607.3]), and Gambella (6791.1 [5370.4–8460.1]) per
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22 236 100,000 people, substantially below the national estimate. The highest incidence of LRIs per
23
24 237 100,000 children were recorded in Benishangul-Gumuz (10,481.8 [8269.5–13,219.0]), Somali
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26 238 (10,062.7 [7949.6–12,802.8]), Afar (9365.5 [7421.7–11,714.7]), and Oromia (9039.4 [7080.5–
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28 239 11,277.7]).

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34 240 The age-standardized decline rate between 1990 and 2019 was 39% for both sexes, and it was 56%
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36 241 in under-five children and 13% in adults older than 70. The lowest decline in age-standardized
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38 242 incidence rate was in Somali (19%); while it was between 38% and 44% for the remaining regions
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40 243 (Appendix Table 2).

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43 244 In children younger than 5, the incidence rates increased slightly between 1990 and 1995, except
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45 245 in Addis Ababa and Amhara region. The highest decline rates were found between the years 2005
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47 246 and 2015 across all regions (Appendix Figure 1).

51 247 **Mortality due to LRIs**

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3 248 In 2019, LRIs caused 46,300.7 (95% UI: 39,515–54,642) deaths in Ethiopia, giving the age-
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5 249 standardized mortality rate of 86.4 (75.3–97.6) per 100,000 people. Under-five mortality accounted
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7
8 250 for 42% (19,591.8 [14,018.4–26,899.0]) of all deaths due to LRIs which resulted in a mortality
9
10 251 rate of 117.4 (84.0–161.2) per 100,000 children. Of the under-five deaths, 71% (13,919.0 [9946.0–
11
12 252 18,860.0]) occurred in the first year of life. In adults older than 70 years, LRIs caused 14,627.6
13
14 253 (12,393.7–16,892.8) deaths, which was a mortality rate of 774.3 (656–894.2) deaths per 100,000
15
16 254 adults (Table 1; Appendix Table 3).

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18
19 255 In 2019, the number of deaths in all age groups by region were highest in Oromia (18,206 [15,193–
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21 256 21745]), Amhara (9525 [7530–11872]), SNNP (9494 [7713–11649]), and Somali (3907.5
22
23 257 [3007.4–4959.4]), followed by Tigray (2551.4 [2090.3–3028.6]), Afar (706.2 [567.7–869.6]),
24
25 258 Benishangul-Gumuz (619 [470.7–803.0]), Dire Dawa (154.6 [120.6–193.8]) and Gambella (123.2
26
27 259 [98.2–151.9]). Harari (93.1 [73.8–116.0]) had the lowest number of deaths. (Appendix Table 3).

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29
30 260 Between 1990 and 2019, the age-standardized mortality rate declined by 61%, and the decline in
31
32 261 under-five children and adults over 70 years was 86% and 30%, respectively (Table 1).

262 *Table 1: Lower Respiratory Infections mortality rates and percentage changes between 1990 and 2019 in Ethiopia, both sexes, with different age*
 263 *groups*

	Age standardized			Children younger than 5			People older than 70		
Location	Deaths per 100 000 people [95% UI], 1990	Deaths per 100 000 people [95% UI], 2019	Change, %	Deaths per 100 000 children [95% UI], 1990	Deaths per 100 000 children [95% UI], 2019	Change, %	Deaths per 100 000 people [95% UI], 1990	Deaths per 100 000 people [95% UI], 2019	Change, %
Addis Ababa	163.4[134.6-206.9]	59.4[49.8-71.4]	64	441.5[320.4-602.7]	23.4[14.1-36.4]	95	909.2[669.5-1264.6]	503.6[410.5-633.7]	45
Oromia	241.3[188.5-292.8]	89.3[75.9-103.1]	63	920.7[629.5-1264.1]	122.3[84.8-171]	87	1174.1[842.8-1543]	849.5[687.3-1009]	28
Amhara	197.7[163.5-236.5]	74.3[59.4-91]	62	691.3[531.7-883.4]	94.9[55.6-146.1]	87	1017.9[755.4-1324]	682.7[537.4-857.9]	33
SNNPs	243.7[196.4-296.9]	98.9[83.8-116.6]	59	971.9[697.2-1273.2]	118.4[79-168.5]	88	1161.3[584.7-822.3]	845.4[685.6-018.1]	28
Tigray	242.7[200.5-292]	84.6[69.2-100.1]	65	780.4[593.5-1009.1]	67.2[43.5-98.3]	92	1166.7[838.2-1586]	788.6[637.9-956.8]	33
Harari	240.2[182.6-303.1]	77[63-92.5]	68	1146.7[730-1604.1]	89.9[51.1-138]	93	762.3[412-1223.7]	694.3[551.9-849]	9
Afar	244.8[186.5-316.9]	103.7[86.6-122.6]	58	723.7[481.5-1023.7]	101.7[65-152.4]	86	1010[658-1541.7]	917.6[720.6-146.8]	10
Somali	147.6[113.8-192.6]	97.5[79.2-118.6]	34	455.9[313-628.5]	197.3[135-279.8]	57	798.8[519.2-1177.6]	765.1[588.8-972.4]	5
BG	284.1[221.8-358.1]	101.8[84-121.7]	64	1266.4[846.7-790.9]	215.1[141.4-311]	84	975.3[656.5-1379.3]	671.9[532.7-848.7]	32
Dire Dawa	220.1[171.6-270.9]	69.9[56.5-84]	68	1084.2[689.1-503.2]	83.7[44.7-135.9]	93	868.7[604.5-1205.5]	621.3[496.4-766.1]	29
Gambella	231.5[176.8-297.4]	82.4[68.3-97.1]	64	1265.5[805.4-764.3]	57[32.4-89.6]	96	739.6[477.7-1074.9]	678.3[540.4-835.3]	9
Ethiopia*	223[184.7-264.3]	86.4[75.3-97.6]	61	822.2[635-1051.2]	117.4[84-161.2]	86	1092.3[844-1391.5]	774.3[656-894.2]	30

N.B: all changes are in decreasing percent. SNNPs: Southern Nations, Nationalities, and Peoples; BG: Benishangul-Gumuz; *national estimate

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267 In Ethiopia, the age-standardized mortality rate was higher among males (100.6 [84.1-121.4]) than
268 females (71.8 [60.2–82.9]) (Appendix Table 4).

269 In 1990, the age-standardized mortality rate per 100,000 people was the highest in Benishangul-
270 Gumuz (284.1 [221.8–358.1]), Afar (244.8 [186.5–316.9]) and SNNP (243.7 [196.4–296.9]),
271 although it is not significantly different from the national estimate. On the other hand, the lowest
272 age standardized mortality rate was exhibited in Somali (147.6 [113.8–192.6]). Although the value
273 was not significantly different from the national value in 1990, Addis Ababa showed the second
274 lowest age-standardized mortality rate (163.4 [134.6–206.9]) (Table 1).

275 In 2019, the age-standardized mortality rate per 100,000 people was significantly lower in Addis
276 Ababa (59.4 [49.8–71.4]) when compared to other regions, although not significantly lower than
277 Gambella and other urban areas (Harari and Dire Dawa). Dire Dawa showed a significantly lower
278 age-standardized mortality rate when compared to Benishangul-Gumuz, Afar, and SNNP.
279 Compared to the national estimate, the regions of Afar (103.7 [86.6–122.6]) and Benishangul-
280 Gumuz (101.8 [84.0–121.7]) recorded the highest age-standardized mortality rates per 100,000
281 people, although the difference is not statistically significant (Table 1). Compared to the 1990s,
282 there was a 58% to 68% decrease in the age-standardized mortality rates across all regions.
283 However, the Somali region recorded a 34% reduction in mortality rates (Table 1 and Figure 3).

284 Among children below the age of 5, the mortality rate per 100,000 people was significantly lower
285 in Addis Ababa (23.4 ([14.1–36.4]) than other regions, although it was not significantly less than
286 Gambella in 2019. The mortality rate was the highest in Benishangul-Gumuz (215.1 [141.4–
287 311.0]), Somali (197.3 [135.2–279.8]), and Oromia (122.3 [84.8–171.0]) despite being not
288 significantly higher than the national estimate (Table 1). Dire Dawa showed a significantly lower
289 mortality rate than Benishangul-Gumuz and Somali. Harari had a significantly lower mortality rate

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3 290 than Benishangul-Gumuz. For all regions, the mortality rate declined for children younger than 5-
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5 291 years between 1990 and 2019 by between 84% (in Benishangul-Gumuz) and 96% (in Gambella),
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8 292 except in Somali, which showed a 57% decline (Table 1). The mortality rate increased slightly
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10 293 between 1990 and 1995 and between 2010 and 2015 in Somali region (Appendix Figure 2).

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13 294 The mortality rate in adults older than 70 was the lowest in Addis Ababa (503.6 [410.5–633.7]).
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15 295 Other regions and cities have not shown a statistically significant difference from the national
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18 296 estimate. The decline in mortality rates between 1990 and 2019 is below 50% across all regions
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20 297 (Table 1). The mortality rate increased in Afar and Somali between 2005 and 2019 and in Gambella
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22 298 between 1990 and 2005 (Appendix Figure 3).

25 299 **Premature Mortality due to LRIs**

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29 300 In 2019, premature death due to LRIs was 2,445,093.7 (95% UI: 1,934,420.8–3,119,838.6) YLLs,
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31 301 yielding an age-standardized rate of 2404.5 per 100,000 people (2059.4–2833.3). Compared to
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34 302 1990, the age-standardized YLL rate declined by 76% in 2019. In parallel, 70% of all premature
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36 303 mortality occurred in children younger than five, which accounted for 1,721,122.3 (1,231,032.1–
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38 304 2,362,958.7) YLLs. The YLL rate of 72,055.4 (55,718.5–92,064) per 100,000 under-five children
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40 305 in 2019 declined by 86% compared to the YLL rate in 1990. Adults over 70 years contributed 8%
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43 306 of all YLLs due to LRIs (194,756.2 [165,462.0–225,502.1]), yielding a rate of 10,309.9 (8759.2–
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45 307 11,937.6) YLLs per 100,000 people (Table 2; Appendix Table 5 and Table 6).

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48 308 Compared to 1990, the number of YLLs has decreased by 70% in all age groups and by 76% in
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50 309 children younger than five in 2019. However, the number of YLLs has increased by 45% in adults
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53 310 older than 70 (Appendix Table 5).

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3 311 The age-standardized YLL rate was significantly lower in Addis Ababa (1285.6 [1065–1561.8])
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5 312 in 2019 compared to the national average. The highest age standardized YLL rate were in
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7 313 Benishangul-Gumuz (3571.1 [2772.4–4510.7]), Somali (3236.4 [2537.4–4006]), and Afar (2824.6
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9 314 [2323–3414]), although not statistically significant compared to the national estimate (Table 2).
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13 315 In children younger than five years, Addis Ababa (2069 [1253–3217.5]) had a significantly lower
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15 316 YLL rate than the national estimate. The YLL rate was observed to be the lowest in Gambella
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17 317 (5031.8 [2867.2–7885.7]), although not significantly lower than the national estimate (Table 2).
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319 *Table 2: Lower Respiratory Infections YLL rates and percentage changes between 1990 and 2019 in Ethiopia, both sexes, with different age*
 320 *groups*

Location	Age-standardized			Children younger than 5 years			People older than 70		
	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change, %	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change, %	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change, %
Addis Ababa	6362.2(5161.9-7847.9)	1285.6(1065-1561.8)	80	38824.7(28230.1-53092.4)	2069(1253-3217.5)	95	13587(9985.4-18978.3)	6857.1(5545.8-8721.2)	50
Oromia	11217.6(8517-14318)	2433.8(2042.2-2879.5)	78	80610.7(55103.7-110696)	10742.8(7456.7-15039.6)	87	18754.2(13297.1-24843)	11119.7(8939.1-13305)	41
Amhara	8690.4(7146.3-10453.8)	2016.4(1551.4-2541.8)	77	60663.3(46712.5-77511.5)	8355(4898.9-12845)	87	15950.4(11723.4-21059.7)	9059.7(7063.2-11529.2)	44
SNNPs	11633(9119.4-14477.9)	2698.1(2243.5-3250.2)	77	85114.7(61203.2-111502.1)	10409.3(6968.1-14819.3)	88	18842.6(13166.1-26081)	11736.6(9426.7-14238.6)	38
Tigray	10346.4(8522.9-12340.3)	1977.1(1593.9-2395)	81	68509.3(52185.7-88712.2)	5927.9(3839.4-8676.8)	92	19502.8(13914.1-26751.2)	10486.8(8439.5-12765.3)	47
Harari	12826.5(9336.5-16985.4)	2060.4(1595.6-2623.1)	84	100421.7(63898.7-140467.8)	7922.5(4518.7-12117.2)	93	11782.6(6360.4-19341.1)	9260.4(7338.7-11340.3)	22
Afar	10993.5(8520.8-14193.6)	2824.6(2323-3414)	74	63570.5(42296.6-89769)	8943.7(5734.6-13390.2)	86	16925.5(10923.7-26001.7)	11867.1(9346-14716.9)	30
Somali	6286.9(4860.5-7970)	3236.4(2537.4-4006)	49	40088.1(27543.7-55109)	17314.3(11890.7-24530)	57	11953.6(7599.2-17885.5)	10246(7797.8-13150.6)	15
BG	14965.1(11197.4-19998.6)	3571.1(2772.4-4510.7)	76	110847.2(74368-156588.4)	18868.3(12442.9-27281.8)	83	16397.3(10917-23228.5)	9541.9(7476.9-12112.3)	42
Dire Dawa	11749.7(8605.4-15249.5)	1832.8(1407.3-2363.1)	84	94905.3(60458.5-131584.5)	7371.3(3953-11962.1)	93	13207.9(9219.6-18328.2)	8371(6616.3-10408.2)	37
Gambella	13175.8(9291-17411)	1937.4(1567.6-2344.6)	85	110783.8(70576-154304.1)	5031.8(2867.2-7885.7)	96	11811.4(7673.5-17012.5)	10030.9(7730.2-12664.9)	16
Ethiopia*	10189.1(8347.5-12201.8)	2404.5(2059.4-2833.3)	76	72055.4(55718.5-92064)	10318.6(7380.4-14166.6)	86	17415.9(13362.7-22228.5)	10309.9(8759.2-11937.6)	41

321 SNNPs: Southern Nations, Nationalities, and Peoples; BG: Benishangul-Gumuz; *national estimate

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3 323 The age-standardized premature mortality rate between 1990 and 2019 showed a continuous
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5 324 decline in all regions, except Somali. Benishangul-Gumuz showed the highest burden between
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8 325 1990 and 2019 (Figure 4).
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11 326 The change in premature mortality in children younger than five was significant throughout the
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13 327 years. However, the reduction in premature mortality among adults older than 70 was not as
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15 328 significant (Appendix Figure 4 and Figure 5).
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18 329 **Risk Factors**

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22 330 Across all population groups, about half (48%) of the mortalities (measured in rates) due to LRIs
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24 331 in Ethiopia were attributed to household air pollution from solid fuel. In addition, lack of access
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26 332 to a hand-washing facility (23%), childhood wasting (23%), low birth weight (9%), short gestation
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28 333 period (7%), and ambient particulate matter pollution (6%) were also risk factors for mortality due
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30 334 to LRIs. The contribution of the risk factors to death due to LRIs in all regions was similar to the
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32 335 national estimate, except in Addis Ababa, where lack of access to hand-washing facilities, ambient
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34 336 particulate matter pollution, and low temperature were the main contributing factors. Ambient
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36 337 particulate matter pollution was also relatively higher in Dire Dawa, Harari, and Tigray regions
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38 338 (Appendix Figure 6).
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43 339 In children younger than five, more than three-fourths of deaths due to LRIs were attributed to
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45 340 childhood wasting (54%) stunting (12%), and child underweight (10%) in Ethiopia. In addition,
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47 341 50% of the LRIs mortalities were attributed to household air pollution from solid fuel. Lack of
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49 342 access to hand-washing facilities (23%), low birth weight (23%), short gestation period (17%),
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51 343 high (4%) or low temperature (4%), absence of exclusive breastfeeding (4%) were also the risk
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53 344 factors with evident contribution. The distribution of risk factors varied among the regions. Child
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3 345 wasting, low birth weight, and pre-term birth were the contributing factors of mortality in Addis
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5 346 Ababa. In Harari and Dire Dawa, child wasting, lack of access to hand-washing facilities, pre-term
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7 347 birth, and household air pollution from solid fuels contributed more to the death from LRIs than
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9 348 the other risk factors in 2019. All the risk factors except for ambient particulate air matter and low
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11 349 temperature were the highest in Somali and Benishangul-Gumuz (Appendix Figure 7).
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15 350 **Discussion**

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19 351 The findings from this study indicate that although the burden of LRIs, measured in incidence or
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21 352 mortality rates, have shown a significant decline, they are still the third leading cause of death after
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23 353 neonatal disorders and diarrheal diseases in 2019 in Ethiopia. Cities and predominantly urban areas
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25 354 had lower mortality rates than predominantly pastoralist regions of the country. The rate of decline
26
27 355 in mortality between 1990 and 2019 varied slightly across regions and chartered cities. The
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29 356 mortality rate decreased by more than three-fourths among children under the age of five and only
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31 357 by one-third among adults older than 70 between 1990 and 2019. Half of LRIs mortalities are
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33 358 attributed to household air pollution from solid fuels in all age groups. About three-fourths of LRIs
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35 359 in children were attributed to malnutrition.
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40 360 The mortality rate of LRIs among children below the age of 5 has declined by 86% between 1990
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42 361 and 2019. This decline could be attributed to improvements in living conditions, access to
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44 362 healthcare, and immunization. The national health delivery infrastructure has grown from 2,600
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46 363 health facilities in 1997 to 21,154 facilities, including 314 hospitals, 3,678 health centers, and
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48 364 17,162 health posts and private health facilities in 2019. As a result, the health workforce has
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50 365 increased from 46,000 in 2007 to 159,545 in 2019 (16). The introduction of HEP since 2004 to
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52 366 provide preventive, health promotion, and curative treatment for pneumonia, malaria and diarrhoea
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3 367 had improved health outcomes for children (14). Moreover, Ethiopia has been implementing
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5 368 holistic child health improvement programs like IMCI since 1997 (15) and ICCM (5). Vaccination
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8 369 against *Streptococcus pneumoniae*, which is responsible for about half of the LRIs mortality in
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10 370 African countries, with the PCV 10 vaccine since 2011 helped reduce the burden of LRIs (4). In
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12 371 addition, improved socioeconomic conditions have supported the reduction of the burden of LRIs
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15 372 in the country (27).

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18 373 Despite the achievements reached in improving child health outcomes in Ethiopia, children are
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20 374 still disproportionately affected by LRIs. Out of the total burden of LRIs, 42% of all the deaths
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22 375 were among children younger than five. In that regard, this study has shown that one out of ten
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24 376 child deaths are due to LRIs. However, another study estimated that pneumonia alone shared about
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26
27 377 17% of all deaths in children younger than five years (28). Among children under five, children
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29 378 younger than one carry the highest burden of LRIs. Furthermore, the mortality rate among children
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31 379 younger than one (397.7 per 100,000 people) was more than nine times higher than that of children
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34 380 between one and four years old (43 per 100,000 people). Although most studies on the high burden
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36 381 of LRIs corroborate our findings, the findings from Global Health Observatory (GHO) estimated
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38 382 a much higher mortality rate than the estimates of this study (i.e. 481.9 in children less than one
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41 383 year and 51.1 per 1000,000 population in children between one and four years) (8). Although we
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43 384 could not explain why this variation occurs, the estimates from GBD are also less than the estimate
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45 385 from findings of the Child Health Epidemiology Reference Group (CHERG), which is primarily
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48 386 due to the difference in the types of data used (29).

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50 387 Urban areas of the country, mainly Addis Ababa and Dire Dawa, had significantly lower mortality
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52 388 rates than pastoralist areas such as Benishangul-Gumuz and Somali. These regional variations
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55 389 could be attributed to gaps in availability and access to healthcare and socioeconomic status

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3 390 differences among the subnational states. A previously conducted study indicated that disease
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5 391 burden is high among people in the poorest wealth quintile and people located mainly in Afar,
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7 392 Somali, Oromia, SNNP, and Benishangul-Gumuz and also have the lowest level of health service
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9 393 utilization (30). The rural area of the country has less healthcare coverage and utilization than the
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11 394 urban areas. The coverage of all basic vaccination is 43% in the country. Across the regions, the
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13 395 coverage of all basic vaccination is lowest in Afar (20%) and highest in Addis Ababa (83%).
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15 396 Coverage of pentavalent vaccines in children is 72% among the urban population while it is 56%
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17 397 among the rural population (15, 28). There is a variation in the performance of immunization
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19 398 across regions. Addis Ababa, Ethiopia's capital has PCV3 coverage of 93% among 1-year-olds in
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21 399 2019, whereas this coverage is only 23% in Afar and Somali. The wasting rate in Somali was 21%
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23 400 in children under five, while it was just 2% in Addis Ababa in 2019 (31)

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29 401 In addition to children, LRIs affects people older than 70 years. The number of people dying from
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31 402 LRIs increased over the years in people older than 70 years, partly due to the increase in the aging
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33 403 population. However, the mortality rate declined by 30% between 1990 and 2019 (3, 32). The
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35 404 incidence rate did not show a significant improvement across the study years, showing only 15%
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37 405 reductions between 1990 and 2019. Among the regions, Somali and Afar have recorded an
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39 406 increased incidence rate between 1990 and 2019. This could partly be explained by poor
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41 407 accessibility and availability of health facilities in the regions (31).

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45 408 Wasting, stunting, and underweight were major risk factors contributing to the death of children
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47 409 younger than five years due to LRIs (33-35). More than 37% of children under five are stunted,
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49 410 with a higher percentage in rural areas (41%) than in urban areas (26%). Similarly, the prevalence
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51 411 of child underweight and wasting is 21% in the rural and 7% in the urban parts of Ethiopia (36).
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53 412 This indicates that more investment is needed to reduce the burden on malnutrition among children
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3 413 and in the rural parts of the country to attain better health outcomes, protecting against LRIs.
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5 414 Although the prevalence of stunting, wasting, and underweight has decreased markedly over time,
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7 415 they are still major risk factors for death caused by LRIs. In the Millennium Development Goals
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9 416 (MDG) era, between 1990 and 2015, about half of the deaths averted due to LRIs were attributed
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11 417 to improvement in the nutritional status of children (reduction in wasting and stunting) (15).
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15 418 Ambient particulate matter and household air pollution from solid fuel use were the two essential
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17 419 components of air pollution. Household air pollution from solid fuel use the was the second
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19 420 leading risk factor for LRIs, and ambient particulate matter is the eight leading risk factor among
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21 421 the top ten risk factors for LRIs (37-39). This indicates that improvement in socio-demographic
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23 422 factors will have a more substantial contribution as the use of electricity and natural gas for cooking
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25 423 increases (3).
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30 424 To reduce the burden of LRIs, both national and global efforts are underway. The Global Action
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32 425 Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD), established by the
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34 426 World Health Organization, set goals in 2013 to reduce child LRI mortality rates to below 3 in
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36 427 1,000 live births and to reduce severe LRI incidence by 75% of the 2010 baseline by 2025. To
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38 428 achieve these goals, reaching 90% of children with full-dose vaccine coverage, 90% access to
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40 429 pneumonia treatment, 50% coverage of exclusive breastfeeding in the first six months, and
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42 430 exclusive breastfeeding promotion were set as prerequisites (17). However, a 6% average annual
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44 431 mortality reduction was recorded between 2000 and 2018 in Ethiopia. With this, the country can
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46 432 only reach the 2025 GAPPD target in 2035, ten years behind the target, according to the Maternal
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48 433 and Child Epidemiology Estimation Group (MICE) estimation (28).
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53 434 Ethiopia's major health sector strategic plan, the Health Sector Transformation Plan-2 (HSTP-2)
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55 435 for the year 2021-2024, aims to reduce the infant mortality rate to 35, the neonatal mortality rate
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3 436 to 21 and the children under-5 mortality rate to 43 per 1,000 live births. Similarly, the 2030
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5 437 Sustainable Development Goals (SDG) has set targets to reduce childhood mortality significantly.
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7 438 These targets can be achieved if the country implements high-impact priority curative and
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9 439 preventive interventions against LRIs (40). To achieve this, concerted action to improve policies,
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11 440 increase investment, foster innovations, and scale-up evidence-based interventions has paramount
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13 441 importance. Parallel to this, an estimated \$274 billion for health is required to achieve the health-
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15 442 related SDGs by 2030 in 67 low and middle-income countries, including Ethiopia. One of the
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17 443 strategies to mobilize the needed resources is to increase government expenditure by 15% and
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19 444 share the population's costs through taxes or insurances (41).
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24 445 This study is not without limitations; limitations in the GBD methods also apply to this study. One
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26 446 of the limitations is the incompleteness of data. A previously conducted study showed that most
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28 447 countries in Africa, including Ethiopia, have had a vast amount of incomplete vital records data
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30 448 (42). This increases the uncertainty in the estimates, which might compromise the accuracy of the
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32 449 findings and reduce the use of these findings for policy decision-making (1). However, to improve
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34 450 the quality of the estimates, the best available data are used and GBD estimates are continuously
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36 451 updated.
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41 452 **Conclusion**

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45 453 Despite the substantial reduction in morbidity and mortality at national and regional states, LRIs
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47 454 still remain one of the leading causes of the burden of disease in Ethiopia. Children and elders are
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49 455 still disproportionately affected by LRIs. The burden of illness and death due to LRIs varies across
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51 456 regional states in Ethiopia, with lower rates in cities and predominantly urban areas while
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53 457 predominantly pastoralist areas of the country have higher rates. Efforts should be made to tackle
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3 458 the major risk factors contributing to death by LRIs. Improving child nutrition, access to
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5 459 immunization and curative health services, as well as universal electrification to reduce indoor air
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7 460 pollution will be very useful strategies to reduce deaths due to LRIs in Ethiopia. Furthermore,
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10 461 improvement in socioeconomic factors will also help to reduce LRI burden at national and regional
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12 462 levels. To reach the targets set at the national and international level, mobilizing resources to health
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14 463 and improving the provision of health services to the community according to the needs of the
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17 464 regions is of paramount importance.

20 465 **List of abbreviations**

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23 466 EPHI: Ethiopian Public Health Institute; GAPPD: Global Action Plan for the Prevention and
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25 467 Control of Pneumonia and Diarrhoea GBD: Global Burden of Disease; GHO: Global Health
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27 468 Observatory; HSTP: Health Sector Transformation Plan; ICCM: integrated community case
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29 469 management; IHME: Institute of Health and Metric Evaluation; LRIs: Lower Respiratory
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31 470 Infections; NDMC: National Data Management Center for health; PCV: Pneumococcal Conjugate
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33 471 Vaccine; SDG: Sustainable Development Goals; SNNPs: Southern Nations, Nationalities and
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35 472 Peoples; UI: Uncertainty Interval; WHO: World Health Organization; YLL: Years of Life Lost.

40 473 **Ethics approval and consent to participate**

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42 474 This manuscript was produced as part of the GBD Collaborator Network and in accordance with
43
44 475 the GBD Protocol.

48 476 **Consent for publication**

49
50 477 Not applicable.

54 478 **Availability of data and material**

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3 479 All relevant data are submitted with this manuscript.
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7 480 **Competing interests**

8
9 481 The authors declare that they have no competing interests.
10

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16
17 485 data analysis, data interpretation, or the writing of the report.
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21 486 **Authors' contributions**

22
23 487 Please see appendix section C for more detailed information about individual author contributions
24
25 488 to the research, divided into the following categories: providing data or critical feedback on data
26
27 489 sources; developing methods or computational machinery; providing critical feedback on methods
28
29 490 or results; drafting the manuscript or revising it critically for important intellectual content; and
30
31 491 managing the estimation or publications process
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36 492 **Declarations**

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46 496 The authors have no acknowledgements to declare
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3 637 *Figure 1: Incidence of lower respiratory infections per 100,000 people in Ethiopia and its regions*
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5 638 *in 2019.*

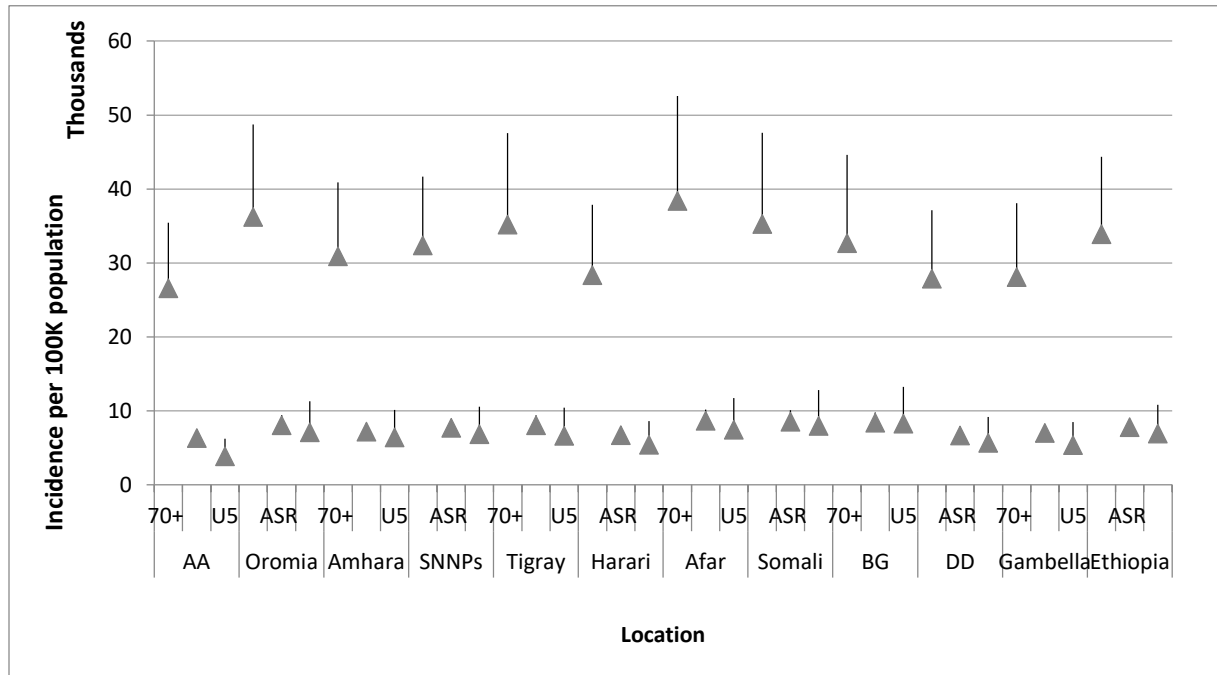
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8 639 *Figure 2: Trend in age-standardized incidence rate of LRIs per 100,000 people in Ethiopia,*
9 640 *1990-2019*

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11 641 *Figure 3: Trend in LRIs age-standardized mortality rates per 100,000 people in Ethiopia, 1990-*
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13 642 *2019*

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16 643 *Figure 4: Trend in LRIs age standardized years of life lost rates per 100,000 people in Ethiopia,*
17 644 *1990-2019*

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Figure 1: Incidence of lower respiratory infections per 100,000 people in Ethiopia and its regions in 2019.



Key: U5: children younger than 5 years; 70+: adults older than 70 years; ASR: Age-standardized rates; AA: Addis Ababa; DD: Dire Dawa; SNNPs: Southern Nations and Nationalities and Peoples; BG: Benishangul Gumuz

Figure 2: Trend in age-standardized incidence rate of LRIs per 100,000 people in Ethiopia, 1990-

2019

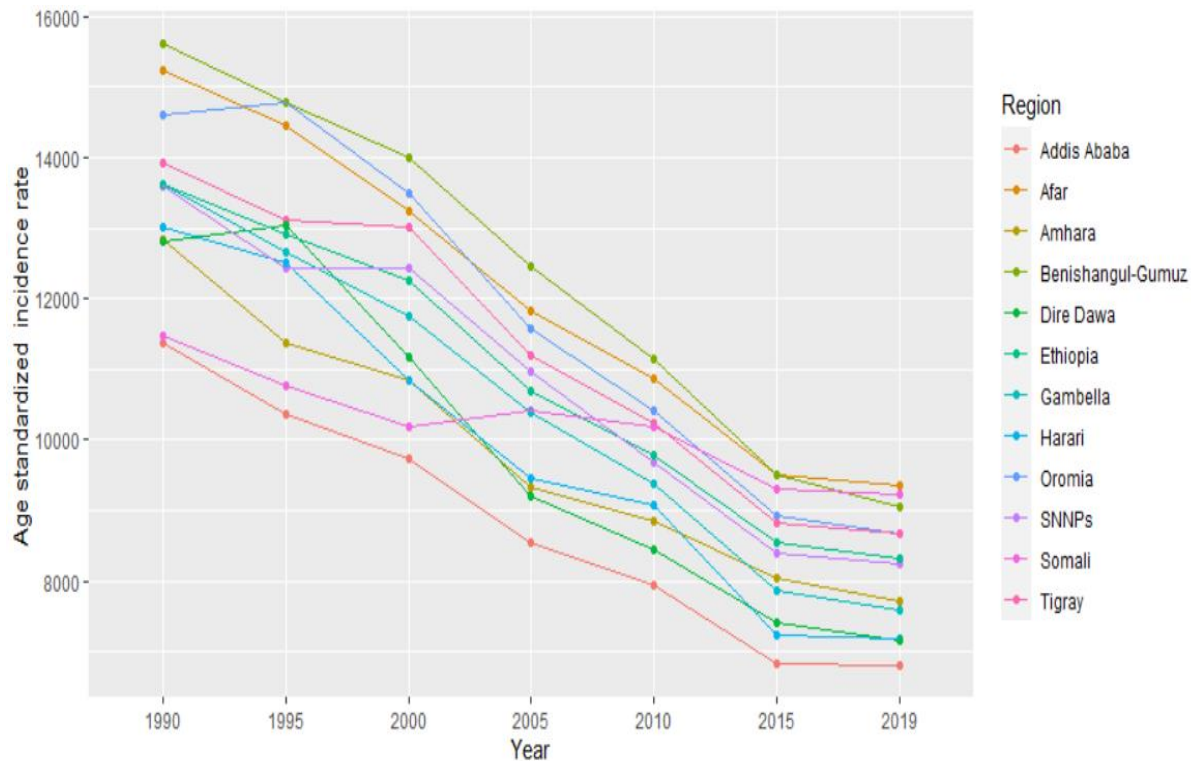


Figure 3: Trend in LRIs age-standardized mortality rates per 100,000 people in Ethiopia, 1990-2019

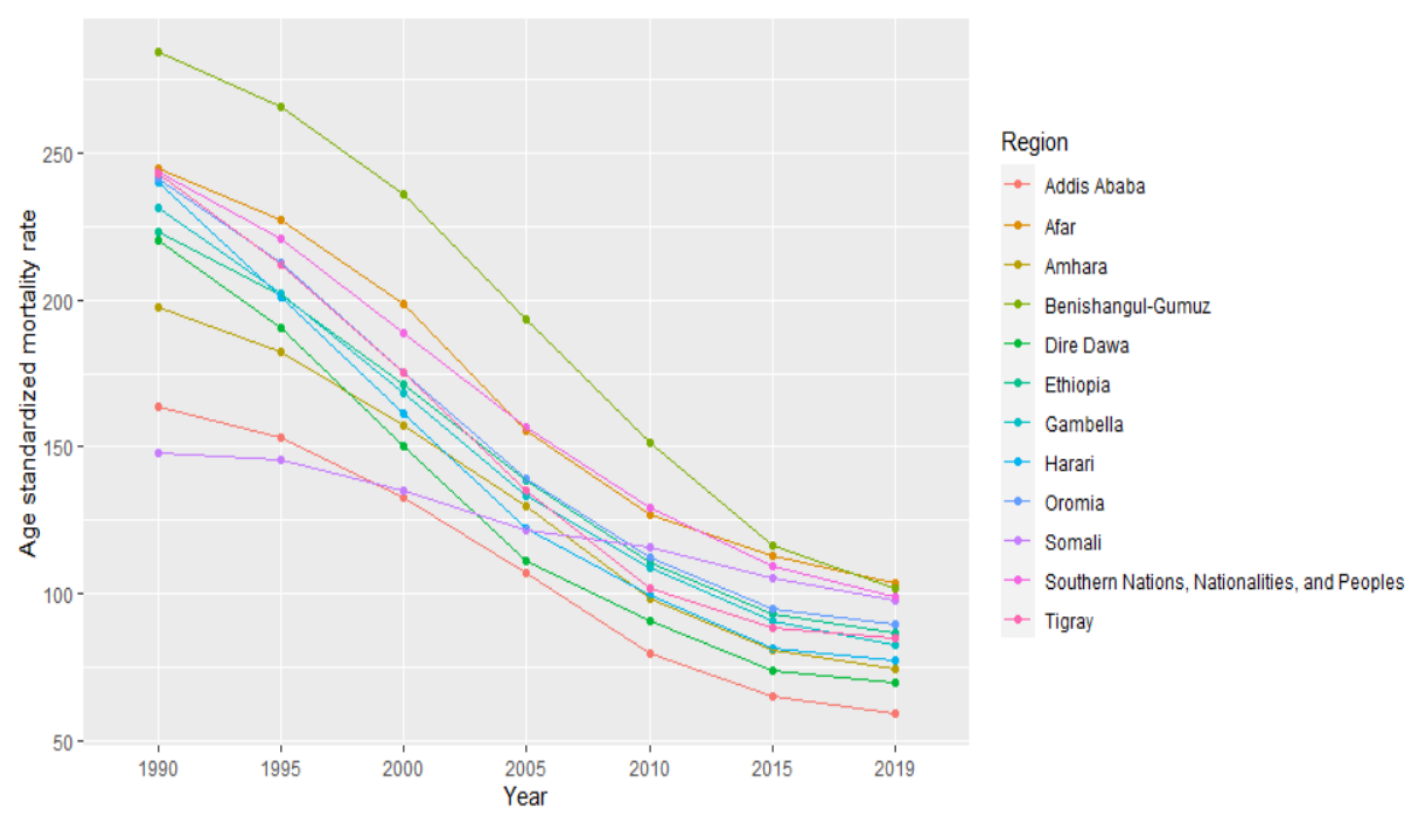
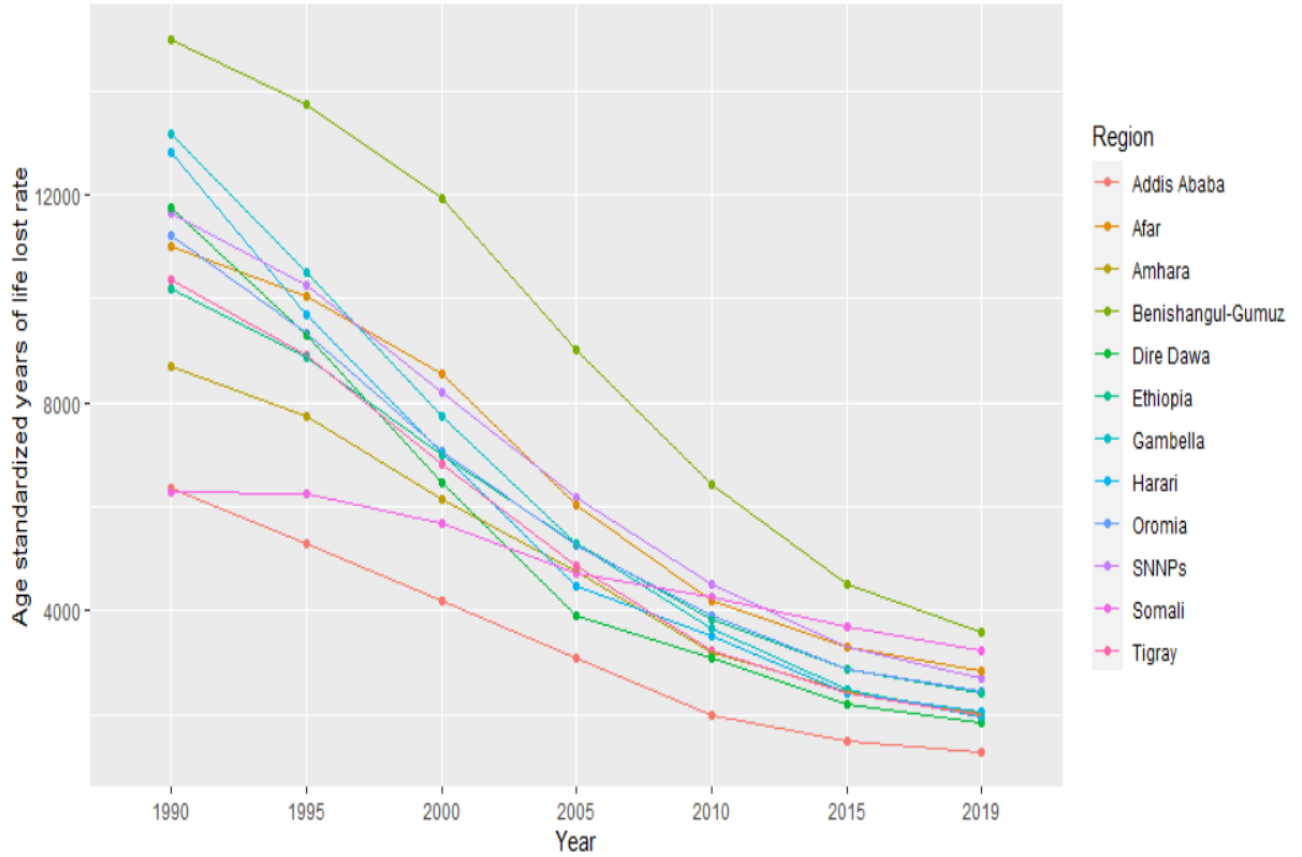
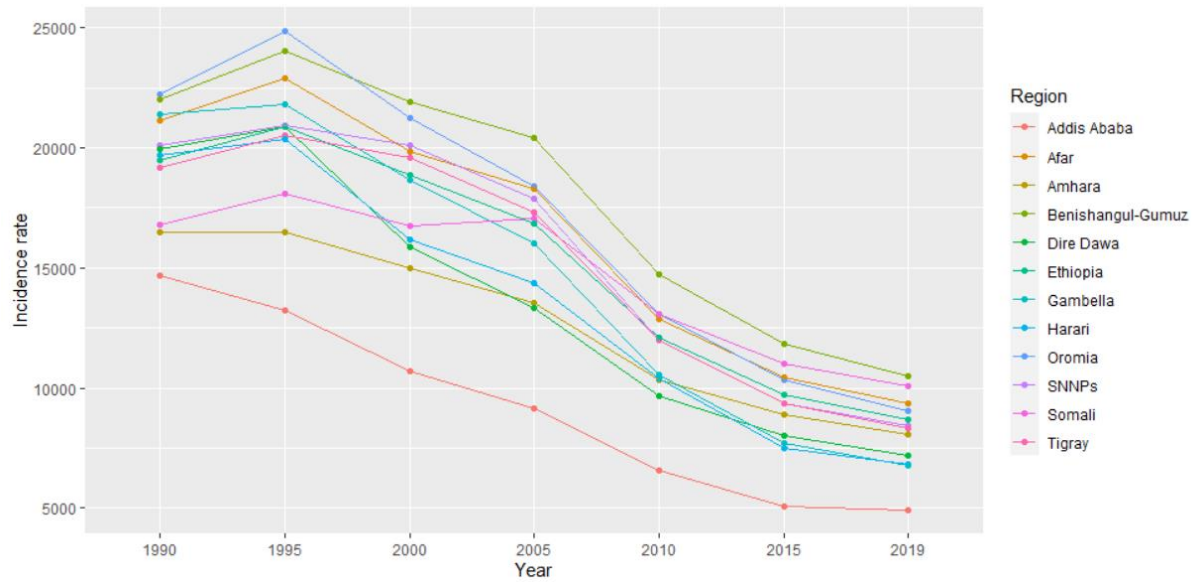


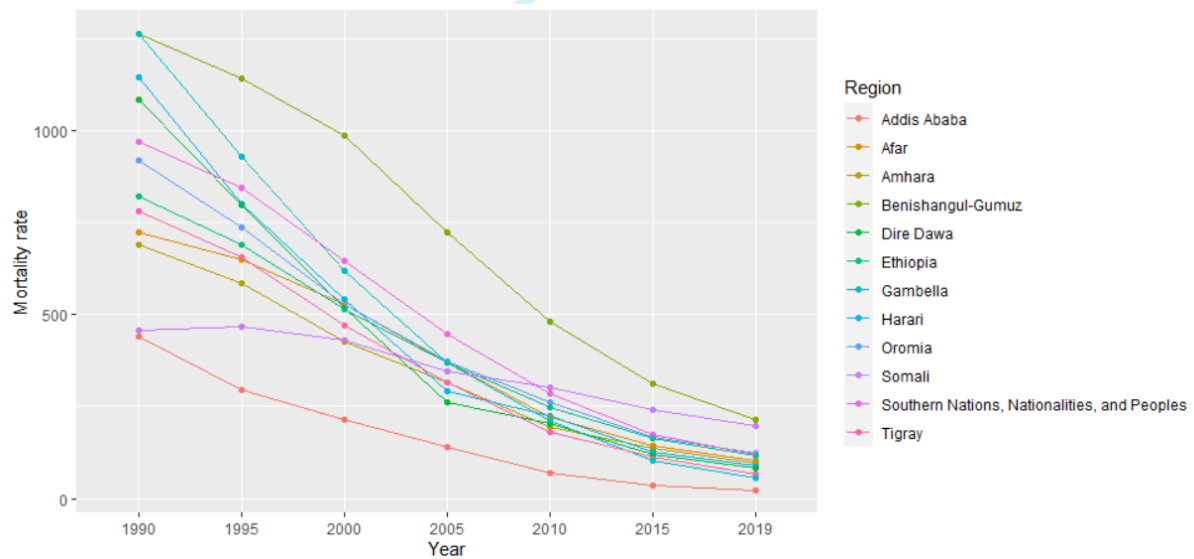
Figure 4: Trend in LRIs age standardized years of life lost rates per 100,000 people in Ethiopia, 1990-2019



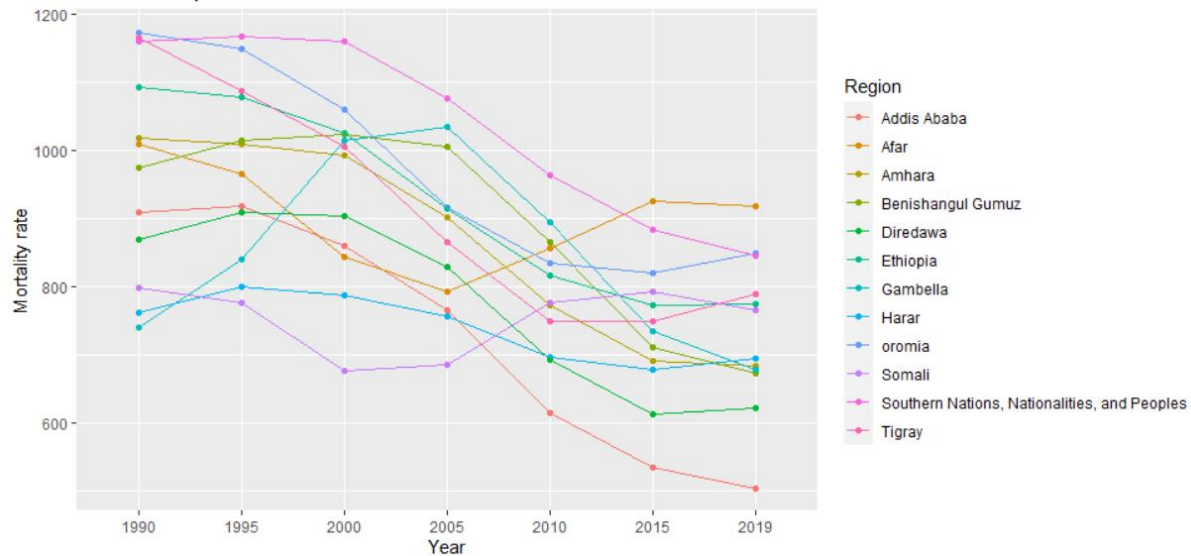
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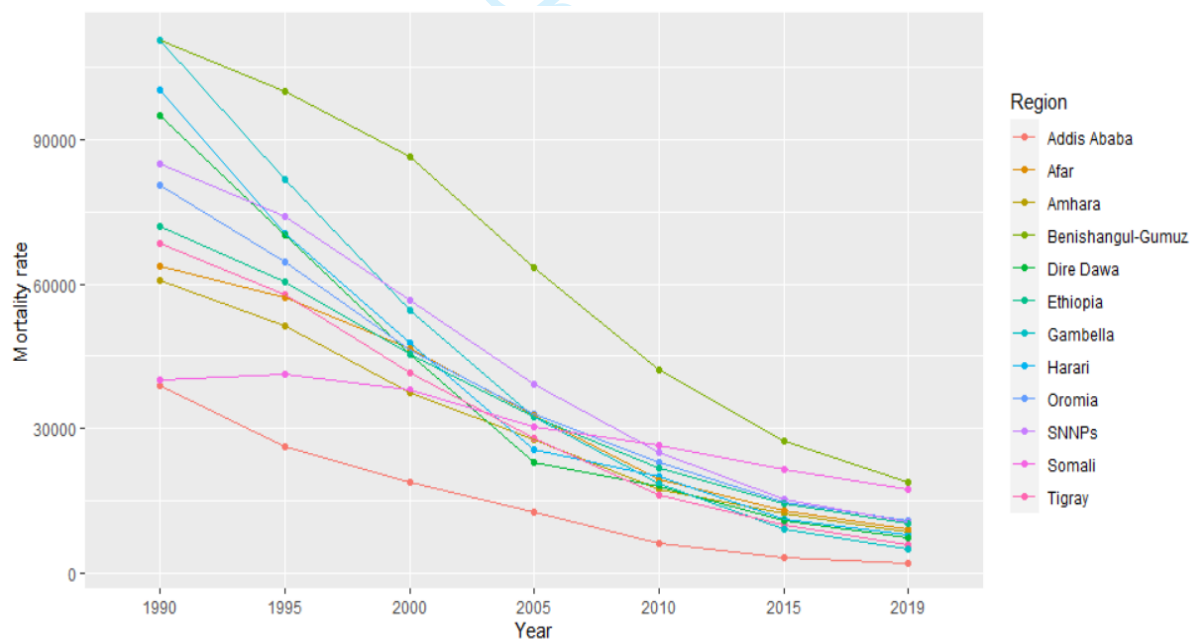
Appendix figure 1: Children under 5 years of age incidence rate per 100,000 populations due to LRI in Ethiopia, 1990- 2019



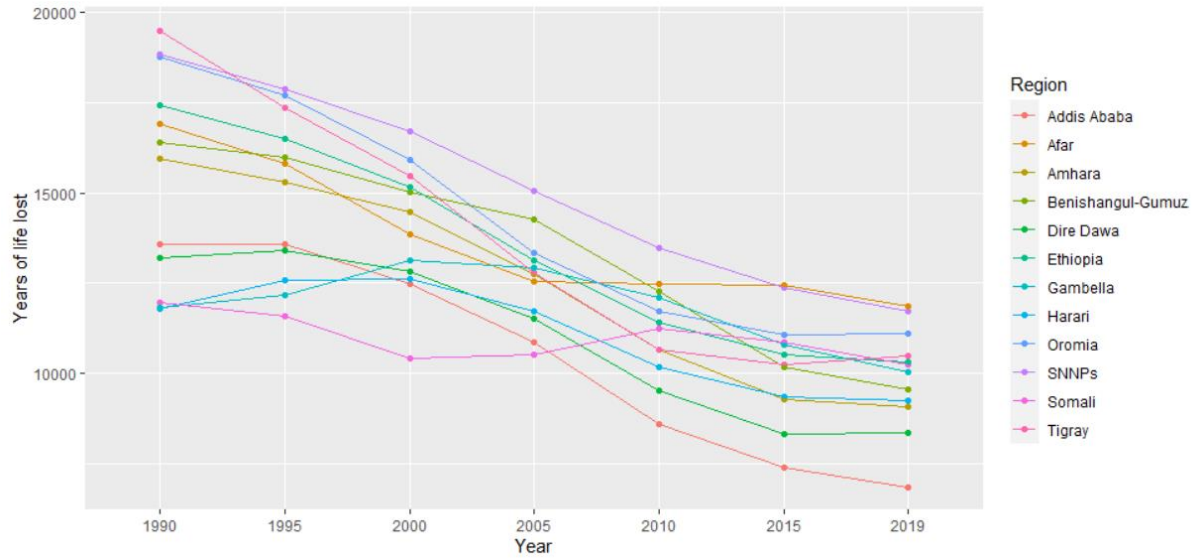
Appendix figure 2: Children younger than 5 years mortality rate per 100,000 populations for lower respiratory infections in Ethiopia, 1990-2019



Appendix figure 3: Adults older than 70 years mortality rate per 100,000 populations for lower respiratory infections in Ethiopia, 1990-2019



Appendix figure 4: Children younger than 5 years YLL per 100,000 populations for lower respiratory infections in Ethiopia, 1990-2019



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17 Appendix figure 5: Adults older than 70 years YLL per 100,000 populations for lower respiratory
18 infections in Ethiopia, 1990-2019

Location	Alcohol use	Ambient particulate matter pollution	Child stunting	Child underweight	child wasting	High temperature	Household air pollution from solid fuel	Low birth weight	Low temperature	No access to handwashing facility	Non-exclusive breastfeeding	Secondhand smoke	Short gestation	Smoking
Addis Ababa	1.4	4	0.1	0.1	0.7	0	1.7	0.7	3.7	4.8	0.1	0.4	0.7	1
Oromia	0.6	2.5	2.5	1.9	11.2	0.9	21.6	4.3	2.2	10.3	0.9	0.6	3.5	1.3
Amhara	0.4	2.5	1.8	1.4	6.7	0.9	19.8	3.3	2.4	9.5	0.4	0.6	2.6	0.4
SNNPs	0.8	2.4	2.7	2.2	10.2	1.8	19.9	3.5	1.4	9.6	0.8	0.5	2.9	0.9
Tigray	0.7	3.3	0.8	0.8	4	1.1	17.7	2.8	1.2	9.4	0.3	0.5	2.4	0.4
Harari	1	3.8	0.9	0.7	5.3	0	9.6	2.4	1.1	7.6	0.6	0.6	2.1	3.2
Afar	0.4	2.1	1.8	1.9	8.5	6.3	21	4.5	0.1	9.4	0.9	0.6	3.6	1.4
Somali	0.3	1.6	3.3	3.8	22.2	4.8	31.6	7.2	0.4	13.3	2.5	0.9	5.7	1.8
Benishangul-Gumuz	0.4	3.4	4.5	3.5	20	4.7	27.7	4.9	0.6	13.3	1.3	0.7	4	0.8
Dire Dawa	0.9	3.6	0.7	0.7	5.1	0.4	8.3	2.4	0.5	6.9	0.4	0.5	2	2.1
Gambella	0.8	2.2	0.4	0.4	3.2	2.5	9.3	2.2	0.1	5.4	0.4	0.3	1.9	2.1
Ethiopia	0.6	2.5	2.2	1.8	9.9	1.4	20.5	3.9	1.9	9.9	0.8	0.6	3.2	1

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20 Appendix figure 6: Attribution of the risk factors to LRIs death rate per 100,000 population in all
21 age groups between 1990 and 2019 for Ethiopia and its regions, both sexes, number of death, 2019.
22 SNNPs: Southern Nations, Nationalities, and Peoples.

	Ambient particulate matter pollution	child stunting	Child under weight	child wasting	high temperature	Household air pollution from solid fuels/ birth weight	Low temperature	No access to handwashing facility	Non-exclusive breastfeeding	Secondhand smoke	Short gestation	
Addis Ababa	3.63	0.82	0.64	8.35	0.00	1.75	8.86	3.29	4.27	1.32	0.31	7.98
Oromia	6.41	14.75	11.45	67.14	2.34	60.08	25.95	6.05	28.32	5.25	1.66	21.03
Amhara	5.40	13.01	9.84	48.10	2.02	46.86	23.47	5.46	21.99	2.81	1.36	18.88
SNNPs	6.36	16.67	13.77	63.88	5.03	57.68	21.95	4.12	27.49	5.28	1.38	18.31
Tigray	5.03	6.15	5.75	29.88	1.87	29.89	20.59	2.00	15.32	1.91	0.79	17.45
Harari	9.12	7.21	5.80	43.66	0.01	25.51	19.63	2.74	19.30	5.00	1.62	17.18
Afar	4.88	11.42	11.57	52.76	15.77	53.12	28.03	0.26	23.50	5.49	1.33	22.31
Somali	5.40	18.08	20.92	121.83	16.76	110.21	39.76	1.46	46.07	13.99	3.18	31.30
Benishangul-Gumuz	12.63	28.22	22.25	125.72	17.81	105.51	30.75	2.22	50.23	8.05	2.61	24.89
Dire Dawa	9.38	5.50	5.64	42.47	1.11	23.88	19.72	1.42	18.88	3.67	1.50	16.71
Gambella	4.75	3.13	3.08	25.92	6.16	23.51	18.20	0.18	13.02	2.86	0.60	15.31
Ethiopia	6.06	14.39	11.93	64.00	4.28	58.22	25.08	4.73	27.20	5.22	1.58	20.40

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25 Appendix figure 7: Attribution of the risk factors to LRIs death rate per 100,000 population in
 26 children younger than 5 years between 1990 and 2019 for Ethiopia and its regions, both sexes,
 27 number of death, 2019. SNNPs: Southern Nations, Nationalities, and Peoples.

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Appendix table 1: Number and percentage changes of episode attributable to LRIs in 1990 and 2019 for Ethiopia, its regions, both sexes

Location	All ages			Children younger than 5 years			People above 70		
	Episode, (95% UI), 1990	Episode, (95% UI), 2019	Change, %	Episode, (95% UI), 1990	Episode, (95% UI), 2019	Change, %	Episode, (95% UI), 1990	Episode, (95% UI), 2019	Change, %
Addis Ababa	194122.9(175403.8-213856.2)	176027.6(162152.3-190557.8)	10	44940.6(35673.3-56859.6)	14522.3(11237-18367.5)	68	8099.5(6891.6-9463.2)	24034.2(20749.5-27702.3)	196**
Oromia	2164243.7(1957719.5-2397957.9)	2597863.9(2372089.2-2859925.6)	20	739239.6(578477-935022.8)	613676.6(480687.2-765626.5)	17	110627.2(95303.7-129579.9)	292179.4(254670.4-342438.5)	164**
Amhara	1508431.4(1368059.8-1671550.1)	1400682.4(1285323-1530939.8)	8	423999.3(334700.8-538426.8)	261397.4(206754.7-327889.7)	39	116332.8(98774.4-137194.5)	198977.5(173809.4-229925.5)	71**
SNNPs	1235554.9(1108317.9-1368520.3)	1330491.5(1217176.7-1452694.1)	7	421825.6(335087.1-526155.2)	307771.3(248326.4-385053.7)	28	68084.5(57450-79640.8)	99723(88168.3-113438)	46**
Tigray	360795.1(328276.3-400714.9)	409829.8(376290.4-445030.2)	13	109047.9(86435.2-137691.1)	69958.2(55210.7-87468.6)	36	20653.3(17469.9-24256.6)	62677.2(53933.1-72927.6)	203**
Harari	15145.9(13618.9-16851.9)	13765.3(12657-15054.7)	10	4693.6(3691.4-5990.1)	2188.4(1723.8-2761.3)	54	307.2(259.6-357)	1614.8(1396-1863.6)	425**
Afar	113506.8(102317-126084.3)	113210.3(102987.9-124578)	1	32991.6(25672.4-42147.6)	26177.2(20744.1-32743.3)	21	2640.2(2212.5-3150.9)	7222.5(6246.8-8559.1)	173**
Somali	300306.3(268988-336331.8)	463220.4(420429.8-516009.4)	54	103526.3(81391.3-131352.8)	126089.6(99611.9-160423.3)	21**	6182.3(5316-7370.4)	30203.2(25942.8-35038.5)	388**
BG	68501.6(61804.9-75736.4)	71675.7(64972.1-79105.8)	4	20970.5(16626.7-26454.5)	18175.6(14339.5-22922.1)	14	3288.9(2784.8-3911.4)	4311.3(3743.8-5113.9)	31**
Dire Dawa	30607.1(27359.8-34252.2)	26221.1(24010.1-28647.8)	15	9547.4(7523-12185)	4387.7(3439.6-5583.9)	55	1274.8(1090.1-1483.5)	2840.1(2469-3289.5)	122**
Gambella	19687.9(17723.9-21945.7)	25685.2(23516.6-28093.2)	30**	6747.7(5338.7-8613.7)	4335.4(3428.4-5400.9)	36	1568.1(1316.6-1825.8)	1489.6(1281.4-1737.3)	6
Ethiopia*	6010904.2(5467801.6-6648644.3)	6628673.6(6108786.2-7230986.3)	10**	1917530.8(1518850.1-2400978.5)	1448680.4(1150089.8-1799704.4)	25	339059.4(293491.9-387514.2)	725273.3(640315.4-837746.3)	113**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 1990 and 2019

Appendix table 2: Rate and percentage changes of episodes attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes

Location	Age standardized			Children younger than 5 years			People above70		
	Episode per 100,000 people (95% UI),1990	Episode per 100,000 people (95% UI),2019	Change,%	Episode per 100,000 people (95% UI),1990	Episode per 100,000 people (95% UI),2019	Change,%	Episode per 100,000 people (95% UI),1990	Episode per 100,000 people (95% UI),2019	Change,%
Addis Ababa	11373(10484.2-12197.4)	6788.1(6285.1-7339.1)	40	14666.9(11642.4-18556.9)	4927.2(3812.5-6231.8)	67	35138(29897.7-41054.2)	30748.4(26546-35441.2)	13
Oromia	14613.1(13525.9-15725.8)	8659.9(8040.1-9411.6)	41	22232(17397.2-28120)	9039.4(7080.5-11277.7)	60	46498.3(40057.6-54464.4)	41564.6(36228.7-48714.4)	11
Amhara	12826.4(11830-13882.8)	7716.9(7162.3-8321.3)	40	16487.1(13014.7-20936.6)	8061.7(6376.4-10112.3)	52	43580(37002.4-51395.2)	35377.7(30902.9-40880.2)	19
SNNPs	13591.9(12538.6-14646.8)	8235.5(7670.5-8846.4)	39	20106.4(15972-25079.3)	8427.1(6799.4-10543.2)	59	44628.1(37657.5-52203.1)	36616.1(32373.5-41652)	18
Tigray	13927.2(12858.2-15100.7)	8663.8(8034-9382.3)	38	19185.4(15207-24224.8)	8342.1(6583.5-10430.1)	57	43748.4(37005.1-51381)	40859(35158.8-47541.2)	7
Harari	13014.6(11941-14066.7)	7190.5(6684.1-7718.6)	45	19672.6(15471.9-25106.9)	6821.6(5373.5-8607.3)	66	33916.7(28665.1-39416.7)	32797.4(28354-37850.7)	4
Afar	15245.7(14050.8-16525.6)	9350.1(8648.8-10157.4)	39	21151.6(16459.1-27021.7)	9365.5(7421.7-11714.7)	56	39849(33393.8-47557.2)	44368.7(38375.2-52580.1)	11**
Somali	11482.7(10638.1-12368.7)	9220(8515.8-10046.3)	20	16792.9(13202.4-21306.6)	10062.7(7949.6-12802.8)	41	32748.3(28159.7-39042.1)	41031.2(35243.4-47600)	25**
BG	15628.1(14481-16809.3)	9054.6(8394.2-9766)	42	22041.1(17475.5-27805)	10481.8(8269.5-13219)	53	42911.6(36334.5-51032.5)	37592.7(32643.9-44591.2)	13
Dire Dawa	12806.6(11807.9-13871.4)	7148.8(6634.6-7750.7)	44	19968.2(15734.3-25484.7)	7191.5(5637.6-9152.1)	64	38333(32779.4-44607)	32033.6(27847.4-37101.4)	17
Gambella	13623.1(12637.4-14572.4)	7575.8(7002.3-8128.2)	44	21419.8(16947.2-27343.2)	6791.1(5370.4-8460.1)	69	40197.8(33751.8-46803.7)	32657.1(28093.9-38087.2)	19
Ethiopia*	13619.7(12640.8-14588.6)	8313.7(7757.6-8918)	39	19486.4(15434.9-24399.3)	8685.3(6895.1-10789.8)	56	44092.2(38166.5-50393.4)	38394.4(33896.9-44348.5)	13

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

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Appendix table 3: Number and percentage changes of death attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes.

Location	All age			Children younger than 5			People above 70 years		
	death, (95% UI),1990	death, (95% UI),2019	Change,%	death, (95% UI), 1990	Death, (95% UI),2019	Change, %	Death , (95% UI),1990	Death, (95% UI),2019	Change,%
Addis Ababa	2159.3(1731.9-2690.7)	918.8(767.4-1116.9)	58	1353(981.9-1846.7)	69.1(41.7-107.4)	95	209.5(154.3-291.5)	393.6(320.9-495.3)	87**
Oromia	40004.4(29432.4-51942.2)	18206.1(15193.3-21745.4)	55	30614.3(20932.5-42033.5)	8306.2(5763.5-11611.8)	73	2793.5(2005.1-3673)	5971.6(4831.7-7093.4)	113**
Amhara	25449.3(20869.5-30724.8)	9525.5(7530.5-11872.2)	63	17780.1(13674.3-22720.1)	3079.5(1805.3-4737.3)	83	2717.2(2016.4-3535.8)	3839.9(3022.6-4825.6)	41**
SNNPs	26044.7(20108-33017)	9494.7(7713.5-11649)	-64	20390.6(14627.6-26712.9)	4326.6(2891.3-6157.2)	79	1771.7(1254.5-2417.6)	2302.6(1867.3-2772.8)	29**
Tigray	6463.8(5272.1-7762.9)	2551.4(2090.3-3028.6)	61	4436(3373.5-5736)	564.2(364.9-825)	88	550.8(395.7-749.1)	1209.7(978.5-1467.8)	119**
Harari	336(233.3-448.8)	93.1(73.8-116)	73	273.5(174.1-382.7)	28.8(16.4-44.3)	90	6.9(3.7-11)	34.1(27.1-41.8)	395**
Afar	1717.5(1300.7-2243.4)	706.2(567.7-869.6)	-59	1128.9(751.1-1596.7)	284.2(182.5-426)	75	66.9(43.5-102.1)	149.3(117.3-186.6)	123**
Somali	3603.8(2620-4713.6)	3907.5(3007.4-4959.4)	#N/A	2811.1(1929.6-3874.8)	2472.2(1695.2-3506.8)	13	150.8(98-222.3)	563.1(433.4-715.8)	273**
BG	1549.2(1131.1-2097)	619(470.7-803)	61	1204.8(805.6-1703.9)	373(245.3-539.3)	70	74.7(50.3-105.7)	77(61.1-97.3)	3**
Dire Dawa	632.3(445.5-830.9)	154.6(120.6-193.8)	76	518.4(329.5-718.7)	51(27.3-82.9)	91	28.8(20.1-40)	55(44-67.9)	90**
Gambella	475.9(328.5-635.7)	123.2(98.2-151.9)	75	398.6(253.7-555.7)	36.4(20.7-57.2)	91	28.8(18.6-41.9)	30.9(24.6-38.1)	7**
Ethiopia*	108436.6(87669-132758.3)	46300.7(39515.8-54642.2)	58	80909.9(62491.6-103448.8)	19591.8(14018.4-26899)	76	8400.1(6490.3-10700.9)	14627.6(12393.7-16892.8)	74**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

Appendix table 4: Age standardized mortality rate, Ethiopia and its regions, by sex, 2019.

Age standardized mortality rate per 100,000 people, 2019		
Location	Female	Male
Addis Ababa	47(35.5-62.5)	73.6(55-98.3)
Oromia	77.3(62-92.4)	100.3(79.9-123.5)
Amhara	57.9(44.1-73.7)	92.5(70.5-122.1)
SNNPs	79.2(63.5-95.2)	118.8(94.3-146.3)
Tigray	73.2(55.9-93.5)	96.9(74.8-122.3)
Harari	63(49-79.9)	95.7(72.5-123.4)
Afar	112.4(87.3-142.3)	98.7(76.9-127.3)
Somali	88.3(69-111.4)	101.7(77.2-130.7)
Benishangul-Gumuz	109.2(82.6-138.8)	95.8(74.6-124.1)
Dire Dawa	56.2(42.5-71.3)	85.4(67.3-109.5)
Gambella	47.9(34.6-60.1)	120.2(95.6-149.5)
Ethiopia	71.8(60.2-82.9)	100.6(84-121.4)

SNNP: Southern Nations, Nationalities, and Peoples

Appendix table 5: Number and percentage changes of YLL attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes

	all age			Children younger than 5 years			People above 70		
	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%
Addis Ababa	149543.9(115542.6-195437)	29703.1(23833.4-36855.7)	81	118961.7(86499.1-162678.7)	6098.2(3693.1-9483.3)	95	3131.8(2301.7-4374.6)	5359.8(4334.8-6816.8)	71**
Oromia	3019031.9(2144916.2-4057496.3)	981808.4(748459.2-1278135)	68	2680397.2(1832260.4-3680767.1)	729313.8(506226.4-1021016.9)	73	44619.5(31636-59105.6)	78166.1(62837.5-93527.9)	75**
Amhara	1813522.3(1445106.4-2246142.2)	428277.8(309674.7-583000.2)	77	1560078.3(1201305.4-1993362.8)	270909.2(158846-416496.1)	83	42578.2(31294.7-56216.9)	50955.1(39726.1-64844.6)	19**
SNNPs	1993643.3(1489598.4-2577052.3)	543135.8(405565.6-711397.4)	73	1785675.1(1284021-2339272.5)	380166.4(254486.8-541224.9)	79	28746.2(20086.2-39789.1)	31964.4(25673.6-38778.5)	11**

Tigray	455613.4(364406.1-569702.1)	96429.9(74139.8-122350.5)	79	389399.3(296618.1-504230.2)	49712.6(32198.3-72764.9)	88	9207.1(6568.7-12629.1)	16086.6(12946.2-19581.8)	74**
Harari	26755.3(17866.5-36380.3)	4273.6(2999.1-5798.4)	85	23959.3(15245.4-33513.8)	2541.6(1449.6-3887.3)	90	106.7(57.6-175.1)	455.9(361.3-558.3)	327**
Afar	124052(89386.4-166880.5)	39507.6(29535.5-52178.5)	69	99155.3(65972.9-140018.8)	24998.1(16028.5-37426.3)	75	1121.4(723.7-1722.7)	1931.7(1521.3-2395.6)	72**
Somali	281532.2(201275.3-374880.8)	266379.4(193669.7-357880.7)	6	247138.5(169803.8-339740.3)	216954(148995.2-307369.5)	13	2256.6(1434.6-3376.4)	7542.1(5740-9680.2)	234**
BG	119211.2(83517.3-165095.7)	42245.6(30388.8-57591.8)	-65	105463.5(70756-148983.1)	32718.1(21576.4-47307.2)	69	1256.7(836.7-1780.3)	1094.3(857.5-1389.1)	13
Dire Dawa	50024.5(33464.5-67580.6)	7267.7(5038-10264.7)	86	45377.4(28907.2-62914.9)	4497.4(2411.8-7298.3)	91	439.2(306.6-609.5)	742.1(586.6-922.8)	68**
Gambella	37680.8(24783.6-51516.1)	6064.4(4389.3-7853.6)	84	34899.5(22233.1-48609.4)	3212.2(1830.4-5034.1)	91	460.7(299.3-663.6)	457.5(352.6-577.6)	1
Ethiopia*	8070611.3(6356905.2-10091563.7)	2445093.7(1934420.8-3119838.6)	70	7090505.4(5482895.7-9059421.2)	1721122.3(1231032.1-2362958.7)	76	133924.6(102756.8-170932.9)	194756.2(165462-225502.1)	45**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

Appendix table 6: Rate and percentage changes of YLL attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes.

Location	all age			Children younger than 5 years			People above 70		
	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%
Addis Ababa	6362.2(5161.9-7847.9)	1285.6(1065-1561.8)	80	38824.7(28230.1-53092.4)	6857.1(5545.8-8721.2)	95	13587(9985.4-18978.3)	6857.1(5545.8-8721.2)	50
Oromia	11217.6(8517-14318)	2433.8(2042.2-2879.5)	78	80610.7(55103.7-110696)	11119.7(8939.1-13305)	87	18754.2(13297.1-24843)	11119.7(8939.1-13305)	41
Amhara	8690.4(7146.3-10453.8)	2016.4(1551.4-2541.8)	77	60663.3(46712.5-77511.5)	9059.7(7063.2-11529.2)	87	15950.4(11723.4-21059.7)	9059.7(7063.2-11529.2)	44
SNNPs	11633(9119.4-14477.9)	2698.1(2243.5-3250.2)	77	85114.7(61203.2-111502.1)	11736.6(9426.7-14238.6)	88	18842.6(13166.1-26081)	11736.6(9426.7-14238.6)	38
Tigray	10346.4(8522.9-12340.3)	1977.1(1593.9-2395)	81	68509.3(52185.7-88712.2)	10486.8(8439.5-12765.3)	92	19502.8(13914.1-26751.2)	10486.8(8439.5-12765.3)	47
Harari	12826.5(9336.5-16985.4)	2060.4(1595.6-2623.1)	84	100421.7(63898.7-140467.8)	9260.4(7338.7-11340.3)	93	11782.6(6360.4-19341.1)	9260.4(7338.7-11340.3)	22

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3 Afar	10993.5(8520.8-14193.6)	2824.6(2323-3414)	74	63570.5(42296.6-89769)	11867.1(9346-14716.9)	86	16925.5(10923.7-26001.7)	11867.1(9346-14716.9)	30
5 Somali	6286.9(4860.5-7970)	3236.4(2537.4-4006)	49	40088.1(27543.7-55109)	10246(7797.8-13150.6)	57	11953.6(7599.2-17885.5)	10246(7797.8-13150.6)	15
7 BG	14965.1(11197.4-19998.6)	3571.1(2772.4-4510.7)	76	110847.2(74368-156588.4)	9541.9(7476.9-12112.3)	83	16397.3(10917-23228.5)	9541.9(7476.9-12112.3)	42
9 Dire Dawa	11749.7(8605.4-15249.5)	1832.8(1407.3-2363.1)	84	94905.3(60458.5-131584.5)	8371(6616.3-10408.2)	93	13207.9(9219.6-18328.2)	8371(6616.3-10408.2)	37
11 Gambella	13175.8(9291-17411)	1937.4(1567.6-2344.6)	85	110783.8(70576-154304.1)	10030.9(7730.2-12664.9)	96	11811.4(7673.5-17012.5)	10030.9(7730.2-12664.9)	16
13 Ethiopia*	10189.1(8347.5-12201.8)	2404.5(2059.4-2833.3)	76	72055.4(55718.5-92064)	10309.9(8759.2-11937.6)	86	17415.9(13362.7-22228.5)	10309.9(8759.2-11937.6)	41

15 SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

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73 Abstract

74 **Objective:** This analysis is to present the burden and trends of morbidity and mortality due to
75 lower respiratory infections, their contributing risk factors, and the disparity across
76 administrative regions and cities from 1990 to 2019.

77 **Design:** This analysis used Global Burden of Disease 2019 framework to estimate morbidity and
78 mortality outcomes of lower respiratory infection and its contributing risk factors. The Global
79 Burden of Disease study uses all available data sources and Cause of Death Ensemble model to
80 estimate deaths from lower respiratory infection and a Meta-Regression Disease Modeling
81 technique to estimate lower respiratory infection non-fatal outcomes with 95% uncertainty
82 intervals.

83 **Study setting:** The study includes nine region states and two chartered cities of Ethiopia

84 **Outcome Measures:** We calculated incidence, death, and years of life lost (YLLs) due to LRIs
85 and contributing risk factors using all accessible data sources. We calculated 95% uncertainty
86 intervals (UI) for the point estimates.

87 **Results:** In 2019, LRIs incidence, death, and YLLs among all age groups were 8,313.7 (95% UI:
88 7,757.6–8,918), 59.4 (49.8–71.4) and 2,404.5 (2059.4–2833.3) per 100,000 people, respectively.
89 From 1990, the corresponding decline rates were 39%, 61%, and 76%, respectively. Children
90 under the age of five years account for 20% of episodes, 42% of mortalities, and 70% of the YLL
91 of the total burden of LRIs in 2019. The mortality rate was significantly higher in predominantly
92 pastoralist regions—Benishangul-Gumuz 101.8 (84.0–121.7) and Afar 103.7 (86.6–122.6). The
93 Somali region showed the least decline in mortality rates. More than three-fourths of under-five
94 child deaths due to LRIs were attributed to malnutrition. Household air pollution from solid fuel
95 attributed to nearly half of the risk factors for all age mortalities due to LRIs in the country.

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3 96 **Conclusion:** In Ethiopia, LRIs have reduced significantly across the regions over the years
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5 97 (except in elders), however are still the third leading cause of mortality, disproportionately
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7 98 affecting children younger than five years old, and predominantly pastoralist regions.
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9
10 99 Interventions need to consider leading risk factors, targeted age groups and pastoralist and cross-
11
12 100 border communities.

13
14
15 101 **Keywords:** *Lower respiratory infections, regions, chartered cities, Ethiopia*

16 17 18 102 **Strengths and limitations of this study**

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21 103 • The analysis has considered political, government and administrative changes of regional
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23 104 states and cities over the years to map available data and populations
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27 105 • The analysis used all available data identified through an extensive collaboration effort and
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29 106 involving more than 700 leading researchers and policy makers from Ethiopia
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33 107 • When data were not available for a particular regional states or city, the modelling process
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35 108 used data from other locations borrowing strength from geographic locations and time, and
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37 109 use predictive covariates
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41 110 • However, limited quality data availability and accessibility for the analysis resulted in wider
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43 111 95% Uncertainty Intervals which largely affect policy debates, prioritization, and health
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45 112 decisions.

46 47 48 113 **INTRODUCTION**

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52 114 Lower Respiratory Infections (LRIs) have been a predominant health problem worldwide,
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54 115 causing more than 2.3 million deaths in 2016 alone, amounting to a mortality rate of 32.2 per

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3 116 100,000 people (1). LRIs comprise diseases of the lower airways such as pneumonia, bronchitis,
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5 117 and bronchiolitis, among others (2). Nearly all (99%) of LRI deaths occur in low- and middle-
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7 118 income countries and highly affect children under the age of five years (3). In sub-Sahara
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9 119 African countries, the mortality rate is 66.4 per 100,000 people, which is four times the mortality
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11 120 rate in East Asia and twice the global average (2).

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14 121 Ethiopia ranked in the top three African countries in the number of under-five child deaths from
15
16 122 LRIs (4). To prevent child death from LRIs and other diseases in early life, Ethiopia has been
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18 123 implementing the “Integrated Management of Childhood Illness” program since 1997 later
19
20 124 scaled up to the national level in 2007 (5). LRIs, and pneumonia in particular, have been among
21
22 125 the top three leading causes of childhood mortality in the country (6). Among LRIs’ aetiologies,
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24 126 S. pneumonia contributed to more deaths than the other LRIs aetiologies combined (3). In 2011,
25
26 127 the country introduced 10-valent pneumococcal conjugate vaccine (PCV 10) into its national
27
28 128 immunization program to reduce the burden of Streptococcal pneumonia (7).

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30
31 129 Morbidity and mortality from LRIs are attributable to multiple underlying factors. Malnutrition
32
33 130 is one of the main underlying risk factors (8, 9). The other main attributable factor are poor
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35 131 living conditions that include household crowding, parental smoking, high use of household solid
36
37 132 fuel/biomass consumption, poor ventilation, and lack of hand-washing facilities (10-12). In
38
39 133 addition, bottle feeding also contributes to the burden of LRIs in children (13).

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42 134 The flagship Ethiopian Health Extension Program (HEP) has been the backbone of the country’s
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44 135 health system strategies to reduce the burden of LRIs and other diseases through preventive and
45
46 136 health promotion activities at the community level. The HEP has also improved broader access
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48 137 to health care, availability of essential antibiotics, and immunization mainly to the rural
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50 138 population since 2004 (14). In 2010, the country also introduced the “integrated community case
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3 139 management” (ICCM) approach to treat pneumonia through trained health cadres of health
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5 140 extension workers (HEWs) implementing HEP (15).

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8 141 Currently, Ethiopia is implementing its Health Sector Transformation Plan-2 (HSTP-2) which is
9
10 142 adapted from the Sustainable Development Goals. Some of the aims include increasing the
11
12 143 proportion of under-five children with pneumonia who received antibiotics from 48% to 69%
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14 144 and improving full vaccination coverage from 44% to 69% between 2020 and 2025 (16).
15
16 145 Commitment to international goals such as The Global Action Plan for the Prevention and
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18 146 Control of Pneumonia and Diarrhoea by 2025 could be reached if enough investment is made in
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20 147 high LRI burden countries like Ethiopia (17).

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23 148 As Ethiopia is a country of stark contrasts in socioeconomic, epidemiological, and geographical
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25 149 variations, estimating disease burden at the regional level could provide valid and reliable
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27 150 information to inform policy decisions, including efficient resource allocation to match the
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29 151 burden in the subnational states. Hence, this article presents the 2019 Global Burden of Diseases,
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31 152 Injuries, and Risk Factors study (GBD) results on the burden, trends and regional variations of
32
33 153 LRIs in Ethiopia from 1990 to 2019.

34 35 36 37 38 154 **METHODS**

39 40 41 42 155 **Study Setting**

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45 156 Ethiopia is the second-most populous country in Africa next to Nigeria, with an estimated
46
47 157 population of 112 million in 2019 (18). More than half of the country's population is under 20,
48
49 158 and over 80% of the population resides in rural areas (19). The country is subdivided into ten
50
51 159 regional states (Afar, Amhara, Benishangul-Gumuz, Gambella, Harari, Oromia, Somali, Sidama,
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53 160 Southern Nations and Nationalities and Peoples (SNNP), and Tigray) and two chartered cities
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3 161 (Addis Ababa and Dire Dawa). During this study, Sidama was a zonal administration under the
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5 162 SNNP region. Oromia, Amhara, and SNNP are the highly populated regions. In this study, we
6
7 163 classified the regions into urban (Addis Ababa, Dire Dawa, and Harari), agrarian (Oromia,
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9 164 Amhara, SNNP, Tigray), and pastoralist (Benishangul-Gumuz, Afar, Gambella, and Somali).
10
11 165 The socio-economy of the regions such as income per person, educational attainment, and total
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13 166 fertility rate (TFR) varies as measured in socio-demographic index (SDI) (20) (Figure 1).
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19 168 The healthcare system of the country is a three-tiered system consisting of primary, secondary,
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21 169 and tertiary levels of healthcare delivery units with 21,154 functioning health facilities and
22
23 170 159,545 health workforce in 2019 (16). The primary health care unit (PHCU) consists of health
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25 171 posts (staffed by HEWs), health centres, and primary hospitals. The secondary level of care
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27 172 consists of general hospitals and the tertiary level of care includes national referral hospitals
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29 173 which provide specialized services (16).
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34 174 **Data Sources and Analysis**

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37 175 The analysis and findings of LRIs presented in this analysis were produced by the Ethiopia
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39 176 Subnational Burden of Disease Initiative, a collaborative endeavour between the National Data
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41 177 Management Center for Health (NDMC) at the Ethiopian Public Health Institute (EPHI) and the
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43 178 Institute for Health Metrics and Evaluation (IHME), as part of GBD. The details of the
44
45 179 methodology were described elsewhere (21). In brief, woreda (district) level geographic
46
47 180 boundary mapping of regions and cities was used because woredas were relatively stable
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49 181 government structures (compared to lower or higher level administrative structures) during
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51 182 political or government changes and through the three census years (1984, 1994, and 2007).
52
53 183 First, the analysis was estimated by mapping population and demography at the district level by
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3 184 time and region. Then, the data sources were mapped by regions before processing the data in the
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5 185 GBD analysis based on GBD protocol. EPHI, in collaboration with IHME, gathered all
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7
8 186 accessible data sources by location for Ethiopia and all regions and cities that included census,
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10 187 demographic surveillance, household surveys, diseases registry, health service utilization,
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12 188 disease notification, and other data for this analysis. A comprehensive description of data
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14
15 189 sources, quality, and modelling for GBD 2019 has been reported on the following online portal:
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17 190 (<http://ghdx.healthdata.org/gbd-2019/data-input-sources>). This study outputs predates the
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19 191 COVID-19 and civil war occurred in the northern and other parts of the country and does not
20
21
22 192 include the impact of COVID-19 or civil war.

23 24 25 193 **GBD Methods and Tools**

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28 194 The GBD details are reported elsewhere (22). Diseases and injuries within the GBD were
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30
31 195 organized into levels: Level 1 being the broadest causes of death and disability to Level 4 being
32
33 196 the most specific. Within the three Level 1 causes (communicable, maternal, neonatal, and
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35 197 nutritional diseases; non-communicable diseases; and injuries), there were 174 Level 3 causes.
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37
38 198 The GBD 2019 study has estimated the burden of disease, including LRIs, for Ethiopia's national
39
40 199 and subnational states. LRIs comprise diseases of the lower airways such as pneumonia,
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42 200 bronchitis, and bronchiolitis, among others (2). LRI mortality was estimated by age, sex,
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45 201 geography, and year using a modelling platform called the Cause of Death Ensemble model. LRI
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47 202 morbidity, including incidence, was modelled using a meta-regression platform known as
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49 203 DisMod-MR, a Bayesian, hierarchical, mixed-effects meta-regression platform (23). Years of life
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51 204 lost (YLLs) were computed by multiplying cause-specific deaths by the life expectancy at the
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54 205 age of death (24, 25). Population risk assessments over time and among risks were estimated
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56 206 using the comparative risk assessment approach developed for the GBD study (26, 27). The

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3 207 GBD risk factors were categorized as follows: Level 1 risk factors are behavioural,
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5 208 environmental, occupational, and metabolic; Level 2 risk factors include 20 clusters of risks;
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7 209 Level 3 consists of 52 clusters of risks; and Level 4 contains 69 specific risk factors. All metrics
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9 210 were estimated separately for Ethiopia's nine regions and two chartered cities, and are presented
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11 211 with their 95% uncertainty intervals (UIs). All estimates produced for GBD report 95%
12
13 212 uncertainty intervals (UIs) that account for sampling and non-sampling error associated with data
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15 213 and various assumptions of the modelling process and are derived from the 2.5th and 97.5th
16
17 214 percentiles of 1000 draws(22, 28).

215 **Presentation of results**

216 We present the burden of LRIs in Ethiopia and its regional states using incidence, deaths, and
217 YLLs categorized by sex, age groups, and year. We used numbers, rates, and percent change for
218 the quantification of the burden. We also estimated the risk factors contributing to LRIs in
219 Ethiopia and the percent change between 1990 and 2019. We reported GBD causes and risk
220 factors using level 3 classifications, with 95% Uncertainty Intervals (UI). Additional tables and
221 figures are attached in the supplementary materials.

222 **Patient and public involvement**

223 Patients and the public were not involved in the design of the study.

224 **RESULTS**

225 **Morbidity Due to LRIs**

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3 226 In 2019, an estimated 6,628,673.6 (95% UI: 6,108,786.2–7,230,986.3) new cases of LRIs
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5 227 occurred in Ethiopia resulting in an age-standardized incidence rate of 8,313.7 per 100,000
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7 228 people (7,757.6–8,918). Out of the total LRI episodes, 22% (1,448,680.0 new cases
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10 229 [1,150,089.8–1,799,704.4]) of new cases occurred among children younger than 5 years, yielding
11
12 230 an annual incidence rate of 8,685.0 per 100,000 children (6,895.1–10,789.8). In adults older than
13
14 231 70 years, there were 725,273.3 (640,315.4–837,746.3) new cases of LRIs with an annual
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16 232 incidence of 38,394.4 per 100,000 people (33,896.9–44,348.5) (Figure 2; Supplemental Table 1
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18 233 and Table 2).

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21 234 Compared to national estimates, a significantly lower age-standardized incidence rate of LRIs
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23 235 per 100,000 people was observed in the chartered cities (6,788.1 [6,285.1–7,339.1] in Addis
24
25 236 Ababa, 7,148.8 [6,634.6–7,750.7] in Dire Dawa), and in Harari region (7,190.5 [6,684.1–
26
27 237 7,718.6]). The highest rates of age-standardized incidence per 100,000 people were observed in
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29 238 Afar (9,350.2 [8,648.8–10,157.4]), Somali (9,220.0 [8,515.9–10,046.4]), and Benishangul-
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31 239 Gumuz (9,054.6 [8,394.2–9,766.0]) although not significant compared to the national estimate
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33 240 (Figure 2; Supplemental Figure 1 and Table 2).

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37 241 In children younger than 5 years, the lowest incidence rates were observed in Addis Ababa
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39 242 (4,927.2 [3,812.5–6,231.8]), Harari (6,821.6 [5,373.5–8,607.3]), and Gambella (6,791.1
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41 243 [5,370.4–8460.1]) per 100,000 people, substantially below the national estimate. The highest
42
43 244 incidence of LRIs per 100,000 children were recorded in Benishangul-Gumuz (10,481.8
44
45 245 [8,269.5–13,219.0]), Somali (10,062.7 [7,949.6–12,802.8]), Afar (9,365.5 [7,421.7–11,714.7]),
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47 246 and Oromia (9,039.4 [7,080.5–11,277.7]).

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52 247 The age-standardized decline rate between 1990 and 2019 was 39% for both sexes, and it was
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54 248 56% in under-five children and 13% in adults older than 70. The lowest decline in age-

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3 249 standardized incidence rate was in Somali (19%); while it was between 38% and 44% for the
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5 250 remaining regions (Supplemental Table 2).

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8 251 In children younger than 5, the incidence rates increased slightly between 1990 and 1995, except
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10 252 in Addis Ababa and Amhara region. The highest decline rates were found between the years
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12 253 2005 and 2015 across all regions (Supplemental Figure 2).

15 254 **Mortality due to LRIs**

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19 255 In 2019, LRIs caused 46,300.7 (95% UI: 39,515–54,642) deaths in Ethiopia, giving the age-
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21 256 standardized mortality rate of 86.4 (75.3–97.6) per 100,000 people. Under-five mortality
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23 257 accounted for 42% (19,591.8 [14,018.4–26,899.0]) of all deaths due to LRIs which resulted in a
24
25 258 mortality rate of 117.4 (84.0–161.2) per 100,000 children. Of the under-five deaths, 71%
26
27 259 (13,919.0 [9,946.0–18,860.0]) occurred in the first year of life. In adults older than 70 years,
28
29 260 LRIs caused 14,627.6 (12,393.7–16,892.8) deaths, which was a mortality rate of 774.3 (656–
30
31 261 894.2) deaths per 100,000 adults (Table 1; Supplemental Table 3).

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35 262 In 2019, the number of deaths in all age groups by region were highest in Oromia (18,206
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37 263 [15,193–21,745]), Amhara (9525 [7,530–11872]), SNNP (9,494 [7,713–11,649]), and Somali
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39 264 (3,907.5 [3,007.4–4,959.4]), followed by Tigray (2,551.4 [2,090.3–3,028.6]), Afar (706.2
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41 265 [567.7–869.6]), Benishangul-Gumuz (619 [470.7–803.0]), Dire Dawa (154.6 [120.6–193.8]) and
42
43 266 Gambella (123.2 [98.2–151.9]). Harari (93.1 [73.8–116.0]) had the lowest number of deaths.
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45 267 (Supplemental Table 3).

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49 268 Between 1990 and 2019, the age-standardized mortality rate declined by 61%, and the decline in
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51 269 under-five children and adults over 70 years was 86% and 30%, respectively (Table 1 and
52
53 270 Supplemental Figure 3).

271 Table 1: Lower Respiratory Infections mortality rates and percentage changes between 1990 and 2019 in Ethiopia, both sexes, with different age
272 groups

	Age standardized		Children younger than 5			People older than 70		
Location	Deaths per 100 000 people [95% UI], 1990	Deaths per 100 000 people [95% UI], 2019	Deaths per 100 000 children [95% UI], 1990	Deaths per 100 000 children [95% UI], 2019	Change,%	Deaths per 100 000 people [95% UI], 1990	Deaths per 100 000 people [95% UI], 2019	Change,%
Addis Ababa	163.4[134.6-206.9]	59.4[49.8-71.4]	441.5[320.4-602.7]	23.4[14.1-36.4]	95	909.2[669.5-1264.6]	503.6[410.5-633.7]	45
Oromia	241.3[188.5-292.8]	89.3[75.9-103.1]	920.7[629.5-1264.1]	122.3[84.8-171]	87	1174.1[842.8-1543]	849.5[687.3-1009]	28
Amhara	197.7[163.5-236.5]	74.3[59.4-91]	691.3[531.7-883.4]	94.9[55.6-146.1]	87	1017.9[755.4-1324]	682.7[537.4-857.9]	33
SNNPs	243.7[196.4-296.9]	98.9[83.8-116.6]	971.9[697.2-1273.2]	118.4[79-168.5]	88	1161.3[584.7-822.3]	845.4[685.6-018.1]	28
Tigray	242.7[200.5-292]	84.6[69.2-100.1]	780.4[593.5-1009.1]	67.2[43.5-98.3]	92	1166.7[838.2-1586]	788.6[637.9-956.8]	33
Harari	240.2[182.6-303.1]	77[63-92.5]	1146.7[730-1604.1]	89.9[51.1-138]	93	762.3[412-1223.7]	694.3[551.9-849]	9
Afar	244.8[186.5-316.9]	103.7[86.6-122.6]	723.7[481.5-1023.7]	101.7[65-152.4]	86	1010[658-1541.7]	917.6[720.6-146.8]	10
Somali	147.6[113.8-192.6]	97.5[79.2-118.6]	455.9[313-628.5]	197.3[135-279.8]	57	798.8[519.2-1177.6]	765.1[588.8-972.4]	5
BG	284.1[221.8-358.1]	101.8[84-121.7]	1266.4[846.7-790.9]	215.1[141.4-311]	84	975.3[656.5-1379.3]	671.9[532.7-848.7]	32
Dire Dawa	220.1[171.6-270.9]	69.9[56.5-84]	1084.2[689.1-503.2]	83.7[44.7-135.9]	93	868.7[604.5-1205.5]	621.3[496.4-766.1]	29
Gambella	231.5[176.8-297.4]	82.4[68.3-97.1]	1265.5[805.4-764.3]	57[32.4-89.6]	96	739.6[477.7-1074.9]	678.3[540.4-835.3]	9
Ethiopia*	223[184.7-264.3]	86.4[75.3-97.6]	822.2[635-1051.2]	117.4[84-161.2]	86	1092.3[844-1391.5]	774.3[656-894.2]	30

273 N.B: all changes are in decreasing percent. SNNPs: Southern Nations, Nationalities, and Peoples; BG: Benishangul-Gumuz; *national estimate

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3 276 In Ethiopia, the age-standardized mortality rate was higher among males (100.6 [84.1-121.4])
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5 277 than females (71.8 [60.2–82.9]) (Supplemental Table 4).
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8 278 In 1990, the age-standardized mortality rate per 100,000 people was the highest in Benishangul-
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10 279 Gumuz (284.1 [221.8–358.1]), Afar (244.8 [186.5–316.9]) and SNNP (243.7 [196.4–296.9]),
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12 280 although it is not significantly different from the national estimate. On the other hand, the lowest
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14 281 age standardized mortality rate was exhibited in Somali (147.6 [113.8–192.6]). Although the
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16 282 value was not significantly different from the national value in 1990, Addis Ababa showed the
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18 283 second lowest age-standardized mortality rate (163.4 [134.6–206.9]) (Table 1).
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22 284 In 2019, the age-standardized mortality rate per 100,000 people was significantly lower in Addis
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24 285 Ababa (59.4 [49.8–71.4]) when compared to other regions, although not significantly lower than
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26 286 Gambella and other urban areas (Harari and Dire Dawa). Dire Dawa showed a significantly
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28 287 lower age-standardized mortality rate when compared to Benishangul-Gumuz, Afar, and SNNP.
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30 288 Compared to the national estimate, the regions of Afar (103.7 [86.6–122.6]) and Benishangul-
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32 289 Gumuz (101.8 [84.0–121.7]) recorded the highest age-standardized mortality rates per 100,000
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34 290 people, although the difference is not statistically significant (Table 1). Compared to the 1990s,
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36 291 there was a 58% to 68% decrease in the age-standardized mortality rates across all regions.
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38 292 However, the Somali region recorded a 34% reduction in mortality rates (Supplemental Figure
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41 293 3).
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46 294 Among children below the age of five, the mortality rate per 100,000 people was significantly
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48 295 lower in Addis Ababa (23.4 ([14.1–36.4]) than other regions, although it was not significantly
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50 296 less than Gambella in 2019. The mortality rate was the highest in Benishangul-Gumuz (215.1
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52 297 [141.4–311.0]), Somali (197.3 [135.2–279.8]), and Oromia (122.3 [84.8–171.0]) despite being
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54 298 not significantly higher than the national estimate (Table 1). Dire Dawa showed a significantly
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3 299 lower mortality rate than Benishangul-Gumuz and Somali. Harari had a significantly lower
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5 300 mortality rate than Benishangul-Gumuz. For all regions, the mortality rate declined for children
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7 301 younger than 5-years between 1990 and 2019 by between 84% (in Benishangul-Gumuz) and
8
9 302 96% (in Gambella), except in Somali, which showed a 57% decline (Table 1). The mortality rate
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11 303 increased slightly between 1990 and 1995 and between 2010 and 2015 in Somali region
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13 304 (Supplemental Figure 4).
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17 305 The mortality rate in adults older than 70 was the lowest in Addis Ababa (503.6 [410.5–633.7]).
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19 306 Other regions and cities have not shown a statistically significant difference from the national
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21 307 estimate. The decline in mortality rates between 1990 and 2019 is below 50% across all regions
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23 308 (Table 1). The mortality rate increased in Afar and Somali between 2005 and 2019 and in
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25 309 Gambella between 1990 and 2005 (Supplemental Figure 5).
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30 **Premature Mortality due to LRIs**

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33 311 In 2019, premature death due to LRIs was 2,445,093.7 (95% UI: 1,934,420.8–3,119,838.6)
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35 312 YLLs, yielding an age-standardized rate of 2404.5 per 100,000 people (2059.4–2833.3).
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37 313 Compared to 1990, the age-standardized YLL rate declined by 76% in 2019. In parallel, 70% of
38
39 314 all premature mortality occurred in children younger than five, which accounted for 1,721,122.3
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41 315 (1,231,032.1–2,362,958.7) YLLs. The YLL rate of 72,055.4 (55,718.5–92,064) per 100,000
42
43 316 under-five children in 2019 declined by 86% compared to the YLL rate in 1990. Adults over 70
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45 317 years contributed 8% of all YLLs due to LRIs (194,756.2 [165,462.0–225,502.1]), yielding a rate
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47 318 of 10,309.9 (8759.2–11,937.6) YLLs per 100,000 people (Table 2; Supplemental Table 5 and
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49 319 Table 6).
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3 320 Compared to 1990, the number of YLLs has decreased by 70% in all age groups and by 76% in
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5 321 children younger than five in 2019. However, the number of YLLs has increased by 45% in
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7 322 adults older than 70 (Supplemental Table 5).

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9
10 323 The age-standardized YLL rate was significantly lower in Addis Ababa (1,285.6 [1,065–
11
12 324 1,561.8]) in 2019 compared to the national average. The highest age standardized YLL rate were
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14 325 in Benishangul-Gumuz (3,571.1 [2,772.4–4,510.7]), Somali (3,236.4 [2,537.4–4,006]), and Afar
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16 326 (2,824.6 [2,323–3,414]), although not statistically significant compared to the national estimate
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18 327 (Table 2).

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22 328 In children younger than five years, Addis Ababa (2,069 [1,253–3,217.5]) had a significantly
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24 329 lower YLL rate than the national estimate. The YLL rate was observed to be the lowest in
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26 330 Gambella (5,031.8 [2,867.2–7,885.7]), although not significantly lower than the national
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28 331 estimate (Table 2).

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333 Table 2: Lower Respiratory Infections YLL rates and percentage changes between 1990 and 2019 in Ethiopia, both sexes, with different age
334 groups

Table with 9 columns: Locatio n, Age-standardized (YLL per 100,000 people, 1990 and 2019), Children younger than 5 years (YLL per 100,000 people, 1990 and 2019, Change, %), and People older than 70 (YLL per 100,000 people, 1990 and 2019, Change, %). Rows include Addis Ababa, Oromia, Amhara, SNNPs, Tigray, Harari, Afar, Somali, BG, Dire Dawa, Gambella, and Ethiopia*.

335 SNNPs: Southern Nations, Nationalities, and Peoples; BG: Benishangul-Gumuz; *national estimate

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3 337 The age-standardized premature mortality rate between 1990 and 2019 showed a continuous
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5 338 decline in all regions, except Somali. Benishangul-Gumuz showed the highest burden between
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8 339 1990 and 2019 (Figure 3).
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11 340 The change in premature mortality in children younger than five was significant throughout the
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13 341 years. However, the reduction in premature mortality among adults older than 70 was not as
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15 342 significant (Supplemental Figure 6 and Figure 7).
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18 343 **Risk Factors**

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22 344 Across all population groups, about half (48%) of the mortalities (measured in rates) due to LRIs
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24 345 in Ethiopia were attributed to household air pollution from solid fuel. In addition, lack of access
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26 346 to a hand-washing facility (23%), childhood wasting (23%), low birth weight (9%), short
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28 347 gestation period (7%), and ambient particulate matter pollution (6%) were also risk factors for
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30 348 mortality due to LRIs. The contribution of the risk factors to death due to LRIs in all regions was
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32 349 similar to the national estimate, except in Addis Ababa, where lack of access to hand-washing
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34 350 facilities, ambient particulate matter pollution, and low temperature were the main contributing
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36 351 factors. Ambient particulate matter pollution was also relatively higher in Dire Dawa, Harari,
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38 352 and Tigray regions (Supplemental Figure 8).
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43 353 In children younger than five, more than three-fourths of deaths due to LRIs were attributed to
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45 354 childhood wasting (54%) stunting (12%), and child underweight (10%) in Ethiopia. In addition,
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47 355 50% of the LRIs mortalities were attributed to household air pollution from solid fuel. Lack of
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49 356 access to hand-washing facilities (23%), low birth weight (23%), short gestation period (17%),
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51 357 high (4%) or low temperature (4%), absence of exclusive breastfeeding (4%) were also the risk
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53 358 factors with evident contribution. The distribution of risk factors varied among the regions. Child
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3 359 wasting, low birth weight, and pre-term birth were the contributing factors of mortality in Addis
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5 360 Ababa. In Harari and Dire Dawa, child wasting, lack of access to hand-washing facilities, pre-
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7 361 term birth, and household air pollution from solid fuels contributed more to the death from LRIs
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9 362 than the other risk factors in 2019. All the risk factors except for ambient particulate air matter
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11 363 and low temperature were the highest in Somali and Benishangul-Gumuz (Supplemental Figure
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13 364 9). When we examine the trend from 1990 to 2019, there is no significant reduction in the risk
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15 365 factors (Supplemental Figure 10).

20 366 **Discussion**

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23 367 The findings from this study indicate that although the burden of LRIs, measured in incidence or
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25 368 mortality rates, have shown a significant decline, they are still the third leading cause of death
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27 369 after neonatal disorders and diarrheal diseases in 2019 in Ethiopia. Cities and predominantly
28
29 370 urban areas had lower mortality rates than predominantly pastoralist regions of the country. The
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31 371 rate of decline in mortality between 1990 and 2019 varied slightly across regions and chartered
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33 372 cities. The mortality rate decreased by more than three-fourths among children under the age of
34
35 373 five and only by one-third among adults older than 70 between 1990 and 2019. Half of LRIs
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37 374 mortalities are attributed to household air pollution from solid fuels in all age groups. About
38
39 375 three-fourths of LRIs in children were attributed to malnutrition.

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41
42 376 The mortality rate of LRIs among children below the age of five has declined by 86% between
43
44 377 1990 and 2019. This decline could be attributed to improvements in living conditions, access to
45
46 378 healthcare, and immunization. The national health delivery infrastructure has grown from 2,600
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48 379 health facilities in 1997 to 21,154 facilities, including 314 hospitals, 3,678 health centers, and
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50 380 17,162 health posts and private health facilities in 2019. As a result, the health workforce has
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3 381 increased from 46,000 in 2007 to 159,545 in 2019 (16). The introduction of HEP since 2004 to
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5 382 provide preventive, health promotion, and curative treatment for pneumonia, malaria and
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7 383 diarrhoea had improved health outcomes for children (14). Moreover, Ethiopia has been
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9 384 implementing holistic child health improvement programs like IMCI since 1997 (15) and ICCM
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11 385 (5). Vaccination against *Streptococcus pneumoniae*, which is responsible for about half of the
12
13 386 LRIs mortality in African countries, with the PCV 10 vaccine since 2011 helped reduce the
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15 387 burden of LRIs (4). In addition, improved socioeconomic conditions have supported the
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17 388 reduction of the burden of LRIs in the country (29).

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19 389 Despite the achievements reached in improving child health outcomes in Ethiopia, children are
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21 390 still disproportionately affected by LRIs. Out of the total burden of LRIs, 42% of all the deaths
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23 391 were among children younger than five. In that regard, this study has shown that one out of ten
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25 392 child deaths are due to LRIs. However, another study estimated that pneumonia alone shared
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27 393 about 17% of all deaths in children younger than five years (30). Among children under five,
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29 394 children younger than one carry the highest burden of LRIs. Furthermore, the mortality rate
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31 395 among children younger than one (397.7 per 100,000 people) was more than nine times higher
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33 396 than that of children between one and four years old (43 per 100,000 people). Although most
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35 397 studies on the high burden of LRIs corroborate our findings, the findings from Global Health
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37 398 Observatory (GHO) estimated a much higher mortality rate than the estimates of this study (i.e.
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39 399 481.9 in children less than one year and 51.1 per 1000,000 population in children between one
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41 400 and four years) (8). Although we could not explain why this variation occurs, the estimates from
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43 401 GBD are also less than the estimate from findings of the Child Health Epidemiology Reference
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45 402 Group (CHERG), which is primarily due to the difference in the types of data used (31).

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3 403 Urban areas of the country, mainly Addis Ababa and Dire Dawa, had significantly lower
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5 404 mortality rates than pastoralist areas such as Benishangul-Gumuz and Somali. These regional
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7 405 variations could be attributed to gaps in availability and access to healthcare and socioeconomic
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9 406 status differences among the subnational states. A previously conducted study indicated that
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11 407 disease burden is high among people in the poorest wealth quintile and people located mainly in
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13 408 Afar, Somali, Oromia, SNNP, and Benishangul-Gumuz and also have the lowest level of health
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15 409 service utilization (32). The rural area of the country has less healthcare coverage and utilization
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17 410 than the urban areas. The coverage of all basic vaccination is 43% in the country. Across the
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19 411 regions, the coverage of all basic vaccination is lowest in Afar (20%) and highest in Addis
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21 412 Ababa (83%). Coverage of pentavalent vaccines in children is 72% among the urban population
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23 413 while it is 56% among the rural population (15, 30). There is a variation in the performance of
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25 414 immunization across regions. Addis Ababa, Ethiopia's capital has PCV3 coverage of 93% among
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27 415 1-year-olds in 2019, whereas this coverage is only 23% in Afar and Somali. The wasting rate in
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29 416 Somali was 21% in children under five, while it was just 2% in Addis Ababa in 2019 (33)
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36 417 In addition to children, LRIs affects people older than 70 years. The number of people dying
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38 418 from LRIs increased over the years in people older than 70 years, partly due to the increase in the
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40 419 aging population. However, the mortality rate declined by 30% between 1990 and 2019 (3, 34).
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42 420 The incidence rate did not show a significant improvement across the study years, showing only
43
44 421 15% reductions between 1990 and 2019. Among the regions, Somali and Afar have recorded an
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46 422 increased incidence rate between 1990 and 2019. This could partly be explained by poor
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48 423 accessibility and availability of health facilities in the regions (33).
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52 424 Wasting, stunting, and underweight were major risk factors contributing to the death of children
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54 425 younger than five years due to LRIs (35-37). More than 37% of children under five are stunted,
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3 426 with a higher percentage in rural areas (41%) than in urban areas (26%). Similarly, the
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5 427 prevalence of child underweight and wasting is 21% in the rural and 7% in the urban parts of
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7 428 Ethiopia (38). This indicates that more investment is needed to reduce the burden on malnutrition
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9 429 among children and in the rural parts of the country to attain better health outcomes, protecting
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11 430 against LRIs. Although the prevalence of stunting, wasting, and underweight has decreased
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13 431 markedly over time, they are still major risk factors for death caused by LRIs. In the Millennium
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15 432 Development Goals (MDG) era, between 1990 and 2015, about half of the deaths averted due to
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17 433 LRIs were attributed to improvement in the nutritional status of children (reduction in wasting
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19 434 and stunting) (15).

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24 435 Ambient particulate matter and household air pollution from solid fuel use were the two essential
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26 436 components of air pollution. Household air pollution from solid fuel use the was the second
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28 437 leading risk factor for LRIs, and ambient particulate matter is the eight leading risk factor among
29
30 438 the top ten risk factors for LRIs (39-41). Our analysis also showed that there is a poor progress
31
32 439 in the reductions of risk factors across the year, which shows there is a weak attempt in reducing
33
34 440 the risk factors to prevent the population from LRIs. This indicates that improved use of
35
36 441 electricity and natural gas for cooking and also appropriate investment in interventions that helps
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38 442 to reduce these risk factors will contribute to the reduction in the burden of the LRIs. (3).

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43 443 To reduce the burden of LRIs, both national and global efforts are underway. The Global Action
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45 444 Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD), established by the
46
47 445 World Health Organization, set goals in 2013 to reduce child LRI mortality rates to below 3 in
48
49 446 1,000 live births and to reduce severe LRI incidence by 75% of the 2010 baseline by 2025. To
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51 447 achieve these goals, reaching 90% of children with full-dose vaccine coverage, 90% access to
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53 448 pneumonia treatment, 50% coverage of exclusive breastfeeding in the first six months, and

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3 449 exclusive breastfeeding promotion were set as prerequisites (17). However, a 6% average annual
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5 450 mortality reduction was recorded between 2000 and 2018 in Ethiopia. With this, the country can
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8 451 only reach the 2025 GAPPD target in 2035, ten years behind the target, according to the
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10 452 Maternal and Child Epidemiology Estimation Group (MICE) estimation (30).

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12
13 453 Ethiopia's major health sector strategic plan, the Health Sector Transformation Plan-2 (HSTP-2)
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15 454 for the year 2021-2024, aims to reduce the infant mortality rate to 35, the neonatal mortality rate
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17 455 to 21 and the children under-5 mortality rate to 43 per 1,000 live births. Similarly, the 2030
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19
20 456 Sustainable Development Goals (SDG) has set targets to reduce childhood mortality
21
22 457 significantly. These targets can be achieved if the country implements high-impact priority
23
24 458 curative and preventive interventions against LRIs (42). To achieve this, concerted action to
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27 459 improve policies, increase investment, foster innovations, and scale-up evidence-based
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29 460 interventions has paramount importance. Parallel to this, an estimated \$274 billion for health is
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31 461 required to achieve the health-related SDGs by 2030 in 67 low and middle-income countries,
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33 462 including Ethiopia. One of the strategies to mobilize the needed resources is to increase
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36 463 government expenditure by 15% and share the population's costs through taxes or insurances
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38 464 (43).

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41 465 This study is not without limitations; limitations in the GBD methods also apply to this study and
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43 466 limitations on Ethiopia subnational burden of disease that includes scarcity of quality data is
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46 467 published elsewhere (28).. When data on causes of death, morbidity or risk factors were not
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48 468 available for a particular regional state such as Afar or Somali, GBD modelled estimates use data
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51 469 from other locations and predictive covariates. Data sources such as household surveys have both
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53 470 sampling and non-sampling errors that account and led a wider 95% uncertainty intervals which
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55 471 might compromise the accuracy of the findings and reduce the use of these findings for policy

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3 472 decision-making (1). Causes of mortality data sources used were mainly from verbal autopsy
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5 473 and sibling history having recall bias, broader category of causes of death report or poor
6
7 474 generalizability to regional states (44). We used the best available data identified through an
8
9 475 extensive collaboration effort and involving more than 700 leading researchers and policy
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11 476 makers from Ethiopia. The generation of estimates and their interpretation have benefited from
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13 477 intensive subnational review workshops and consultative meetings with domain experts.
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18 478 **Conclusion**

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21 479 Despite the substantial reduction in morbidity and mortality at national and regional states, LRIs
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23 480 still remain one of the leading causes of the burden of disease in Ethiopia. Children and elders
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25 481 are still disproportionately affected by LRIs. The burden of illness and death due to LRIs varies
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27 482 across regional states in Ethiopia, with lower rates in cities and predominantly urban areas while
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29 483 predominantly pastoralist areas of the country have higher rates. Efforts should be made to tackle
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31 484 the major risk factors contributing to death by LRIs. Improving child nutrition, access to
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33 485 immunization and curative health services, as well as universal electrification to reduce indoor
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35 486 air pollution will be very useful strategies to reduce deaths due to LRIs in Ethiopia. Furthermore,
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37 487 improvement in socioeconomic factors will also help to reduce LRI burden at national and
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39 488 regional levels. To reach the targets set at the national and international level, mobilizing
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41 489 resources to health and improving the provision of health services to the community according to
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43 490 the needs of the regions is of paramount importance.
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50 491 **List of abbreviations**

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53 492 EPHI: Ethiopian Public Health Institute; GAPPD: Global Action Plan for the Prevention and
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55 493 Control of Pneumonia and Diarrhoea GBD: Global Burden of Disease; GHO: Global Health
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3 494 Observatory; HSTP: Health Sector Transformation Plan; ICCM: integrated community case
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5 495 management; IHME: Institute of Health and Metric Evaluation; LRIs: Lower Respiratory
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7 496 Infections; NDMC: National Data Management Center for health; PCV: Pneumococcal
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9 497 Conjugate Vaccine; SDG: Sustainable Development Goals; SNNPs: Southern Nations,
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11 498 Nationalities and Peoples; UI: Uncertainty Interval; WHO: World Health Organization; YLL:
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13 499 Years of Life Lost.
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18 500 **Ethics approval and consent to participate**

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20 501 This manuscript was produced as part of the GBD Collaborator Network and in accordance with
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22 502 the GBD Protocol.
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26 503 **Consent for publication**

27
28 504 Not applicable.
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31 505 **Availability of data and material**

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33 506 All relevant data are submitted with this manuscript.
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36

37 507 **Competing interests**

38
39 508 The authors declare that they have no competing interests.
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41

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47
48 512 collection, data analysis, data interpretation, or the writing of the report.
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51 513 **Authors' contributions**

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53 514 Authors contribution
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3 515 Providing data or critical feedback on data sources
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17 521 Developing methods or computational machinery
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46 535 Yismaw.
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3 707 *Figure 1: Socio-demographic index, Ethiopia, 2019*
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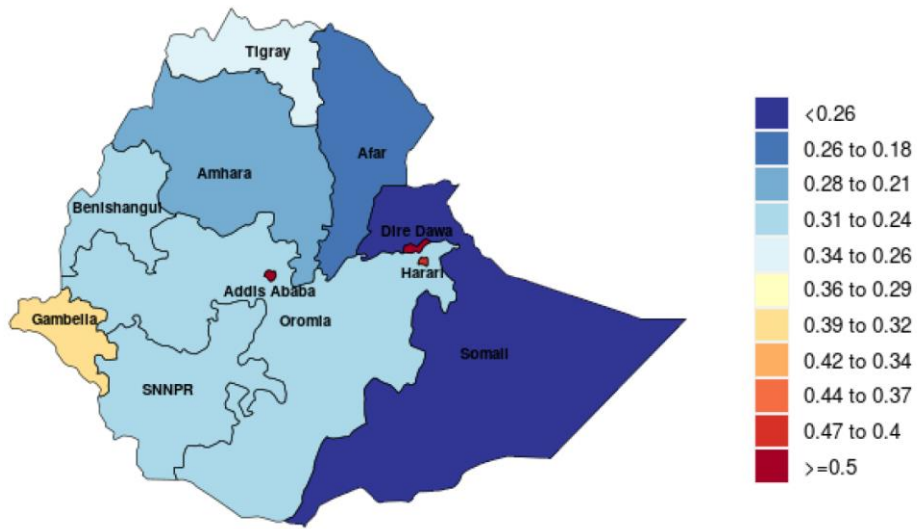
5 708 *Figure 2: Incidence of lower respiratory infections per 100,000 people in Ethiopia and its*
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8 709 *regions in 2019.*
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10 710 *Figure 3: Trend in LRIs age standardized years of life lost rates per 100,000 people in Ethiopia,*
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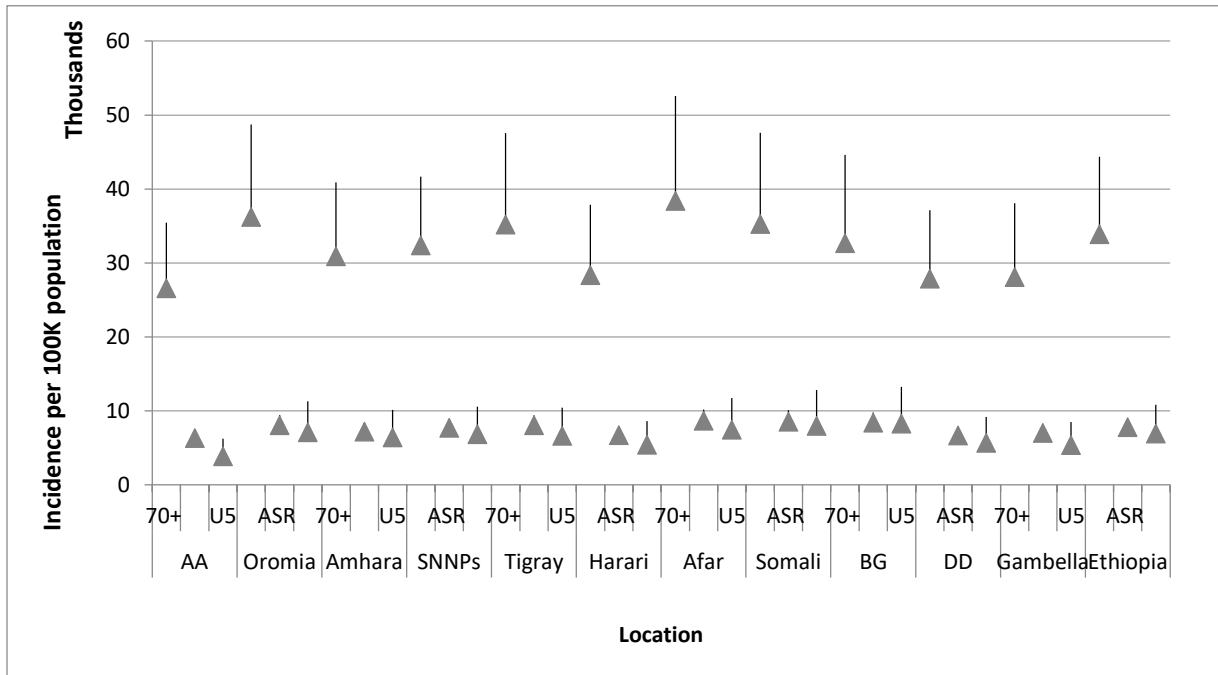
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Figure 1: Socio-demographic index, Ethiopia, 2019



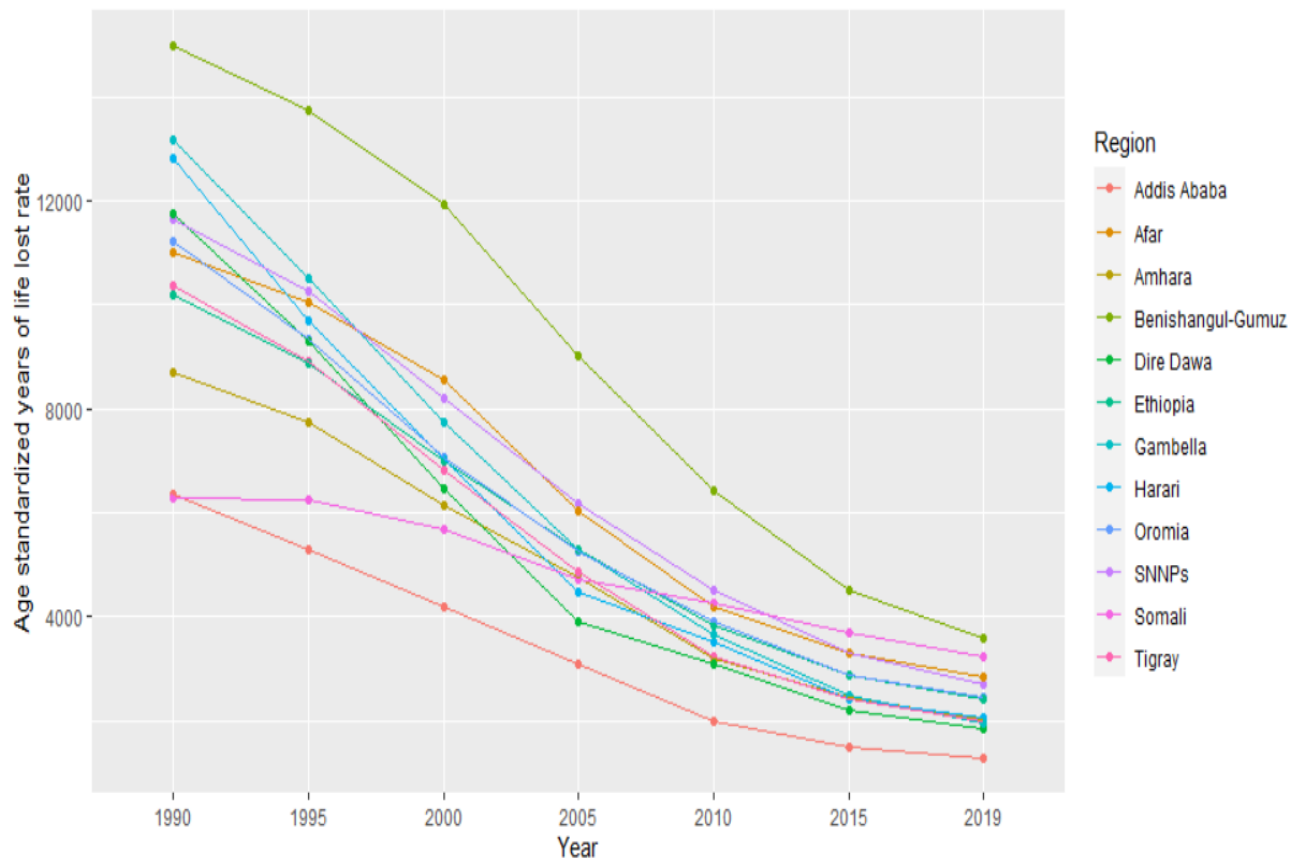
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Figure 2: Incidence of lower respiratory infections per 100,000 people in Ethiopia and its regions in 2019.



Key: U5: children younger than 5 years; 70+: adults older than 70 years; ASR: Age-standardized rates; AA: Addis Ababa; DD: Dire Dawa; SNNPs: Southern Nations and Nationalities and Peoples; BG: Benishangul Gumuz

Figure 3: Trend in LRIs age standardized years of life lost rates per 100,000 people in Ethiopia, 1990-2019



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3 **1 Supplementary material to “The burden of lower respiratory infections and associated risk**
4 **factors across regions in Ethiopia: A subnational analysis of the Global Burden of Diseases**
5 **2019 Study”**
6
7

8 This supplementary material provides supplemental figures and tables more detailed results for
9 ““The burden of lower respiratory infections and associated risk factors across regions in
10 Ethiopia: A subnational analysis of the Global Burden of Diseases 2019 Study”
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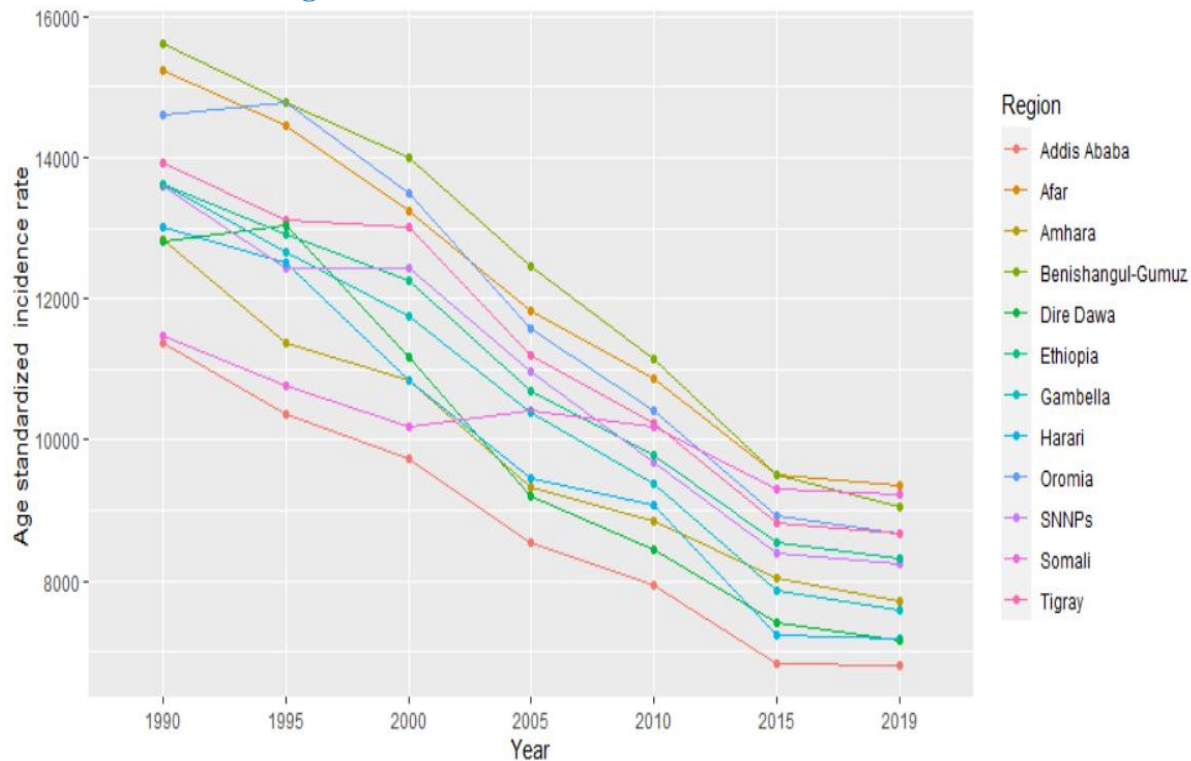
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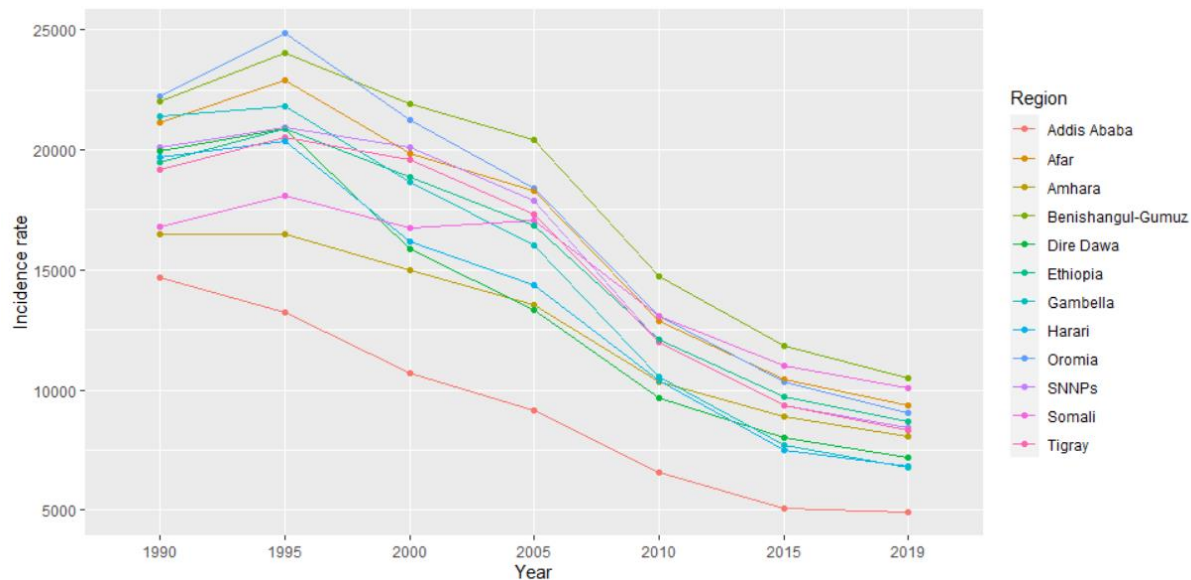


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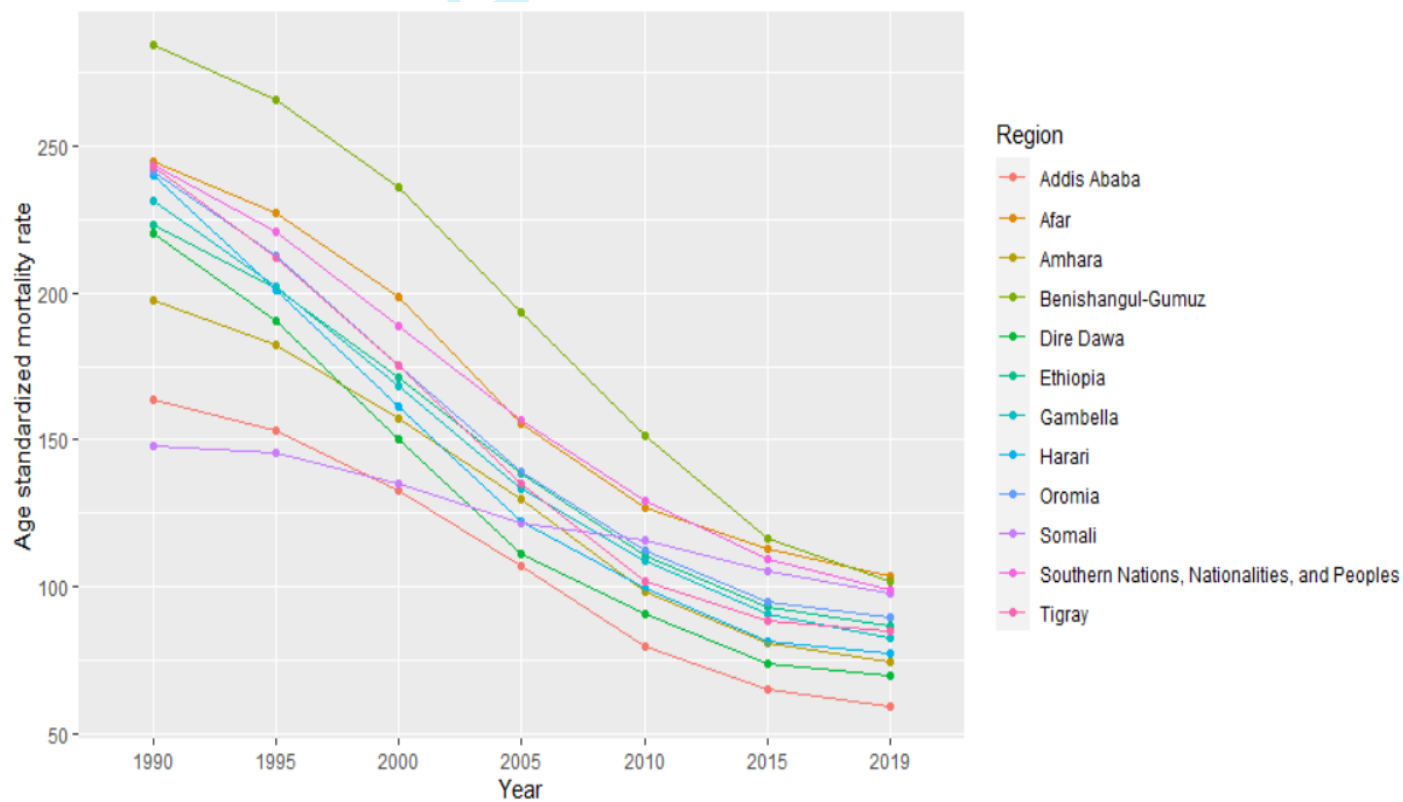
43 Supplemental Figure 1: Trend in age-standardized incidence rate of LRIs per 100,000 people in
44 Ethiopia, 1990-2019

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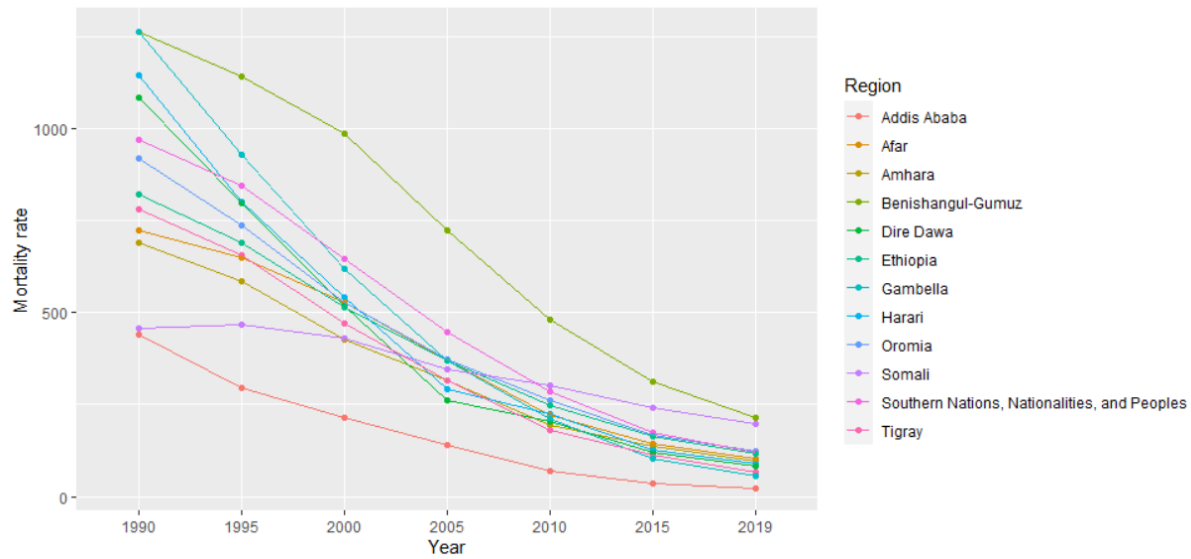
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48 to LRI in Ethiopia, 1990- 2019



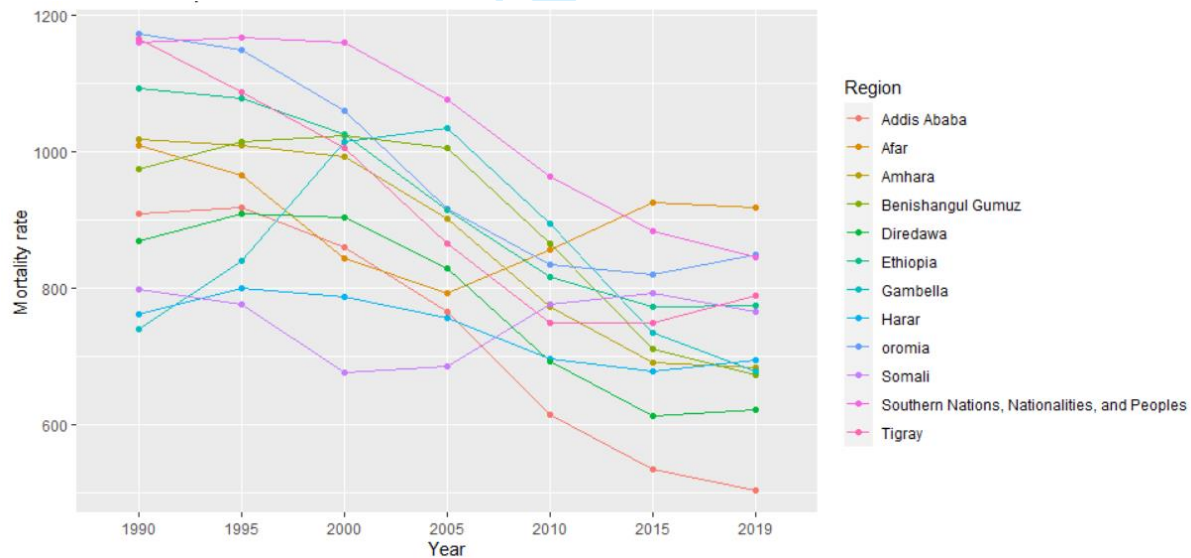
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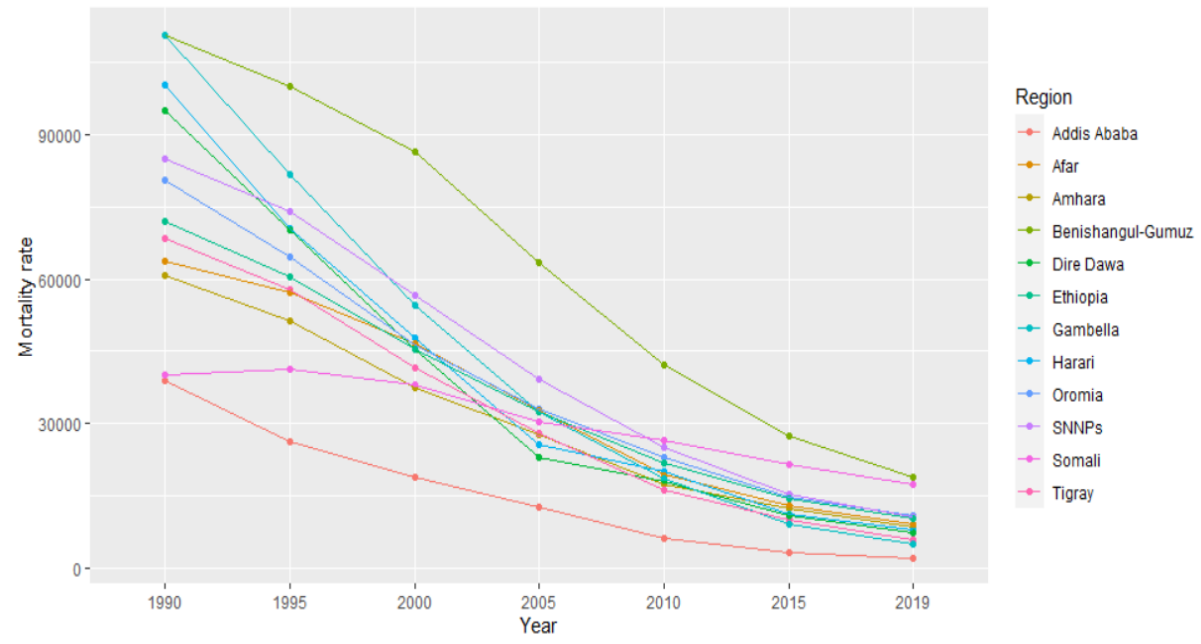
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 52 Ethiopia, 1990-2019



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 55 lower respiratory infections in Ethiopia, 1990-2019

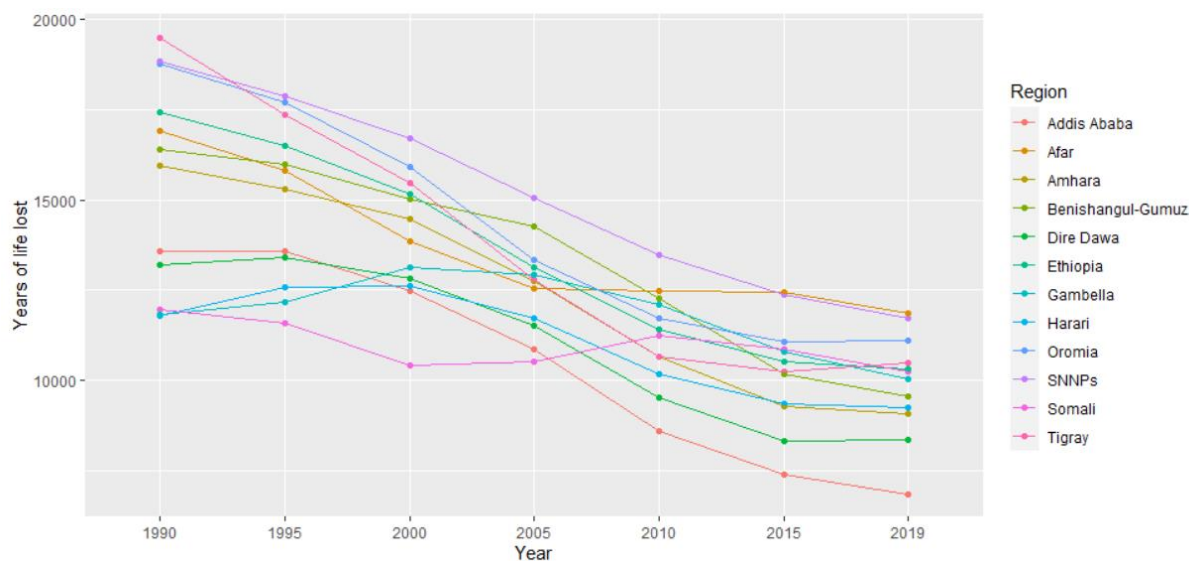


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 58 lower respiratory infections in Ethiopia, 1990-2019
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Supplemental Figure 6: Children younger than 5 years YLL per 100,000 populations for lower respiratory infections in Ethiopia, 1990-2019

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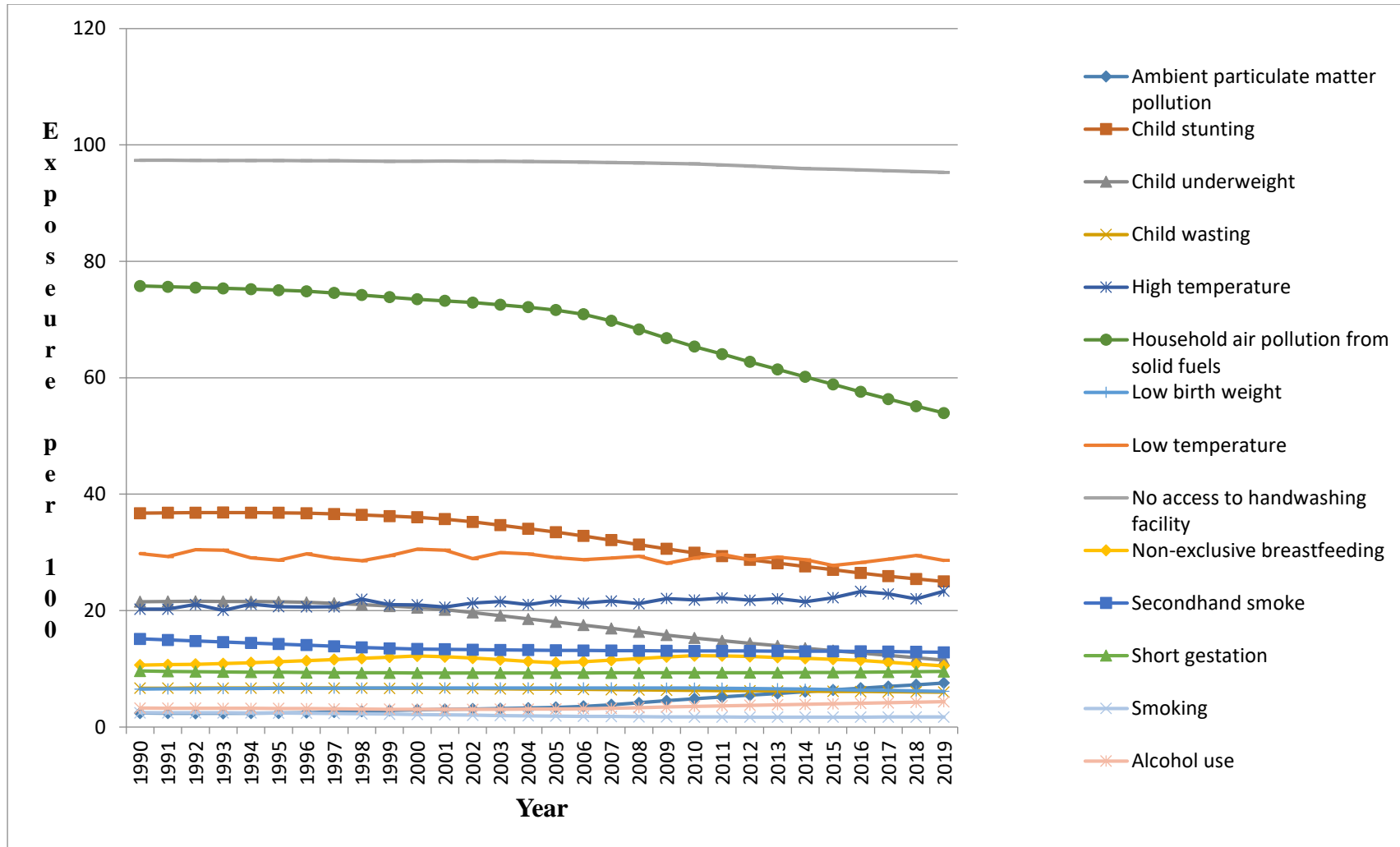
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73 Supplemental Figure 7: Adults older than 70 years YLL per 100,000 populations for lower
74 respiratory infections in Ethiopia, 1990-2019

Location	Alcohol use	Ambient particulate matter pollution	Child stunting	Child underweight	child wasting	High temperature	Household air pollution from solid fuel	Low birth weight	Low temperature	No access to handwashing facility	Non-exclusive breastfeeding	Secondhand smoke	Short gestation	Smoking
Addis Ababa	1.4	4	0.1	0.1	0.7	0	1.7	0.7	3.7	4.8	0.1	0.4	0.7	1
Oromia	0.6	2.5	2.5	1.9	11.2	0.9	21.6	4.3	2.2	10.3	0.9	0.6	3.5	1.3
Amhara	0.4	2.5	1.8	1.4	6.7	0.9	19.8	3.3	2.4	9.5	0.4	0.6	2.6	0.4
SNNPs	0.8	2.4	2.7	2.2	10.2	1.8	19.9	3.5	1.4	9.6	0.8	0.5	2.9	0.9
Tigray	0.7	3.3	0.8	0.8	4	1.1	17.7	2.8	1.2	9.4	0.3	0.5	2.4	0.4
Harari	1	3.8	0.9	0.7	5.3	0	9.6	2.4	1.1	7.6	0.6	0.6	2.1	3.2
Afar	0.4	2.1	1.8	1.9	8.5	6.3	21	4.5	0.1	9.4	0.9	0.6	3.6	1.4
Somali	0.3	1.6	3.3	3.8	22.2	4.8	31.6	7.2	0.4	13.3	2.5	0.9	5.7	1.8
Benishangul-Gumuz	0.4	3.4	4.5	3.5	20	4.7	27.7	4.9	0.6	13.3	1.3	0.7	4	0.8
Dire Dawa	0.9	3.6	0.7	0.7	5.1	0.4	8.3	2.4	0.5	6.9	0.4	0.5	2	2.1
Gambella	0.8	2.2	0.4	0.4	3.2	2.5	9.3	2.2	0.1	5.4	0.4	0.3	1.9	2.1
Ethiopia	0.6	2.5	2.2	1.8	9.9	1.4	20.5	3.9	1.9	9.9	0.8	0.6	3.2	1

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76 Supplemental Figure 8: Attribution of the risk factors to LRIs death rate per 100,000 population
77 in all age groups between 1990 and 2019 for Ethiopia and its regions, both sexes, number of
78 death, 2019. SNNPs: Southern Nations, Nationalities, and Peoples.
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	Ambient particulate matter pollution	child stunting	Child under weight	child wasting	high temperature	Household air pollution from solid fuels/ birth weight	Low temperature	No access to handwashing facility	Non-exclusive breastfeeding	Secondhand smoke	Short gestation	
Addis Ababa	3.63	0.82	0.64	8.35	0.00	1.75	8.86	3.29	4.27	1.32	0.31	7.98
Oromia	6.41	14.75	11.45	67.14	2.34	60.08	25.95	6.05	28.32	5.25	1.66	21.03
Amhara	5.40	13.01	9.84	48.10	2.02	46.86	23.47	5.46	21.99	2.81	1.36	18.88
SNNPs	6.36	16.67	13.77	63.88	5.03	57.68	21.95	4.12	27.49	5.28	1.38	18.31
Tigray	5.03	6.15	5.75	29.88	1.87	29.89	20.59	2.00	15.32	1.91	0.79	17.45
Harari	9.12	7.21	5.80	43.66	0.01	25.51	19.63	2.74	19.30	5.00	1.62	17.18
Afar	4.88	11.42	11.57	52.76	15.77	53.12	28.03	0.26	23.50	5.49	1.33	22.31
Somali	5.40	18.08	20.92	121.83	16.76	110.21	39.76	1.46	46.07	13.99	3.18	31.30
Benishangul-Gumuz	12.63	28.22	22.25	125.72	17.81	105.51	30.75	2.22	50.23	8.05	2.61	24.89
Dire Dawa	9.38	5.50	5.64	42.47	1.11	23.88	19.72	1.42	18.88	3.67	1.50	16.71
Gambella	4.75	3.13	3.08	25.92	6.16	23.51	18.20	0.18	13.02	2.86	0.60	15.31
Ethiopia	6.06	14.39	11.93	64.00	4.28	58.22	25.08	4.73	27.20	5.22	1.58	20.40

Supplemental Figure 9: Attribution of the risk factors to LRIs death rate per 100,000 population in children younger than 5 years between 1990 and 2019 for Ethiopia and its regions, both sexes, number of death, 2019. SNNPs: Southern Nations, Nationalities, and Peoples.



Supplemental Figure 10: Trends in the risk factors between 1990 and 2019 for all ages for Ethiopia

Tables

Supplemental Table 1: Number and percentage changes of episode attributable to LRI in 1990 and 2019 for Ethiopia, its regions, both sexes

Location	All ages			Children younger than 5 years			People above 70		
	Episode, (95% UI),1990	Episode, (95% UI),2019	Change, %	Episode, (95% UI),1990	Episode, (95% UI),2019	Change, %	Episode, (95% UI),1990	Episode, (95% UI),2019	Change,%
Addis Ababa	194122.9(175403.8-213856.2)	176027.6(162152.3-190557.8)	10	44940.6(35673.3-56859.6)	14522.3(11237-18367.5)	68	8099.5(6891.6-9463.2)	24034.2(20749.5-27702.3)	196**
Oromia	2164243.7(1957719.5-2397957.9)	2597863.9(2372089.2-2859925.6)	20	739239.6(578477-935022.8)	613676.6(480687.2-765626.5)	17	110627.2(95303.7-129579.9)	292179.4(254670.4-342438.5)	164**
Amhara	1508431.4(1368059.8-1671550.1)	1400682.4(1285323-1530939.8)	8	423999.3(334700.8-538426.8)	261397.4(206754.7-327889.7)	39	116332.8(98774.4-137194.5)	198977.5(173809.4-229925.5)	71**
SNNPs	1235554.9(1108317.9-1368520.3)	1330491.5(1217176.7-1452694.1)	7	421825.6(335087.1-526155.2)	307771.3(248326.4-385053.7)	28	68084.5(57450.7-79640.8)	99723(88168.3-113438)	46**
Tigray	360795.1(328276.3-400714.9)	409829.8(376290.4-445030.2)	13	109047.9(86435.2-137691.1)	69958.2(55210.7-87468.6)	36	20653.3(17469.9-24256.6)	62677.2(53933.1-72927.6)	203**
Harari	15145.9(13618.9-16851.9)	13765.3(12657-15054.7)	10	4693.6(3691.4-5990.1)	2188.4(1723.8-2761.3)	54	307.2(259.6-357)	1614.8(1396-1863.6)	425**
Afar	113506.8(102317-126084.3)	113210.3(102987.9-124578)	1	32991.6(25672.4-42147.6)	26177.2(20744.1-32743.3)	21	2640.2(2212.5-3150.9)	7222.5(6246.8-8559.1)	173**
Somali	300306.3(268988-336331.8)	463220.4(420429.8-516009.4)	54	103526.3(81391.3-131352.8)	126089.6(99611.9-160423.3)	21**	6182.3(5316-7370.4)	30203.2(25942.8-35038.5)	388**
BG	68501.6(61804.9-75736.4)	71675.7(64972.1-79105.8)	4	20970.5(16626.7-26454.5)	18175.6(14339.5-22922.1)	14	3288.9(2784.8-3911.4)	4311.3(3743.8-5113.9)	31**
Dire Dawa	30607.1(27359.8-34252.2)	26221.1(24010.1-28647.8)	15	9547.4(7523-12185)	4387.7(3439.6-5583.9)	55	1274.8(1090.1-1483.5)	2840.1(2469-3289.5)	122**
Gambella	19687.9(17723.9-21945.7)	25685.2(23516.6-28093.2)	30**	6747.7(5338.7-8613.7)	4335.4(3428.4-5400.9)	36	1568.1(1316.6-1825.8)	1489.6(1281.4-1737.3)	6
Ethiopia*	6010904.2(5467801.6-6648644.3)	6628673.6(6108786.2-7230986.3)	10**	1917530.8(1518850.1-2400978.5)	1448680.4(1150089.8-1799704.4)	25	339059.4(293491.9-387514.2)	725273.3(640315.4-837746.3)	113**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 1990 and 2019

Supplemental Table 2: Rate and percentage changes of episodes attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes

Location	Age standardized			Children younger than 5 years			People above 70		
	Episode per 100,000 people (95% UI), 1990	Episode per 100,000 people (95% UI), 2019	Change, %	Episode per 100,000 people (95% UI), 1990	Episode per 100,000 people (95% UI), 2019	Change, %	Episode per 100,000 people (95% UI), 1990	Episode per 100,000 people (95% UI), 2019	Change, %
Addis Ababa	11373(10484.2-12197.4)	6788.1(6285.1-7339.1)	40	14666.9(11642.4-18556.9)	4927.2(3812.5-6231.8)	67	35138(29897.7-41054.2)	30748.4(26546-35441.2)	13
Oromia	14613.1(13525.9-15725.8)	8659.9(8040.1-9411.6)	41	22232(17397.2-28120)	9039.4(7080.5-11277.7)	60	46498.3(40057.6-54464.4)	41564.6(36228.7-48714.4)	11
Amhara	12826.4(11830-13882.8)	7716.9(7162.3-8321.3)	40	16487.1(13014.7-20936.6)	8061.7(6376.4-10112.3)	52	43580(37002.4-51395.2)	35377.7(30902.9-40880.2)	19
SNNPs	13591.9(12538.6-14646.8)	8235.5(7670.5-8846.4)	39	20106.4(15972-25079.3)	8427.1(6799.4-10543.2)	59	44628.1(37657.5-52203.1)	36616.1(32373.5-41652)	18
Tigray	13927.2(12858.2-15100.7)	8663.8(8034-9382.3)	38	19185.4(15207-24224.8)	8342.1(6583.5-10430.1)	57	43748.4(37005.1-51381)	40859(35158.8-47541.2)	7
Harari	13014.6(11941-14066.7)	7190.5(6684.1-7718.6)	45	19672.6(15471.9-25106.9)	6821.6(5373.5-8607.3)	66	33916.7(28665.1-39416.7)	32797.4(28354-37850.7)	4
Afar	15245.7(14050.8-16525.6)	9350.1(8648.8-10157.4)	39	21151.6(16459.1-27021.7)	9365.5(7421.7-11714.7)	56	39849(33393.8-47557.2)	44368.7(38375.2-52580.1)	11**
Somali	11482.7(10638.1-12368.7)	9220(8515.8-10046.3)	20	16792.9(13202.4-21306.6)	10062.7(7949.6-12802.8)	41	32748.3(28159.7-39042.1)	41031.2(35243.4-47600)	25**
BG	15628.1(14481-16809.3)	9054.6(8394.2-9766)	42	22041.1(17475.5-27805)	10481.8(8269.5-13219)	53	42911.6(36334.5-51032.5)	37592.7(32643.9-44591.2)	13
Dire Dawa	12806.6(11807.9-13871.4)	7148.8(6634.6-7750.7)	44	19968.2(15734.3-25484.7)	7191.5(5637.6-9152.1)	64	38333(32779.4-44607)	32033.6(27847.4-37101.4)	17
Gambella	13623.1(12637.4-14572.4)	7575.8(7002.3-8128.2)	44	21419.8(16947.2-27343.2)	6791.1(5370.4-8460.1)	69	40197.8(33751.8-46803.7)	32657.1(28093.9-38087.2)	19
Ethiopia*	13619.7(12640.8-14588.6)	8313.7(7757.6-8918)	39	19486.4(15434.9-24399.3)	8685.3(6895.1-10789.8)	56	44092.2(38166.5-50393.4)	38394.4(33896.9-44348.5)	13

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

Supplemental Table 3: Number and percentage changes of death attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes.

Location	All age			Children younger than 5			People above 70 years		
	death, (95% UI), 1990	death, (95% UI), 2019	Change, %	death, (95% UI), 1990	Death, (95% UI), 2019	Change, %	Death, (95% UI), 1990	Death, (95% UI), 2019	Change, %
Addis Ababa	2159.3(1731.9-2690.7)	918.8(767.4-1116.9)	58	1353(981.9-1846.7)	69.1(41.7-107.4)	95	209.5(154.3-291.5)	393.6(320.9-495.3)	87**
Oromia	40004.4(29432.4-51942.2)	18206.1(15193.3-21745.4)	55	30614.3(20932.5-42033.5)	8306.2(5763.5-11611.8)	73	2793.5(2005.1-3673)	5971.6(4831.7-7093.4)	113**
Amhara	25449.3(20869.5-30724.8)	9525.5(7530.5-11872.2)	63	17780.1(13674.3-22720.1)	3079.5(1805.3-4737.3)	83	2717.2(2016.4-3535.8)	3839.9(3022.6-4825.6)	41**
SNNPs	26044.7(20108-33017)	9494.7(7713.5-11649)	-64	20390.6(14627.6-26712.9)	4326.6(2891.3-6157.2)	79	1771.7(1254.5-2417.6)	2302.6(1867.3-2772.8)	29**
Gigay	6463.8(5272.1-7762.9)	2551.4(2090.3-3028.6)	61	4436(3373.5-5736)	564.2(364.9-825)	88	550.8(395.7-749.1)	1209.7(978.5-1467.8)	119**
Harari	336(233.3-448.8)	93.1(73.8-116)	73	273.5(174.1-382.7)	28.8(16.4-44.3)	90	6.9(3.7-11)	34.1(27.1-41.8)	395**
Afar	1717.5(1300.7-2243.4)	706.2(567.7-869.6)	-59	1128.9(751.1-1596.7)	284.2(182.5-426)	75	66.9(43.5-102.1)	149.3(117.3-186.6)	123**
Somali	3603.8(2620-4713.6)	3907.5(3007.4-4959.4)	#N/A	2811.1(1929.6-3874.8)	2472.2(1695.2-3506.8)	13	150.8(98-222.3)	563.1(433.4-715.8)	273**
BG	1549.2(1131.1-2097)	619(470.7-803)	61	1204.8(805.6-1703.9)	373(245.3-539.3)	70	74.7(50.3-105.7)	77(61.1-97.3)	3**
Dire Dawa	632.3(445.5-830.9)	154.6(120.6-193.8)	76	518.4(329.5-718.7)	51(27.3-82.9)	91	28.8(20.1-40)	55(44-67.9)	90**
Gambella	475.9(328.5-635.7)	123.2(98.2-151.9)	75	398.6(253.7-555.7)	36.4(20.7-57.2)	91	28.8(18.6-41.9)	30.9(24.6-38.1)	7**
Ethiopia*	108436.6(87669-132758.3)	46300.7(39515.8-54642.2)	58	80909.9(62491.6-103448.8)	19591.8(14018.4-26899)	76	8400.1(6490.3-10700.9)	14627.6(12393.7-16892.8)	74**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

Supplemental Table 4: Age standardized mortality rate, Ethiopia and its regions, by sex, 2019.

Age standardized mortality rate per 100,000 people, 2019		
Location	Female	Male
Addis Ababa	47(35.5-62.5)	73.6(55-98.3)
Oromia	77.3(62-92.4)	100.3(79.9-123.5)
Amhara	57.9(44.1-73.7)	92.5(70.5-122.1)
SNNPs	79.2(63.5-95.2)	118.8(94.3-146.3)
Tigray	73.2(55.9-93.5)	96.9(74.8-122.3)
Harari	63(49-79.9)	95.7(72.5-123.4)
Afar	112.4(87.3-142.3)	98.7(76.9-127.3)
Somali	88.3(69-111.4)	101.7(77.2-130.7)
Benishangul-Gumuz	109.2(82.6-138.8)	95.8(74.6-124.1)
Dire Dawa	56.2(42.5-71.3)	85.4(67.3-109.5)
Gambella	47.9(34.6-60.1)	120.2(95.6-149.5)
Ethiopia	71.8(60.2-82.9)	100.6(84-121.4)

SNNP: Southern Nations, Nationalities, and Peoples

Supplemental Table 5: Number and percentage changes of YLL attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes

	all age			Children younger than 5 years			People above 70		
	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%	YLL, (95% UI),1990	YLL, (95% UI),2019	Change,%
Addis Ababa	149543.9(115542.6-195437)	29703.1(23833.4-36855.7)	81	118961.7(86499.1-162678.7)	6098.2(3693.1-9483.3)	95	3131.8(2301.7-4374.6)	5359.8(4334.8-6816.8)	71**
Oromia	3019031.9(2144916.2-4057496.3)	981808.4(748459.2-1278135)	68	2680397.2(1832260.4-3680767.1)	729313.8(506226.4-1021016.9)	73	44619.5(31636-59105.6)	78166.1(62837.5-93527.9)	75**
Amhara	1813522.3(1445106.4-2246142.2)	428277.8(309674.7-583000.2)	77	1560078.3(1201305.4-1993362.8)	270909.2(158846-416496.1)	83	42578.2(31294.7-56216.9)	50955.1(39726.1-64844.6)	19**
SNNPs	1993643.3(1489598.4-2577052.3)	543135.8(405565.6-711397.4)	73	1785675.1(1284021-2339272.5)	380166.4(254486.8-541224.9)	79	28746.2(20086.2-39789.1)	31964.4(25673.6-38778.5)	11**
Tigray	455613.4(364406.1-569702.1)	96429.9(74139.8-122350.5)	79	389399.3(296618.1-504230.2)	49712.6(32198.3-72764.9)	88	9207.1(6568.7-12629.1)	16086.6(12946.2-19581.8)	74**
Harari	26755.3(17866.5-36380.3)	4273.6(2999.1-5798.4)	85	23959.3(15245.4-33513.8)	2541.6(1449.6-3887.3)	90	106.7(57.6-175.1)	455.9(361.3-558.3)	327**

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Afar	124052(89386.4-166880.5)	39507.6(29535.5-52178.5)	69	99155.3(65972.9-140018.8)	24998.1(16028.5-37426.3)	75	1121.4(723.7-1722.7)	1931.7(1521.3-2395.6)	72**
Somali	281532.2(201275.3-374880.8)	266379.4(193669.7-357880.7)	6	247138.5(169803.8-339740.3)	216954(148995.2-307369.5)	13	2256.6(1434.6-3376.4)	7542.1(5740-9680.2)	234**
BG	119211.2(83517.3-165095.7)	42245.6(30388.8-57591.8)	-65	105463.5(70756-148983.1)	32718.1(21576.4-47307.2)	69	1256.7(836.7-1780.3)	1094.3(857.5-1389.1)	13
Dire Dawa	50024.5(33464.5-67580.6)	7267.7(5038-10264.7)	86	45377.4(28907.2-62914.9)	4497.4(2411.8-7298.3)	91	439.2(306.6-609.5)	742.1(586.6-922.8)	68**
Gambella	37680.8(24783.6-51516.1)	6064.4(4389.3-7853.6)	84	34899.5(22233.1-48609.4)	3212.2(1830.4-5034.1)	91	460.7(299.3-663.6)	457.5(352.6-577.6)	1
Ethiopia*	8070611.3(6356905.2-10091563.7)	2445093.7(1934420.8-3119838.6)	70	7090505.4(5482895.7-9059421.2)	1721122.3(1231032.1-2362958.7)	76	133924.6(102756.8-170932.9)	194756.2(165462-225502.1)	45**

SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

Supplemental Table 6: Rate and percentage changes of YLL attributable to LRIs in 1990 and 2019 for Ethiopia and its regions, both sexes.

Location	all age			Children younger than 5 years			People above 70		
	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%	YLL per 100,000 people, 1990	YLL per 100,000 people, 2019	Change,%
Addis Ababa	6362.2(5161.9-7847.9)	1285.6(1065-1561.8)	80	38824.7(28230.1-53092.4)	6857.1(5545.8-8721.2)	95	13587(9985.4-18978.3)	6857.1(5545.8-8721.2)	50
Oromia	11217.6(8517-14318)	2433.8(2042.2-2879.5)	78	80610.7(55103.7-110696)	11119.7(8939.1-13305)	87	18754.2(13297.1-24843)	11119.7(8939.1-13305)	41
Amhara	8690.4(7146.3-10453.8)	2016.4(1551.4-2541.8)	77	60663.3(46712.5-77511.5)	9059.7(7063.2-11529.2)	87	15950.4(11723.4-21059.7)	9059.7(7063.2-11529.2)	44
SNNPs	11633(9119.4-14477.9)	2698.1(2243.5-3250.2)	77	85114.7(61203.2-111502.1)	11736.6(9426.7-14238.6)	88	18842.6(13166.1-26081)	11736.6(9426.7-14238.6)	38
Tigray	10346.4(8522.9-12340.3)	1977.1(1593.9-2395)	81	68509.3(52185.7-88712.2)	10486.8(8439.5-12765.3)	92	19502.8(13914.1-26751.2)	10486.8(8439.5-12765.3)	47
Harari	12826.5(9336.5-16985.4)	2060.4(1595.6-2623.1)	84	100421.7(63898.7-140467.8)	9260.4(7338.7-11340.3)	93	11782.6(6360.4-19341.1)	9260.4(7338.7-11340.3)	22
Afar	10993.5(8520.8-14193.6)	2824.6(2323-3414)	74	63570.5(42296.6-89769)	11867.1(9346-14716.9)	86	16925.5(10923.7-26001.7)	11867.1(9346-14716.9)	30
Somali	6286.9(4860.5-7970)	3236.4(2537.4-4006)	49	40088.1(27543.7-55109)	10246(7797.8-13150.6)	57	11953.6(7599.2-17885.5)	10246(7797.8-13150.6)	15
BG	14965.1(11197.4-19998.6)	3571.1(2772.4-4510.7)	76	110847.2(74368-156588.4)	9541.9(7476.9-12112.3)	83	16397.3(10917-23228.5)	9541.9(7476.9-12112.3)	42

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3 Dire Dawa	11749.7(8605.4-15249.5)	1832.8(1407.3-2363.1)	84	94905.3(60458.5-131584.5)	8371(6616.3-10408.2)	93	13207.9(9219.6-18328.2)	8371(6616.3-10408.2)	37
4 Gambella	13175.8(9291-17411)	1937.4(1567.6-2344.6)	85	110783.8(70576-154304.1)	10030.9(7730.2-12664.9)	96	11811.4(7673.5-17012.5)	10030.9(7730.2-12664.9)	16
5 Ethiopia*	10189.1(8347.5-12201.8)	2404.5(2059.4-2833.3)	76	72055.4(55718.5-92064)	10309.9(8759.2-11937.6)	86	17415.9(13362.7-22228.5)	10309.9(8759.2-11937.6)	41

6 SNNP: Southern Nations, Nationalities, and Peoples; BG: Benishangul Gumuz; *country's estimate; **percentage increase between 2019 and 1990

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This table indicate the rates of the years of life lost due to lower respiratory infection per 100,000 population for the year 1990 and 2019 and the percentage changes between the two years for three age categories (for all age groups, children younger than 5 years and people above 70 years).

Authors contributions

Providing data or critical feedback on data sources

Semagn Mekonnen Abate, Mesafint Molla Adane, Addis Aklilu, Dejene Tsegaye Alem, Mulusew A Asemahagn, Hunegnaw Abebe, Melaku Ashagrie Belete, Tekleberhan Hailemariam, Tezera Moshago Berheto, Belay Boda Abule Bodicha, Daniel Baza Gargamo, Alemayehu Hailu, Awoke Misganaw, Mohsen Naghavi, Negussie Boti Sidamo, Yonatan Solomon, Shambel Wedajo, Melat Weldemariam, Amanuel Yigezu, Fentabil Getnet, and Yazachew Yismaw.

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Providing critical feedback on methods or results

Semagn Mekonnen Abate, Mesafint Molla Adane, Gizachew Taddesse Akalu, Addis Aklilu, Dejene Tsegaye Alem, Zeleke Gebru, Mulusew Andualem Asemahagn, Daniel Atlaw, Tewachew Awoke, Hunegnaw Abebe, Melaku Ashagrie Belete, Tekleberhan Hailemariam, Tezera Moshago Berheto, Alesmeshet Yirga, Setognal Birara Aychiluhm, Belay Boda Abule Bodicha, Chuchu Churko, Feleke Mekonnen Demeke, Abebaw Alemayehu Desta, Lankamo Ena, Tahir Eyayu, Zinabu Fentaw, Daniel Baza Gargamo, Mesfin Damtew Gebrehiwot, Mathewos Alemu Gebremichael, Melaku Getachew, Ababi Zergaw, Alemayehu Hailu, Getahun Molla, Awoke Misganaw, Mohsen Naghavi, Biniyam Sahiledengle, Bereket Beyene, Migbar Sibhat, Negussie Boti Sidamo, Damtew Damtew Solomon, Yonatan Solomon, Birhanu Wagaye, Shambel Wedajo, Melat Weldemariam, Amanuel Yigezu, Fentabil Getnet, and Yazachew Yismaw.

Drafting the work or revising is critically for important intellectual content

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Managing the estimation or publications process

Semagn Mekonnen Abate, Awoke Misganaw, Mohsen Naghavi, Negussie Boti Sidamo, and Amanuel Yigezu.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No. (Line No.)
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1 (1-2)
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	4 and 5 (73-89)
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	7 (140-147)
Objectives	3	State specific objectives, including any prespecified hypotheses	7 (148-153)
Methods			
Study design	4	Present key elements of study design early in the paper	10 (194-214)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8 and 9 (175-192)
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	8 and 9 (175-192)
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9 and 10 (194-214)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8 and 9 (175-192)
Bias	9	Describe any efforts to address potential sources of bias	10 (211-214)
Study size	10	Explain how the study size was arrived at	8 (175-184)

Continued on next page

1					
2	Quantitative	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which	9 (200-206)	
3	variables		groupings were chosen and why		
4					
5	Statistical	12	(a) Describe all statistical methods, including those used to control for confounding	9 (200-206)	
6	methods		(b) Describe any methods used to examine subgroups and interactions	10 (211-214)	
7			(c) Explain how missing data were addressed	9 and 10	
8				(194-214)	
9					
10			(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed		
11			<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed		
12			<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling		
13			strategy		
14					
15			(e) Describe any sensitivity analyses	10 (211-214)	
16					
17	Results				
18	Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined	10 (216-221)	
19			for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed		
20			(b) Give reasons for non-participation at each stage		This is a population level study
21			(c) Consider use of a flow diagram		
22					
23	Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on	7 and 8	Described in the method section
24			exposures and potential confounders	(156-168)	
25			(b) Indicate number of participants with missing data for each variable of interest		This is a population level study
26			(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	12-19 (255-	
27				361	
28					
29	Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time		
30			<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure		
31			<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	12-19 (255-	
32				361	
33					
34	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision	12-19 (255-	
35			(eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were	361	
36			included		
37			(b) Report category boundaries when continuous variables were categorized	12-19 (255-	
38				361	
39			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time		
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period

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-19 (255-361)
Discussion			
Key results	18	Summarise key results with reference to study objectives	19 (363-371)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	23 and 24 (461-471)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19-23 (373-460)
Generalisability	21	Discuss the generalisability (external validity) of the study results	24 (475-486)
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	25 (506-508)

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.