RESEARCH ARTICLE

Spatial distribution and determinants of acute respiratory infection among under-five children in Ethiopia: Ethiopian Demographic Health Survey 2016

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Abstract

Background

Childhood acute respiratory infection remains the commonest global cause of morbidity and mortality among under-five children. In Ethiopia, it remains the highest burden of the health care system. The problem varies in space and time, and exploring its spatial distribution has supreme importance for monitoring and designing effective intervention programs.

Methods

A two stage stratified cluster sampling technique was utilized along with the 2016 Ethiopian Demographic and Health Survey (EDHS) data. About 10,006 under-five children were included in this study. Bernoulli model was used to investigate the presence of purely spatial clusters of under-five acute respiratory infection using SaTScan. ArcGIS version 10.1 was used to visualize the distribution of pneumonia cases across the country. Mixed-effect logistic regression model was used to identify the determinants of acute respiratory infection.

Result

In this study, acute respiratory infection among under-five children had spatial variations across the country (Moran’s I: 0.34, p < 0.001). Acute respiratory infection among under-five children in Tigray (p < 0.001) and Oromia (p < 0.001) National Regional States clustered spatially. History of diarrhoea (Adjusted Odds Ratio (AOR) = 4.71, 95% CI: (3.89–5.71)), 45–59 months of age (AOR = 0.63, 95% CI: (0.45–0.89)), working mothers (AOR = 1.27, 95% CI: (1.06–1.52)), mothers’ secondary school education (AOR = 0.65; 95% CI: (0.43–0.99)), and stunting (AOR = 1.24, 95% CI: (1.00–1.54)) were predictors of under-five acute respiratory infection.
Conclusion and recommendation

In Ethiopia, acute respiratory infection had spatial variations across the country. Areas with excess acute respiratory infection need high priority in allocation of resources including: mobilizing resources, skilled human power, and improved access to health facilities.

Background

Although global child mortality rates have declined consistently over the last decades, preventable infectious diseases continue to require special attention. Infectious diseases are the most significant causes of under-five mortality and accounts for 68% of all deaths among children under the age of five years [1]. According to Global Health Observatory (GHO) 2016 report the leading causes of death among under-five children were preterm birth complications, acute respiratory infections, intrapartum-related complications, congenital anomalies, and diarrhoea [2]. Acute respiratory infection (ARI) is characterized by cough accompanied by short rapid breathing and commonly resulted in death through co-morbidities with other childhood illnesses [3].

Globally, ARI among children remains the second common cause of morbidity and mortality among under-five children. In developing countries including Ethiopia, ARI remains the highest burden [4]. In 2015, it killed around one million children under the age of five years and constitutes 16% of all deaths [5], which is higher than the proportion of deaths from diarrhoea, malaria, and measles combined [6].

About 90% of all ARI among under-five children deaths were reported in the Sub-Saharan Africa and Southeast Asia. Globally, more than 12 million children with severe ARI were admitted to hospitals every year [7]. In Ethiopia, about 3.4 million children suffer from ARI annually and Ethiopia is among the top 15 countries with highest burdens of ARI [8]. It accounts for 18% of all deaths, and kills over 40,000 under-five children every year [9].

The incidence of ARI among under-five children varies among countries at large and regions in particular. These differences can be attributed to child, mother, environment related factors, and co-morbid diseases like: measles, diarrhoea, and malaria [10].

These factors have also favoured the occurrence of ARI cases in clusters or ‘hotspots’ in both high-income [11–13] and low-income countries [14] as well as across geographic settings at both household [14] and regional levels of analyses [15].

Thus, the identification of geographical areas with high burden of disease transmission using geographic information systems (GIS) and spatial statistical analyses has become indispensable to guide targeted interventions. However, past studies in Ethiopia have focused on prevalence and factors associated with the disease [16–18]. The findings of these studies are insufficient and limited to capture geographic patterns of the disease. Therefore, the current study was done to explore the spatial distribution and determinants of ARI among under-five children in Ethiopia using geographic analysis techniques.

Method and materials

Study design, setting, and period

A community-based cross-sectional study was conducted from January 18 to June 27, 2016. The study was conducted in Ethiopia (3°-14° N and 33° - 48° E), situated in the eastern tip of Africa (Fig 1). The country covers an area of 1.1 million km² (square kilometre) with
geographical diversity, ranging from 4,550 meter (m) above sea level down to the Afar depression 110 m below sea level. There are nine regional states and two city administrations subdivided into 68 zones, 817 districts, and 16,253 kebeles (lowest local administrative units of the country) in the administrative structure of the country [19].

Population and sample
The source population was all under-five children (10,006) included in the 2016 EDHS. A stratified two-stage cluster sampling procedure was employed where enumeration areas (EAs) were the sampling units for the first stage and households were the second stage. In the 2016 EDHS, a total of 645 EAs (202 urban and 443 rural) were selected with a probability proportional to EAs size (based on the 2007 housing and population census) and independent selection in each sampling stratum. Of these, 18,008 households and 16,583 eligible women were included. The detailed sampling procedure was presented in the full EDHS report [19].

Data collection procedures and variables
Acute respiratory infection among under-five children two weeks prior to data collection were used as a dependent variable. The independent variables were classified as socio-demographic factors including sex, age of child, residence, maternal education, maternal occupation, number of under-five children, religion, and wealth index; environmental factors were source of water, types of toilet facility, and types of cooking fuel. Clinical factors including vaccination history and drug for intestinal parasites, nutritional factors: breast feeding duration, stunting, wasting, and vitamin A supplement, and co-morbidity conditions including history of diarrhoea, HIV status, anaemia status, and measles.

Acute respiratory infection was defined as children that had history of cough, accompanied by short rapid breathing and/or difficulty of breathing reported by mothers or caregivers within two weeks preceding the survey [20, 21]. Co-morbidity was defined as the presence of one or more additional diseases co-occurring with a primary disease, pneumonia in under-five children [18, 22].
A letter of approval for the use of the data was secured from the Measure DHS and the data set was downloaded from the website www.measuredhs.com(https://dhsprogram.com/data/available-datasets.cfm). We used EDHS 2016 child data set and extracted the outcome and explanatory variables. Location data (latitude and longitude coordinates) was also taken from selected enumeration areas (clusters).

A structured and pre-tested questionnaire was used as a tool for data collection. The 2016 EDHS interviewers used tablet computers to record responses during interviews. The tablets were equipped with Bluetooth technology to enable remote electronic transfer of files (transfer assignment sheets from team supervisors to interviewers and transfer of completed copies from interviewers to supervisors) [19].

Data management and analysis
Prior to the actual data collection, interviewers were trained and a pre-test was performed. Interviews were performed using local languages [19]. Cross tabulations and summary statistics were used to describe the study population. Descriptive and summary statistics were done using STATA version 14 software. In EDHS data, children within a cluster may be more similar to each other than children in the rest of the country. This violates the assumption of traditional regression model which are the independence of observations and equal variance across clusters. This implies that the need to consider the between-cluster variability using advanced models. Therefore, a multilevel model (both fixed and random effects) was used. As the response variable was dichotomous, logistic regression and Generalized Linear Mixed models (GLMM) were fitted. Model comparison was done based on Akakie Information Criteria (AIC), Bayesian information Criteria (BIC), and intra cluster correlation (ICC) values. The model with the lowest AIC was chosen. Variables with $p \leq 0.2$ p-values in the bi-variable analysis were fitted in the multivariable model. Adjusted Odds Ratio (AOR) with a 95% Confidence Interval (CI) and p-value $<0.05$ in the multivariable model were used to declare significant association with ARI. Goodness of fit was checked using deviance and ICC.

Spatial autocorrelation analysis
Spatial autocorrelation (Global Moran’s I) statistic measure was used to evaluate whether disease patterns were dispersed, clustered, or randomly distributed in the study area. Moran’s I values close to $-1$ indicated disease dispersed, whereas I close to $+1$ indicated disease clustered, and disease distributed randomly if I value was zero. A statistically significant Moran’s I ($p < 0.05$) led to the rejection of the null hypothesis and indicated the presence of spatial autocorrelation. ArcGIS version 10.1 was used for doing the Moran I analysis.

Spatial scan statistical analysis
Spatial scan statistical analysis was employed to identify the geographical locations of statistically significant spatial clusters of ARI among under-five children using Kulldorf’s SaTScan version 9.4 software [23]. Spatial scan statistic used a scanning window that moves across the study area. Children with ARI were taken as cases and those without the disease as controls to fit the Bernoulli model. The number of cases in each location had Bernoulli distribution and the model required data with or without the disease. The default maximum spatial cluster size of <50% of the population was used as an upper limit, allowing both small and large clusters to be detected, and ignored clusters that contained more than the maximum limit with circular shape of window. A Likelihood ratio test statistic was used to determine whether the number of observed ARI cases within the potential cluster were significantly higher than the expected
or not. Primary and secondary clusters were identified using p-values and likelihood ratio tests on the basis of the 999 Monte Carlo replications [24].

**Ethical issues**
Ethical clearance was obtained from the University of Gondar Ethical Review Board (IRB). Permission was obtained from Measure DHS International Program which authorized the datasets. All data used in this study were publicly available; and aggregated secondary data with no any personal identity.

**Results**

**Socio-demographic characteristics of respondents**
A total of 10,641 under-five children were included in the 2016 EDHS survey. Of these, 10,006 of the children were included the analysis. Of 10,006 children, 5,107 (51.04%) were males and 8,099 (80.94%), rural dwellers. Regarding maternal educational status, 6,387 (63.83%) had no formal schooling. The mean age of the children was 2.4 years or 28.88 months (S.D ± 17.45 months). In terms of wealth index, 3,706 (37.04%) of the participants were from the poorest families. About 2,096 (20.95%) of the children were in the age range of 45–59 months (Table 1).

**Environmental characteristics of respondents**
In this study, 5,935 (59.3%) of the households obtained water from improved sources. The majority, 8,156 (81.5%) used unimproved toilet facilities. Most of them, 8,312 (83.1%) used wood for cooking (Table 2).

**Nutritional and co-morbid characteristics of respondents**
Of the children, 8,916 (89.1%) had no history of diarrhoea. About 7,517 (75.1%) were not vaccinated against any type of vaccine preventable diseases and 9,622 (96.2%) were never breastfed. Regarding nutritional status, 7,876 (78.7%), were wasted and 6,009 (60.1%) were stunted. The majority, 8,830 (88.3%) of children received no drugs for intestinal parasites in the last 6 months, and 5,626 (56.2%) did not get vitamin A in the same period (Table 3).

The overall prevalence of ARI among under-five children in Ethiopia was 7.9% (95%CI: 7.4%, 8.5%). Distribution of ARI among under-five children was highest in Tigray (14.92%) and lowest in Benishangul-Gumuz (2.21%) National Regional States. Tigray, Oromia, Amhara, and SNNP National Regional States demonstrated regional variations in the prevalence of under-five ARI (Fig 2).

**Spatial distribution of under-five pneumonia**
This study revealed that the spatial distribution of ARI among under-five children was non-random with Global Moran’s I 0.34 (p<0.001). The clustered patterns (on right sides) showed that high rates of ARI occurred across the study area. A z-score of 6.3 indicated that there was less than 1% likelihood for this clustered pattern to be the result of a random chance. The bright red and blue colours at the end tails indicated an increased significance level.

Each spot (point data) on the map represents one census enumeration area which encompasses a number of ARI cases. More cases in the diagram depict ARI hotspot areas. The red colour indicates areas with high rates of ARI cases, whereas the green one indicates low rates.
A total of 58 significant clusters were identified at which 22 were most likely (primary) and 36 secondary clusters. The primary clusters were located in Tigray National Regional State (central part). The primary clusters were centred at 13.769067N, 38.215600E with 85.3 km radius, a relative risk (RR) of 2.95 and Log-Likelihood ratio (LLR) of 38.5, at p < 0.001. It showed that children within this area had 3.0 times higher risk for ARI than children outside the area (Table 4).

The bright red colours (rings) indicate that the most statistically significant spatial windows contain primary clusters of ARI. There was a higher risk of ARI within the cluster than outside the cluster (Fig 3).

Determinants of under-five ARI

Model comparison. AIC and BIC were checked, and the mixed effect model was chosen because of the smallest value of AIC (Table 5). Furthermore, the ICC value was 0.2 which informed us to choose GLMM over the basic model.

Table 1. Socio-demographic characteristics of respondents in Ethiopia from January 18 to June 27, 2016 (N = 10,006).

| Variable                  | Frequency (N) | Percent (%) |
|---------------------------|---------------|-------------|
| Residence                 |               |             |
| Urban                     | 1,907         | 19.06       |
| Rural                     | 8,099         | 80.94       |
| Age of child              |               |             |
| < 6 months                | 1,109         | 11.08       |
| 6–11 months               | 1,016         | 10.15       |
| 12–23 months              | 1,929         | 19.28       |
| 24–35 months              | 1,926         | 19.25       |
| 36–47 months              | 1,930         | 19.29       |
| 48–59 months              | 2,096         | 20.95       |
| Sex of child              |               |             |
| Male                      | 5,107         | 51.04       |
| Female                    | 4,899         | 48.96       |
| Mother Educational level  |               |             |
| No education              | 6,387         | 63.83       |
| Primary                   | 2,538         | 25.36       |
| Secondary                 | 697           | 6.97        |
| Higher                    | 384           | 3.84        |
| Wealth Index              |               |             |
| Poorest                   | 3,706         | 37.04       |
| Poorer                    | 1,670         | 16.69       |
| Middle                    | 1,386         | 13.85       |
| Richer                    | 1,227         | 12.26       |
| Richest                   | 2,017         | 20.16       |
| Mother Occupation         |               |             |
| Not working               | 5,920         | 59.16       |
| Working                   | 4,086         | 40.84       |
| Religion                  |               |             |
| Orthodox                  | 2,944         | 29.42       |
| Protestant                | 1,761         | 17.60       |
| Muslim                    | 5,068         | 50.65       |
| Other                     | 233           | 2.33        |
| Number of living children |               |             |
| 1–3                       | 5,045         | 50.42       |
| 4–6                       | 3,549         | 35.47       |
| above 6                   | 1,412         | 14.11       |
In the mixed effect logistic regression model, number of under-five children in the house, age of child, stunting status, wasting status, residence, maternal educational level, history of diarrhoea in the last two weeks, family wealth index, breastfeeding status, duration of breastfeeding, types of fuel for cooking, types of toilet facility, water source for drinking, maternal occupation, history of vaccination, child caretaker, drugs for intestinal parasites in the last six months, and vitamin A supplement in the same period were significant in the bi-variable analysis at p-value < 0.05.

However, in the multivariable mixed effect logistic regression analysis, age of child, history of diarrhoea, stunting, maternal education and occupation were significantly associated predictors of ARI among under-five children.

The odds of developing ARI were nearly five times (AOR = 4.7, 95% CI: 3.9, 5.7) higher in children who had diarrhoea compared with their counterparts.

The odds of developing ARI among children age between 48–59 months were decreased by 37% (AOR = 0.63, 95% CI: 0.45, 0.89) compared with children age less than 6 months. The odds of developing ARI were 24% (AOR = 1.24, 95% CI: 1.01, 1.54) more in moderately stunted children compared with normal ones.

The odds of developing ARI among mothers who completed secondary school were decreased by 35% (AOR = 0.65; 95% CI: 0.43, 0.99) compared with children whose mothers had no formal education. The odds of ARI among children who had working mothers were 27% (AOR = 1.27, 95% CI: 1.06, 1.52) higher compared with children whose mothers were not working at the moment (Table 6).

### Table 2. Environmental characteristics of the respondents in Ethiopia from January 18 to June 27, 2016 (N = 10,006).

| Variable                          | Frequency(N) | Percent (%) |
|-----------------------------------|--------------|-------------|
| **Type of cooking fuel**          |              |             |
| Electricity                       | 518          | 5.18        |
| Charcoal                          | 896          | 8.95        |
| Wood                              | 8,312        | 83.07       |
| Others*                           | 280          | 2.80        |
| Child lives with respondent       | 9,748        | 97.42       |
| Elsewhere                         | 258          | 2.58        |
| **Source of drinking water**      |              |             |
| Improved                          | 5,935        | 59.31       |
| not improved                      | 3,943        | 39.41       |
| other**                           | 128          | 1.28        |
| **Type of toilet facility**       |              |             |
| Improved                          | 1,686        | 16.85       |
| not improved                      | 8,156        | 81.51       |
| Other***                          | 164          |             |

*Other Fuel: Kerosene, straw/shrubs/grass, agricultural crop
**Other water source: not a de jure resident, lake
***Other toilet facility: not a de jure resident, no facility/bush/field

Improved water source: (piped into dwelling, piped to yard/plot, public tap/standpipe, tube well or borehole, protected well, protected spring, bottled water); Improved toilet facility: (flush to piped sewer system, flush to septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, composting toilet.

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Table 3. Nutritional and co-morbid characteristics of ARI among under-five children in Ethiopia from January 18 to June 27, 2016 (N = 10,006).

| Variable                          | Frequency (N) | Percent (%) |
|----------------------------------|---------------|-------------|
| **Duration of breastfeeding**     |               |             |
| ever breastfed                   | 9,622         | 96.16       |
| never breastfed                  | 384           | 3.84        |
| **Currently breastfeeding**       |               |             |
| Yes                              | 6,578         | 65.74       |
| No                               | 3,428         | 34.26       |
| **Vitamin A supplement**         |               |             |
| Yes                              | 4,380         | 43.77       |
| No                               | 5,626         | 56.23       |
| **Stunting**                      |               |             |
| normal                           | 6,009         | 60.05       |
| moderate                         | 1,614         | 16.13       |
| severe                           | 2,383         | 23.82       |
| **Wasting**                       |               |             |
| normal                           | 7,876         | 78.71       |
| moderate                         | 828           | 8.28        |
| severe                           | 1,302         | 13.01       |
| **Had diarrhoea**                 |               |             |
| Yes                              | 1,090         | 10.89       |
| No                               | 8,916         | 89.11       |
| **Drug for intestinal parasites**|               |             |
| Yes                              | 1,176         | 11.75       |
| No                               | 8,830         | 88.25       |

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Discussion

In this study, the distribution of ARI among under-five children varied in the country. The Global Moran’s I value 0.3 (p<0.001) indicated that there was a significant clustering of under-five ARI in the study area.
The Spatial scan statistical analysis identified 58 clusters and all of which were statistically significant. The high risk regions for ARI were the Northern and Central parts of the country mainly Tigray and Oromia. These areas were highland setting implying a high burden of ARI among under-five children. In cold environmental conditions, children are indoors for longer periods and in close contact with a number of bacteria, fungi, or viruses. Flu, viruses, and bacteria are prone to be stable in the air when there is a drop in temperature and the particles remain in the air in respiratory droplets. Bacteria present on our skin are usually harmless; however, during the cold and flu season, immunity decreases weakening the system and even causing damage to the airways creating opportunities for bacteria to cause infections, mainly ARI in the lungs. Another possible reason for this could be a huge number of children were under one year of age, and the majority of the household in these regions used charcoal as a source of fuel [25].

Under-five children who had past history of diarrhoea were more affected by ARI in this study. This finding was supported by a case control study done in Oromia zone, northeast

![Spatial distribution of ARI](https://doi.org/10.1371/journal.pone.0215572.g003)

**Table 4. Significant spatial clusters of ARI among under-five children in Ethiopia, 2016.**

| Clusters | Enumeration areas(clusters) detected | Coordinates/radius | Population | Cases | RR | LLR | P- value |
|----------|-------------------------------------|--------------------|------------|-------|----|-----|---------|
| 1        | 40, 188, 551, 181, 98, 584, 425, 255, 156, 583, 597, 636, 258, 528, 400, 590, 81, 80, 579, 78, 268, 575 | 13.769067N,38.215600E)/85.29 km | 390 | 86 | 2.95 | 38.53 | <0.001 |
| 2        | 555, 558,17,586 | 8.130989N, 35.637972E)/60.43 km | 95 | 28 | 4.39 | 22.27 | <0.001 |
| 3        | 223, 271, 272, 297, 577, 359, 537, 331, 174, 41, 14, 633, 502, 204, 142, 360, 420, 388, 373, 262, 609, 54, 565, 126, 139, 578, 162, 522, 227, 347, 217, 113 | (7.775278N,37.939392E)/95.73km | 589 | 89 | 2.17 | 21.29 | <0.001 |

The two secondary clusters were typically located in the border of Oromia National Regional State. The first secondary clusters was centred at 8.130989 N, 35.637972 E with 60.4 km radius, RR of 4.39and LLR of 22.3, at p < 0.001. It showed that children within the area had 4 times higher risk of ARI than children outside the area. The second secondary clusters was centred at 7.775278 N, 37.939392 E within 95.7 km radius, and RR of 2.17 and LLR of 21.29, at p < 0.001. It showed that children within the area had 2 times higher risk of ARI than children outside the area.

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![Spatial distribution of ARI](https://doi.org/10.1371/journal.pone.0215572.g003)
Ethiopia and Zimbabwe where children who had history of diarrhoea were 3 times more likely to develop ARI than their counterparts [16, 26]. Similar studies were done in southwest Ethiopia [27] and Ghana [28]. A Cross sectional survey in Bangladesh [29] also reported that children who had history of diarrhoea were at increased risk for ARI. The possible explanation could be that children who have a concomitant illness like diarrhoea may have a lowered immunity, making them more susceptible to a disease like ARI.

This study showed that working mothers were positively associated with ARI among under-five children. The finding is in line with EDHS 2011 [30], in Pakistan [31], where the risk of developing ARI is significantly higher in children whose mothers were working than children whose mothers were not working. The possible justification could be related to childcare in which mothers play a critical role in childhood ARI[32].The other explanation could be that working mothers have been exposed to certain chemicals, pollutants, or toxic fumes in the working environment, thereby transmitting the infection to their children may be increased. When mothers are at work, they don’t have enough time for breastfeeding their children; thus children become vulnerable to ARI.

Child age was also significantly associated with ARI. The result is consistent with studies conducted in urban areas of Oromia region, Ethiopia [16], where children in the age range of 2–11 months had higher chance of having ARI compared to older age ones. Similarly, a study from Wondo-Genet district, southern Ethiopia [18] younger children (2–12 months) were more likely to develop ARI compared to older age. Similarly, according to the 2013 Lancet report, there was a high occurrence of ARI in children younger than 2 years of age, and a case control study done in Pakistan showed that pneumonia commonly occurred to younger children [31, 33]. Other studies conducted in Indian and the south-eastern regions of Brazil also indicated that children under the age of one year were more likely to be hospitalized for ARI [34, 35]. The possible reason could be that these children build their immune systems over time to fight off infectious agents including ARI.

Stunting was significantly associated with the presence of ARI among under-five children. This result was consistent with those of studies done in South Gondar zone, Ethiopia [17], Bangladesh [36] and Nepal [37]. The possible reason could be that stunting shows a long term malnutrition, which weakens the child’s immunity and makes them vulnerable to ARI. Secondary to Thymo-lymphocyte depletion, malnourished children have defective cell mediated immunity which, leading to infections and sepsis. In addition to this malnutrition also resulted in occurrence of an abnormal immunoglobulin and impairments of key enzymes involved in bactericidal action of leukocytes, which prone to ARI.

In this study, maternal education was found to be significantly associated with ARI. This finding is consistent with those previous studies done in Ethiopia by using EDHS 2011 [30], Bangladesh [36], in developing countries [38], and in Southeast Asia regions [32]. Knowledge that mothers acquire from formal education could help them to adopt essential nutrition and hygienic behaviours that prevent ARI. Another possible reason might be that uneducated mothers compared to educated ones have better health-seeking behaviour which could help them to prevent ARI.

However, studies done in Este, northwest Ethiopia [17], Wondo-Genet district, southern Ethiopia[18], Debre-Berhan district, northeast Ethiopia (35), Bangladesh [36], and urban

| Proposed models                        | AIC value | BIC value |
|----------------------------------------|-----------|-----------|
| Logistic regression                    | 5178.605  | 5438.199  |
| Mixed effect logistic regression       | 4970.02   | 5258.465  |

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| Variable                      | ARI | No | Yes | COR (95%CI) | AOR (95%CI) |
|------------------------------|-----|----|-----|-------------|-------------|
| Residence                    |     |    |     |             |             |
| Urban                        | 1,799 | 108 | 688 | 1.51 (1.12,2.04) | 1.28 (0.81,2.04) |
| Rural                        | 7,411 |     |     |             |             |
| Maternal education           |     |    |     |             |             |
| No education                 | 5,872 | 515 | 226 | 1.06 (0.88,1.27) | 0.95 (0.77,1.17) |
| Primary                      | 2,312 | 266 | 36  | 0.68 (0.47,1.01) | 0.65 (0.43,0.99) |
| Secondary                    | 661  | 36  | 19  | 0.66 (0.39)     | 0.71 (0.38,1.24) |
| Higher                       | 365  | 19  |     |             |             |
| Currently breastfeeding      |     |    |     |             |             |
| No                           | 3,190 | 238 | 558 | 1.21 (1.02,1.43) | 0.80 (0.63,1.03) |
| Yes                          | 6,020 |     |     |             |             |
| Age of child                 |     |    |     |             |             |
| <6 months                    | 1,024 | 85  | 114 | 1.57 (1.15,2.16) | 1.13 (0.82,1.58) |
| 6–11 months                  | 902  | 114 | 202 | 1.48 (1.11,1.96) | 1.01 (0.74,1.37) |
| 12–23 months                 | 1,727 | 152 | 139 | 1.07 (0.79,1.44) | 0.80 (0.57,1.12) |
| 24–35 months                 | 1,774 | 139 | 202 | 0.96 (0.72,1.29) | 0.90 (0.65,1.25) |
| 36–47 months                 | 1,791 | 104 | 202 | 0.63 (0.46,0.86) | 0.63 (0.45,0.89) |
| 48–59 months                 | 1,992 | 104 | 202 |             |             |
| Fuel type                    |     |    |     |             |             |
| Electricity                  | 492  | 26  | 114 | 1.40 (0.83,2.38) | 1.21 (0.69,2.12) |
| Charcoal                     | 837  | 59  | 674 | 1.71 (1.07,2.72) | 1.19 (0.68,2.11) |
| Wood                         | 7,638| 674 | 243 | 2.42 (1.33,4.43) | 1.47 (0.66,3.27) |
| Other                        | 243  | 37  |     |             |             |
| Toilet facility              |     |    |     |             |             |
| Improved                     | 1,581 | 105 | 668 | 1.13 (0.87,1.46) | 0.88 (0.65,1.19) |
| Not improved                 | 7,488| 668 | 23  | 1.93 (1.12,3.33) | 2.23 (0.81,6.16) |
| Other                        | 141  | 23  |     |             |             |
| Mothers occupation           |     |    |     |             |             |
| Not working                  | 5,506| 414 | 382 | 1.28 (1.09,1.52) | 1.27 (1.07,1.52) |
| Working                      | 3,704| 382 |     |             |             |
| Wasting status               |     |    |     |             |             |
| Normal                       | 7,227| 649 | 81  | 1.29 (0.99,1.68) | 1.21 (0.92,1.61) |
| Moderate                     | 747  | 81  |     | 0.68 (0.51,0.89) | 0.97 (0.68,1.38) |
| Severe                       | 1,236| 66  |     |             |             |
| Stunting                     |     |    |     |             |             |
| Normal                       | 5,514| 495 | 167 | 1.28 (1.05,1.56) | 1.24 (1.01,1.54) |
| Moderate                     | 1,447| 167 | 134 | 0.71 (0.57,0.87) | 0.80 (0.62,1.05) |
| Severe                       | 2,249| 134 |     |             |             |
| Ever had vaccination         |     |    |     |             |             |
| No                           | 6,976| 541 | 255 | 1.49 (1.25,1.76) | 1.20 (0.97,1.49) |
| Yes                          | 2,234| 255 |     |             |             |
| Child lives with whom        |     |    |     |             |             |
| With parents                 | 8,960| 788 | 8   | 0.39 (0.18,0.80) | 0.64 (0.29,1.44) |
| Lives elsewhere              | 250  | 8   |     |             |             |
| Duration of breastfeeding    |     |    |     |             |             |
| Ever breastfed               | 8,846| 776 | 20  | 0.60 (0.37,0.70) | 0.75 (0.45,1.25) |
| Never breastfed              | 364  | 20  |     |             |             |

ARI: Acute Respiratory Infection, COR: Crude odds Ratio, AOR: Adjusted odds Ratio

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eastern Indonesia [39] showed that mothers’ education did not show a significant association. This discrepancy might be due to differences in sample sizes (larger sample size was used in our study).

One of the strengths of this study was its representativeness at national and regional levels, so it can be generalized to all under-five children in Ethiopia. Moreover, the use GIS and Sat Scan statistical tests helped to detect similar and statistically significant high-risk clusters/hotspots of ARI. However, the study didn’t show exact case locations because location data values were shifted 1–2 km for urban and 5km for rural areas for data confidentiality reasons and didn’t take seasonal variations into account of ARI among under-five children. Furthermore, the DHS surveys did not base themselves on clinically confirmed data; rather they relied on mother or caregivers’ reports and might underestimate or overestimate the finding.

The findings of this study have valuable policy implications for health program design and interventions. The ARI hotspot areas can be easily identified to make local interventions. It may also be important to prevent and control ARI outbreaks. In general, these findings are of supreme importance for the Ministry of Health, health Bureaus, and partners to develop intervention programs against under-five ARI.

**Conclusion**

In Ethiopia, ARI had spatial variations across the country. Statistically significant high hotspots of ARI among under-five children were found in the northern and central parts of Ethiopia, whereas low hotspots of ARI among under-five children were detected in the western and eastern parts of the country. Stunting, diarrhoea, and maternal working status were predictors that increased the odds of ARI among under-five children. Age of child (45–59 months) and secondary school education of mothers were protective to ARI among under-five children.

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