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Research Article

Spatio-Temporal Variation in Acute Respiratory Infection in Under-Five Children Across State/UTs and Districts in India: The Case of India 2016-2021

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Abstract

Background: In low and middle-income countries (LMICs), a substantial proportion of childhood deaths are attributed to easily preventable and treatable illnesses such as Acute Respiratory Infection (ARI), diarrhoea, and malaria. Despite the implementation of several initiatives, the prevalence of ARI among under-five (U5) children in India has increased from 2016 to 2021. The present study aims to examine the prevalence and spatio-temporal changes of ARI among U5 children in India.

Data Source and Methodology: The current research has utilized the last two rounds of National Family Health Survey data. STATA 14 software has been used to analyse the data. The spatial analysis software (ArcGIS-10.8) has been used to show the prevalence and spatio-temporal changes across districts in India.

Results: The prevalence of childhood ARI has increased from 2.7% to 2.8% percent from 2016 to 2021 in India. The northeastern (0.9%) region shows the highest increase in the prevalence of ARI, while the central (-0.6%) region shows a decrease in prevalence. States like Delhi, Meghalaya, Jammu and Kashmir, Uttar Pradesh Puducherry, and Panjab exhibited high ARI prevalence in both years. Around 16 states/UTs and 333, districts show an increase in the prevalence of ARI during the same period. The highest increase in ARI prevalence was observed in Delhi, followed by Puducherry and Andhra Pradesh.

Conclusion: In conclusion, while progress has been made in reducing ARI prevalence in India, achieving Sustainable Development Goals 3.2 by 2030 will require a concentrated and sustained effort, particularly in regions with high or increasing ARI prevalence.

Keywords: *Acute Respiratory Infection; Spatio-Temporal; Sustainable Development Goals; ArcGIS; Spatial Analysis*

Abbreviations

ARI: Acute Respiratory Infection; AC: Absolute Change; GAPPD: Global Action Plan for Pneumonia and Diarrhoea; NFHS: National Family Health Survey; SDG: Sustainable Development Goal; U5: Under-five (children); UNICEF: United Nations International Children's Emergency Fund; UT: Union Territory; WHO: World Health Organization

Introduction

The Sustainable Development Goals (SDGs) aim to reduce the deaths from preventable diseases among newborn babies and children under-five (U5) years by the year 2030 in the world [1]. In low and middle-income countries (LMICs), a substantial proportion of childhood

deaths are attributed to easily preventable and treatable illnesses such as ARI, diarrhoea, and malaria [2]. It has been estimated that around 5.5 million children under the age of five years died from preventable diseases in 2017 [3].

Acute Respiratory Infection is a cough accompanied by short rapid breathing associated with death, especially with other comorbidities [4]. The viruses like influenza virus (IV), parainfluenza viruses (PIV), adenovirus, and coronaviruses (CVs) are the main infectious agents of ARIs [5]. Globally lower respiratory tract infections are the leading causes of morbidity and mortality among children U5 years [6,7]. ARI is one of the leading causes of childhood illnesses, often resulting in serious health complications and accounting for 20 percent of deaths among children under five in the world [7]. According to the Global Burden of Disease (GBD) report in 2018, a lower respiratory infection is responsible for 704,000 deaths in children younger than five years [8]. Approximately 73 percent of children died in African (49%) and Southeast Asian (24%) countries due to ARI [6].

ARI is the major cause of mortality among children aged less than 5 years, especially in low-income and developing countries like India [9-11]. It is estimated that Bangladesh, India, Indonesia, and Nepal together account for 40% of the global ARI mortality [12]. India is listed among the top 15 nations facing the highest rates of pneumonia incidents and associated mortality among children [6,13]. Every year, about 400,000 children under five years of age succumb to diseases related to ARI in India [13].

World Health Organisation (WHO) and The United Nations Children's Fund (UNICEF) have also framed a global strategy to prevent pneumonia and diarrhoea deaths by 2025 through the Global Action Plan for Pneumonia and Diarrhoea (GAPPD) [14]. Various efforts by International and National agencies to control and prevent, childhood preventable diseases lead to unprecedented levels of child mortality and morbidity in developing countries, including India [15,16]. The prevalence of ARIs among U5 children increased from 2.7 percent to 2.8 percent from 2016 to 2021 [17]. India has already set its goal to achieve the SDGs target to reduce U5 child mortality to 25 per 1000 live births in 2030, which is 42/1000 live births as per the National Family Health Survey-V [1,17]. In the context of SDG-3.2 targets ending preventable deaths of newborns and U5 children by 2030 (SDG UN, 2015) it's important to analyze the micro-level data to find out the prevalence of ARI among U5 children in the country [1]. Previous studies did not explore the spatial prevalence of ARI among U5 children using district-level data available in NFHS-IV and NFHS-V.

Aim of the Study

The present study aims to examine the prevalence and spatio-temporal changes of ARI among U5 children in India. The present study helps to identify high and increased prevalence areas with childhood ARI from India. It will help policymakers to implement a state/UTs or district-specific policy to prevent the prevalence of the disease.

Data Source and Methodology

Data source

The last two rounds of National Family Health Survey (NFHS) data has been used for the study. The International Institute for Population Science (IIPS), Mumbai is a nodal agency of this survey operating under the Ministry of Health and Family Welfare (MoHFW) New Delhi, Government of India. NFHS is a large-scale India-based Demographic and Health Survey (DHS) started in 1992-93. The five rounds of the surveys have been completed. It is a comprehensive survey conducted in a representative sample of households across India. Two-stage stratified sampling techniques are being used for this large-scale survey. In the first stage urban areas, Census Enumeration Blocks (CEB) are selected and from rural residences, villages are selected as Primary Sampling Units (PSUs). In the second stage, households are selected both in urban and rural areas. The last two rounds of NFHS provide national-level information along with the States/UTs and districts in India. The survey covered maternal and child health aspects. We have used the kid's file for the study and the data is freely available from the DHS website: https://dhsprogram.com/data/dataset_admin/login_main.cfm.

Measurement of variables

Computation of prevalence of ARI

Prevalence of ARI is defined as the "number of U5 children suffering with symptoms of ARI at any time in the 2 weeks preceding the survey out of the total number of living children less than 5 years of age" (NFHS). According to the NFHS definition ARI consists of a cough accompanied by:

a. Short, rapid breathing that is chest-related, and/or

b. Difficult breathing that is chest related.

Computation of absolute change

Absolute change has been calculated to measure the spatio-temporal changes in the prevalence of ARI between 2016 and 2021. It is the simple difference in the indicator between two different periods of time. An absolute change refers to the actual increase or decrease from a reference value to a new value and is synonymous with the term "difference." Mathematically, it is calculated as the new value minus the reference value (Absolute change = new value - reference value).

$AC=T_2-T_1$

Whereas,

AC=Absolute change.

T_1= Prevalence of ARI among under-five children in the year T1 (2016).

T_2= Prevalence of ARI among under-five children in the year T2 (2021).

Results

Prevalence of ARI among under-five children in India

Prevalence of ARI among children across the regions in India from 2016-2021

Over the study period, the prevalence of ARI in India slightly increased from 2.7 percent to 2.8 percent from 2016 to 2021. A Regional analysis provides deeper insights, revealing prevalence rates of 2.8 percent, 2.9 percent, and 3.8 percent in India's eastern, northern, and central regions, respectively, exceeding the national average in 2016. On the other hand, the northeast, eastern, and central regions show a prevalence more than the national average (i.e. 2.8%) in 2021 (Table 1).

Prevalence with geographical variance of ARI among 0-5-year-old children in India (2015-16)

Table 1 represents the prevalence of ARI among children at the state/UT level in India (2015-16). The survey results indicate that approximately 2.7 percent of children in India experienced ARI in the two weeks preceding the survey. Furthermore, the ARI prevalence has been reported to range from the lowest in Sikkim (0.30%) to the highest in Meghalaya (5.8%) in 2016. Interestingly, a significant portion of States/UTs, around 66 percent, report ARI prevalence rates exceeding the national average of 2.7%. ARI was most prevalent in Meghalaya (5.8%), followed by Jammu and Kashmir (5.44%), Uttar Pradesh (4.65%), Uttarakhand (4.63%), and Punjab (4.11%). The eastern (2.8%), northern (2.9%), and central (3.8%) regions show a prevalence of more than the national average.

State/UTs	Weighted Prevalence of ARI (in Percentage)			
	NFHS-IV	Sample (N)	NFHS-V	Sample (N)
A. North Region	**2.9**	**31, 622**	**3**	**29, 963**
Chandigarh	2.8	142	0.3	141
Nct Of Delhi	2.4	2, 900	5.6	2, 868
Haryana	3.2	5, 489	2.3	4, 256
Himachal Pradesh	1.6	1, 076	1.5	934
Jammu and Kashmir	5.4	2, 126	3.9	1, 611
Punjab	4.1	3, 980	2.5	3, 949
Rajasthan	2.1	13, 984	2.9	14, 430
Uttarakhand	4.6	1, 925	2.3	1, 748
Ladakh	NA	NA	5.3	26
B. Central Region	**3.8**	**63, 451**	**3.2**	**61, 096**
Chhattisgarh	2.2	5, 795	1.5	4, 849
Madhya Pradesh	2.1	16, 107	2.6	13, 271
Uttar Pradesh	4.7	41, 549	3.5	42, 976
C. East Region	**2.8**	**60, 802**	**3.1**	**57, 887**
Bihar	2.5	29, 782	3.5	28, 959
Jharkhand	3.2	7, 084	2.1	6, 678
Odisha	2.4	7, 849	3.2	6, 906
West Bengal	3.3	16, 087	2.8	15, 344
D. Northeast Region	**1.6**	**8, 446**	**2.5**	**8, 115**
Arunachal Pradesh	2.1	207	2.1	170
Assam	1	5, 885	2.5	5, 649
Manipur	1.7	475	1.8	437
Meghalaya	5.8	727	4.8	838
Mizoram	2.2	203	0.6	176
Nagaland	1.4	324	1.1	206
Sikkim	0.3	58	0.7	60
Tripura	2.6	566	1.3	579
E. West Region	**2.1**	**30, 903**	**2.4**	**27, 916**
Dadra and Nagar Haveli and Daman and Diu	1.5	98	0.3	85
Goa	1.4	208	0.9	199
Gujarat	1.4	10, 319	1	9, 418
Maharashtra	2.4	20, 279	3.2	18, 213
F. South Region	**1.7**	**43, 721**	**1.8**	**37, 256**
Andaman and Nicobar Islands	1.5	49	1.7	39
Andhra Pradesh	0.5	8, 647	2.4	7, 081
Karnataka	1.2	10, 034	1.5	9, 881
Kerala	0.8	4, 258	2.4	4, 502
Lakshadweep	0.9	12	1.4	10
Puducherry	3	205	4.9	145
Tamil Nadu	2.8	13, 720	1.1	10, 610
Telangana	2	6, 796	2.2	4, 988
India	2.7	2, 38, 945	2.8	2, 22, 233

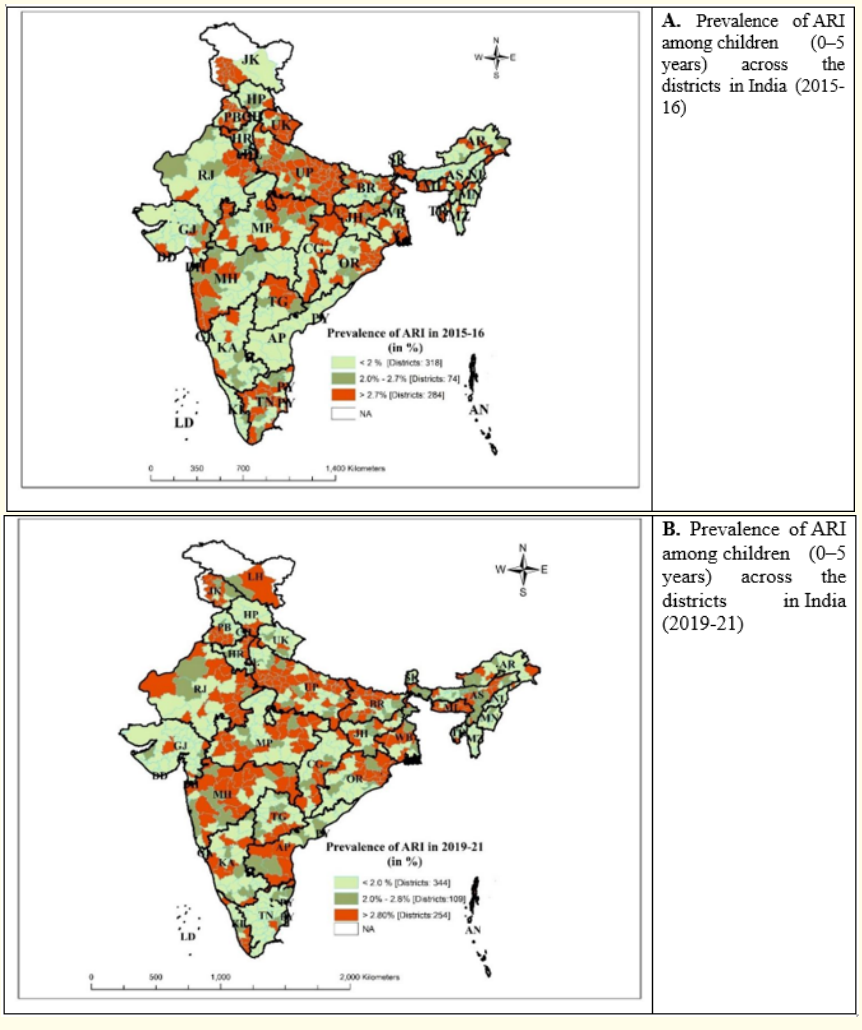
Table 1: *Prevalence of ARI among children (0-5 years) across the state and UTs in India in NFHS-IV (2015-16) and NFHS-V (2019-21).*

Prevalence with a geographical variance of ARI among 0-5-year-old children in India (2019-21)

Table 1 represents the prevalence of childhood ARI across the State/UTs in India. The prevalence has slightly increased from 2.7 to 2.8 percent from 2016 to 2021. Delhi (5.6%) shows the highest prevalence of ARI whereas Dadra and Nagar Haveli/Daman and Diu (0.3%) shows a low prevalence of ARI in 2021. Around 72 percent of States/UTs show more ARI prevalence among children than the national average (i.e. 2.8%). Childhood ARI prevalence is highly concentrated in Delhi (5.59), Ladak (5.31%) Puducherry (4.87%), Meghalaya (4.80%), Jammu and Kashmir (3.85%), and Uttar Pradesh (3.54%) in the year of 2021. The northeast, eastern, and central regions show a prevalence more than the national average (i.e. 2.8%).

Spatial prevalence of ARI among children (0-5 years) across the districts in India (2015-16)

The map in figure 1A illustrates the spatial prevalence of acute respiratory infection (ARI) across the 640 districts in India in the year 2015-16. The map indicates that approximately 39% of districts (248 out of 640) in India reported a prevalence of ARI higher than the national average of 2.7%. For 11% (74 districts), the prevalence ranged between 2% and 2.7%, while the remaining 50% of districts (318 districts) reported a prevalence of less than 2% in 2016. Ramban (19.5%) and Kishtwar (16.6%) districts in Jammu and Kashmir exhibited the highest prevalence of ARI. These high prevalence districts are located in the central, western, eastern, southern, and northern parts of India, primarily in the states of Uttar Pradesh, Tamil Nadu, Maharashtra, Madhya Pradesh, Bihar, Uttarakhand, West Bengal, Odisha, and Jharkhand, Jammu and Kashmir, Chhattisgarh, and Arunachal Pradesh.



A. Prevalence of ARI among children (0–5 years) across the districts in India (2015-16)

B. Prevalence of ARI among children (0–5 years) across the districts in India (2019-21)

Figure 1: *Prevalence of ARI among children (0-5 years) across the districts in India.*

Spatial prevalence of ARI among children (0-5 years) across the districts in India (2019-21)

The map in figure 1B illustrates the spatial prevalence of acute respiratory infection (ARI) across the 707 districts in India in the year 2019-21. The map indicates that approximately 36% of districts (254 out of 707) in India reported a prevalence of ARI higher than the national average of 2.8 percent. Moreover, for 15% (109 districts), the prevalence ranged between 2% and 2.8%, while the remaining 49% of districts (344 districts) reported a prevalence of less than 2% in 2021. Gonda (19.5%) and Bundi (16.6%) districts in Uttar Pradesh and Rajasthan exhibited the highest prevalence of ARI. These high prevalence districts are located primarily in the states of Uttar Pradesh, Bihar, Madhya Pradesh, Jammu and Kashmir, Chhattisgarh, Meghalaya, Delhi, Odisha, Rajasthan, Telangana, and Andhra Pradesh.

Spatio-temporal changes in ARI Prevalence among under-five children in India 2016-21

Spatio-temporal changes of ARI across regions in India (2016-2021)

With regards to temporal changes specific to certain regions, all regions in India except the central region have shown an increase in the prevalence of childhood ARI (Table 2). The northeast region displayed the highest increase in the prevalence of ARI, while the north region had the lowest increase in the prevalence. In terms of place of residence, northern, eastern, and northeastern regions showed an increasing trend, while east, northeast, west, and south rural regions also showed an increase in the prevalence of ARI from 2016 to 2021.

State/UTs	Weighted Prevalence of ARI (in Percentage)		
	NFHS-IV	NFHS-V	AC
North Region	2.9	3	0.10
Central Region	3.8	3.2	-0.60
East Region	2.8	3.1	0.30
Northeast Region	1.6	2.5	0.90
West Region	2.1	2.4	0.30
South Region	1.7	1.8	0.10
India	2.7	2.8	0.10

Table 2*: Spatial-temporal changes of ARI across regions in India from 2016 to 2021.*

Note: AC=Absolute change.

Spatial-temporal changes of ARI among children across the State/UTs in India from 2016 to 2021

Delhi reported the highest increase in prevalence (3.2%) while Chandigarh showed the highest decrease (-2.5%). Figure 2 illustrates the changes in the prevalence of ARI among children across different states and union territories of India between 2016 to 2021. Approximately 18 states and union territories, including Chandigarh, Uttarakhand, Tamil Nadu, Punjab, Jammu and Kashmir, Mizoram, Tripura, Dadra and Nagar Haveli and Daman and Diu, Jharkhand, Uttar Pradesh, Meghalaya, Haryana, Chhattisgarh, Goa, West Bengal, Gujarat, Nagaland, and Himachal Pradesh, showed a decrease in the prevalence of ARI. On the other hand, 16 states and union territories, such as Manipur, Andaman and Nicobar Islands, Telangana, Karnataka, Sikkim, Lakshadweep, Madhya Pradesh, Odisha, Maharashtra, Rajasthan, Bihar, Assam, Kerala, Andhra Pradesh, and NCT of Delhi, recorded an increase in the prevalence rate of this condition (Figure 2).

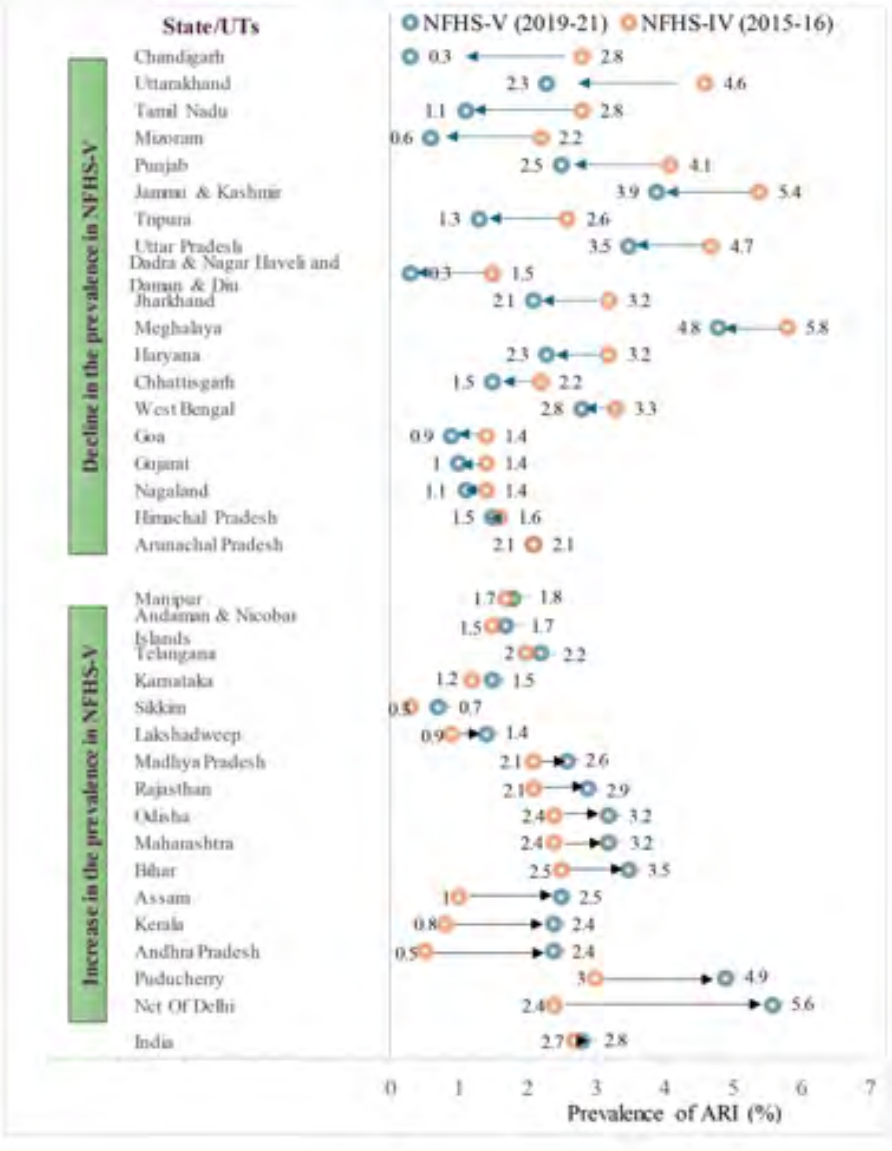


Figure 2: *Spatio-temporal changes of ARI among children across the state and UTs in India (2016-2021).*

Spatial-temporal changes across the 640 districts in India

Figure 3 represents the spatial-temporal changes across the 640 districts in India from 2016 to 2021. The map indicates a wide variation in the change of prevalence across different districts in India. Approximately 48% of districts (309 out of 640) in India reported a decrease in the prevalence of ARI, whereas 52% of districts showed an increase in the prevalence of ARI in India. Ramban district in Jammu and Kashmir reported the highest decrease in prevalence (-16.1%), while Bundi district in Rajasthan showed the highest increase (8%). Most of the districts with increasing prevalence belong to the states of Madhya Pradesh, Karnataka, Andhra Pradesh, Assam, Bihar, Gujarat, Maharashtra, Nagaland, Odisha, Rajasthan, Uttar Pradesh, and West Bengal. On the other hand, three districts i.e. Dhule (Maharashtra), Jalaun (Uttar Pradesh) and the south district of Sikkim showed no change in the prevalence of ARI.

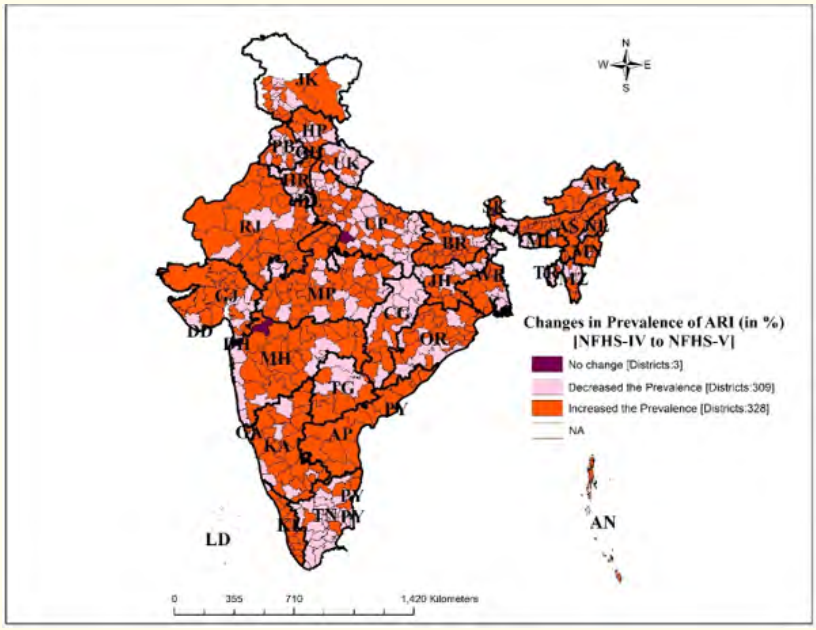


Figure 3: *Spatio-temporal changes in the prevalence of ARI among children in India from 2016 to 2021.*

Discussion

The present study aims to examine the prevalence of ARI among children in India using NFHS-IV (2015-16) to NFHS-IV (2019-21) data. Furthermore, the study also examines the spatio-temporal changes for the diseases in the last two rounds in the NFHS.

The government of India has implemented several programs to reduce preventable death among U5 children in the country. Instead of the implementation of several programs, the prevalence of ARI has increased from 2.7 percent to 2.8 percent. The geographical disparities in childhood ARI have been observed across the regions in India. Higher prevalence rates were reported in the northern, eastern, and central regions of India in both periods. It may be due to regional disparities in healthcare access, environmental factors, and socio-economic conditions. Many previous studies indicate it is due to Socio economic status and indoor and outdoor environmental differences across the states and territories of India [18,19]. The differences in environmental quality, such as air pollution and population density, may significantly contribute to a region in India regarding the incidence of ARI among U5 children [20]. On the other hand, temporal changes indicate that northeastern states show the highest increase in the prevalence of ARI from 2016 to 2021.

The prevalence of ARI among children across the state/UTs was also observed. States like Delhi, Meghalaya, Jammu and Kashmir, Uttar Pradesh, Puducherry, and Panjab exhibited high ARI prevalence in both years. All the states are located at high altitudes, so this may be a possible reason. Previous research indicates that living at high elevations influences the prevalence of childhood ARI, and an altitude of more than 2500 m is a significant predictor for respiratory syncytial virus infection [13,21]. The spatio-temporal analysis indicates the changes in ARI prevalence across states/UTs from 2016 to 2021. Around 16 states and union territories, such as Manipur, Andaman and Nicobar Islands, Telangana, Karnataka, Sikkim, Lakshadweep, Madhya Pradesh, Odisha, Maharashtra, Rajasthan, Bihar, Assam, Kerala, Andhra Pradesh, and NCT of Delhi, recorded an increase in the prevalence rate of this condition. The highest increase in ARI prevalence was

observed in Delhi, followed by Puducherry and Andhra Pradesh. The concentration of particulate matter (PM) is very high in Delhi, which could be a possible reason for the highest increase in the incidence. Several research studies have investigated the correlation between PM2.5 pollution and ARI in India among children [22,23]. Regions with high population density, such as Uttar Pradesh, Punjab, Bihar (with a density of >800 persons/sq. km), have exhibited a high incidence of ARI [24]. This association between high population density and ARI prevalence has been highlighted in various studies, indicating that population density may be a significant contributing factor to the prevalence of ARI. Additionally, bidi consumption is highly prevalent in the states of Himachal Pradesh, Haryana, Uttarakhand, and Madhya Pradesh so the prevalence of ARI in those states may increase.[13,25] Study also suggested that tobacco consumption and smoking behaviours, increase indoor air pollution, which increases the prevalence of ARI [25].

The spatial analysis of ARI prevalence at the district level in both 2015-16 and 2019-21 indicates that approximately 36 - 39% of districts across India report prevalence rates higher than the national average. Additionally, around 48 percent of districts in India reported a decrease in the prevalence of ARI, whereas 52 percent of districts showed an increase in the prevalence of ARI in India. So, this is a major concern as more than half of the districts increase the burden the childhood mortality and morbidity in our country.

The previous studies identify the risk factors associated with the ARI among U5 children in India. Factors such as unclean cooking fuel, smoking exposure in the household [26], households do not have a separate kitchen for cooking [26], mothers having respiratory diseases or asthma [25] and maternal smoking behaviour [27] are the significant risk factors of ARI. Additionally, children characteristics such as children born with low birth weights, [28] and children who had diarrhoea 2 weeks before the survey also increase the risk of ARI among U5 children [13].

Limitations of the Study

The current study provides geographical variation and spatio-temporal changes of ARI among U5 children in India. However, we have some limitations to the study: Firstly, we only focus on the prevalence and spatiotemporal changes of ARI, the different risk factors not covered in the survey. Secondly, ARI was classified as per the signs and symptoms reported by the children's mothers without confirmation from medical professionals. Thirdly, mothers were asked to recall their children's symptoms from the past 2 weeks of the survey, which may raise the possibility of recall bias. Our study justifies the increase in prevalence in the region based on previous research; further investigation is required to identify the specific risk factors contributing to the disease.

Conclusion

This study presents a remarkable geographical variation in the Prevalence of ARI among U5 children across the regions in India. It reveals a slight increase in prevalence from NFHS-IV to NFHS-V. However, substantial regional and state-level variations have been observed in prevalence. States like Delhi, Meghalaya, Jammu and Kashmir, Uttar Pradesh, Puducherry, and Punjab exhibit high prevalence rates in both rounds of the survey. In terms of spatio-temporal changes, 16 states/Union Territories (UTs) and 333 districts reported an increase in the prevalence of these diseases over the years. This study underscores the areas with high and increasing prevalence at both state/UT and district levels. These findings suggest the need for suitable policy implementations that address the districts with high and rising ARI prevalence. To achieve SDG 3.2 (reducing U5 mortality due to pneumonia and other preventable diseases) by 2030, India must focus its efforts of targeted policy interventions on the regions most affected by ARI.

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Conflicts of Interest/Competing Interests

Not applicable.

Ethics Approval

There is no formal ethics approval required for this particular study since the study is based on secondary data and the survey data is available in the public domain.

Availability of Data and Material

The data of a particular study is available in the public domain and can be extracted from: https://dhsprogram.com/Data/.

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