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Do malnutrition, pre-existing morbidities, and poor household environmental conditions aggravate susceptibility to Coronavirus disease (COVID-19)? A study on under-five children in India

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ABSTRACT

Background: The novel Coronavirus disease 2019 (2019-nCoV) outbreak, caused by severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2), has become the worst serious global risk to humanity in the last century and linked with various risk factors.

Objective: To find out the risk zone associated with Coronavirus disease among children under-five age using malnourished status, pre-existing morbidity conditions, poor household environmental conditions, and also with case fatality rate (CFR) and active case rate (ACR) of COVID-19 in India.

Data sources & methods: Data was collected from the 4th round of the National Family Health Survey (NFHS)-4, 2015–16, and CFR and ACR of COVID-19 related data collected from the Ministry of Health and Family Welfare (MoHFW) on 18th May 2020. Mean, standard deviation, and Z-score statistical methods have been employed to identify the risk factors zone and Hot Spot analysis (Getis-Ord Gi) has been done.

Results: The states and union territories (UTs) which have a high composite vulnerability score (CVS) of COVID-19 among under-five children are in Meghalaya (CVS = 1), Uttar Pradesh (CVS = 0.93), Jharkhand (CVS = 0.86), Bihar (CVS = 0.74), Madhya Pradesh (CVS = 0.74), and Odisha (CVS = 0.55). The states and UTs which have low composite vulnerability score of COVID-19 among under-five children are in Sikkim (CVS = -0.90), Daman & Diu (CVS = -0.76) Lakshadweep (CVS = -0.74), Kerala (CVS = -0.72), Chandigarh (CVS = -0.71). The COVID-19 high-risk zones (hot spot: 99% Confidence interval [CI]) were observed in Madhya Pradesh, Uttar Pradesh, Jharkhand, Bihar, and Meghalaya states of India, which are spatially high clustered and the low-risk zones (cold spot: 95% CI) were observed in Kerala, Mizoram states of India.

Conclusions: Well-built public health measures, including rapidly searching in high focus areas and testing of COVID-19, should be performed in vulnerable regions of COVID-19.

1. Introduction

Globally, at least 1 in 3 under-five children are not growing well due to malnutrition in its more visible forms, i.e. stunting, wasting, underweight, and overweight (UNICEF, 2019a). UNICEF estimated that nearly 2.6 million children, who die each year due to malnutrition, are equivalent to one-third of all registered child deaths globally (UN, 2011). The United Nations International Children's Emergency Fund (UNICEF) has recently published a report on 'The State of the World's Children 2019' highlighting the state of children's health in India and around the world. As per the report, 35%, 17%, 33%, and 2% of children are suffering from stunting, wasting, underweight, and overweight respectively in India (UNICEF, 2019a).

Adequate access to proper health services, safe drinking water supplies, adequate sanitation, and good housing are preconditions for adequate nutrition among under-five children. Inadequate sanitation, unhygiene environment, inappropriate childcare, and poor household environment conditions also directly influence the under-five children's malnutrition and morbidities (Linnemayr et al., 2008; Masibo, 2013; Poda et al., 2017; Mshida et al., 2018). The most important disease for the cause of the morbidity are acute respiratory infections (ARIs), cold & cough, and fever, etc (Ramani et al., 2016; Rehman and Ishaq, 2018). The acute respiratory infection (ARI) i.e. short and rapid breaths, cold & cough, and fever among human beings are the primary symptoms of

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Coronavirus disease (Saha & Chouhan, 2020; Cascella et al., 2020) and severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2) which have widespread effects because it is hazardous or risk factor for under-five children health having a weak immune system (Chan et al., 2020; Jin et al., 2020; Lai et al., 2020; Peeri et al., 2020; Saha & Chouhan, 2020; Singhai, 2020; Velavan and Meyer, 2020). The prevalence of morbidity was found among those under-five children who are malnourished, living in over-crowded and poorly ventilated houses, and those children's families are use unimproved toilet facilities. Several socio-demographics, nutritional, health, and environmental conditions are associated directly and indirectly with the occurrence of disease among under-five children. Household environmental conditions include drinking water quality, sanitation condition, and household dwelling characteristics (Godana and Mengiste, 2013; Mihrete et al., 2014; Adane et al., 2017; Nsabimana et al., 2017; Getachew et al., 2018; Zedie & Kassa, 2018; Workie et al., 2019; Vijayan and Ramanathan, 2020; Abuzerr et al., 2020).

The novel Coronavirus disease 2019 (2019-nCoV) outbreak, epicentered in Wuhan city, Hubei Province of the People's Republic of China on December 8, 2019 (Saha & Chouhan, 2021), caused by severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2), has become the worst serious global risk to humanity in the last century (Saha et al., 2020). Pointing to over 118,000 confirmed COVID-19 cases in over 110 countries and territories around the world and the continued threat of further global transmission, the World Health Organization (WHO) declared COVID-19 a pandemic on 11th March 2020 (Saha et al., 2020) and asked all countries to get imperative and aggressive steps against this community health disaster. Globally, as of 31st July 2020, a total of 17,113,205 confirmed cases of Coronavirus disease, including 663, 667 deaths have been reported and 216 countries and territories have been affected by the COVID-19 pandemic (WHO, 2020). As of 31 July 2020 as of 08:00 IST (GMT + 5:30), the Ministry of Health and Family Welfare, the Government of India reported, a total of 1,638,870 confirmed cases, and 35,747 deaths have been reported spreaded over 35 states and UTs of India (MoHFW, 2020). Currently, as of July 2020, no vaccine or medicine for COVID-19, prevention of infection is the only tool available, and this is dependent on home isolation, social distancing, mask-wearing, constant hand washing, increasing consciousness, and human being resistance against infection i.e. boost of individual immunity level. Globally, and also in developing countries like India, the under-five children are most vulnerable groups compared to the other age classes, so we considered only the under-five age group and in 2018 an estimated 5.3 million children were died under the age of five years (UNICEF, 2019b), mostly from preventable childhood morbidities. For that very rationale, under-five children with these pre-existing symptoms and areas with poor household environmental conditions are aggravate susceptibility to COVID-19 deaths in the coming days.

This type of study is yet not done, so considering this huge research gap this study also aims to determine the impact of malnutrition and pre-existing morbidities, and poor household environmental conditions aggravate susceptibility to Coronavirus disease among under-five children in the states and UTs of India. So, this very research would be helpful for policymakers, strategy developers, and public health workers to combat and reduce the future pandemic situation.

2. Data & methods

2.1. Data sources

For this study, data was collected from the fourth round of the National Family Health Survey, 2015–16, consisting of nationally representative sample surveys. The purpose of this survey was to gather essential information on family planning, fertility, maternal and child health, under-five nutrition, anemia, infant, child, and maternal mortality indicators, other adult health issues HIV/AIDS-related knowledge, attitudes, and behavior, domestic violence (IIPS & ICF, 2017). A total of 247,743 living children (0–59 months) were utilized from the NFHS-4 in India from different pre-existing morbidities, nutritional status, and environmental characteristics of under-five children. The data used in this study were retrieved from the public domain.

Data on the COVID-19 is collected from the https://www.mohfw.gov.in/ naming 'COVD-19 state-wise status', provides the most updated figures on the daily and a total number of confirmed cases, recovered or cured cases, and deaths (MoHFW, 2020) for each affected states and union territories of India. This data was collected from the Ministry of Health and Family Welfare (MoHFW), Government of India website. We have collected data on confirmed cases, the number of death cases, and cured cases as of July 14, 2020, 08:00 IST (GMT + 5:30) of affected states and UTs of India.

2.2. Variables used

For the investigation of the study, pre-existing childhood morbidities, malnutrition status, and poor household environmental conditions among under-five children, and COVID-19 related indicators were included. The prevalence of pre-existing morbidities indicators includes the percentage of children who had symptoms of acute respiratory infection in the last two weeks before the survey, the percentage of children who had cold & cough, and percentage of children who had fever in the last two weeks preceding the survey among under-five children. The nutritional status (based on WHO Multicentre Growth Reference Study of the under-five children) indicators include stunting (children whose height-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population), wasting (children whose weight-for-height Z-score is below minus two standard deviations (-2 SD) from the median of the reference population), and underweight (children whose weight-for-age Z score is below minus two standard deviations (-2 SD) from the median of the reference population) of the states and UTs of India (De Onis et al., 2004). The COVID-19 factors are active case rate and case fatality rate (Table 1).

Child's poor household environmental conditions include smoky cooking fuel (solid fuel for cooking, with virtually all being wood or dung cakes), unimproved sources of drinking water (unimproved [Unprotected (dug) well; unprotected spring, the cart with small tank or drum; tanker truck-provided water, surface water (river, dam, lake, pond, stream, canal, irrigation channel); bottled water (IIPS & ICF, 2017)]), unimproved toilet facilities (Flush or pour-flush to elsewhere, - Pit latrine without a slab or open pit, - Bucket, hanging toilet or hanging latrine and - No facilities or bush or field (open defecation) (IIPS & ICF, 2017)]), rudimentary roof material, and unclean floor material (Table 1).

2.3. Methods

The prevalence of malnutrition (stunting, wasting, and underweight), the prevalence of pre-existing childhood morbidities (ARI, cold & cough, and fever), percentage of children family use smoky cooking fuel or solid biomass, unimproved sources of drinking water, unimproved toilet facilities, rudimentary roof material, and unclean floor material among under-five children were calculated using the Statistical Package and Data Science software STATA version 14.1 (StataCorp LP, College Station, TV, USA).

The case fatality rate is calculated as the rate of the total number of death cases due to COVD-19 to the total number of confirmed cases of the COVID-19. Similarly, the COVID-19 active case rate is calculated as the rate of the total number of cured/ discharged cases of the COVID-19 to the total number of confirmed cases of the COVID-19.

For the identification of the vulnerable/risk zone of the Coronavirus disease, the mean composite vulnerable score (CVS) method has been employed. For each state and UT, all the variables (V_1, V_2, V_3 up to V_{13}) are sum up and the mean was calculated, then standard deviation was

Table 1
Dimension with their indicators and source of data.

Dimension	Indicators code	Indicators	Details	Source
Prevalence of malnutrition	**V1**	Stunting	Children whose height-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are considered short for their age (stunted), or chronically undernourished.	National Family and Health Survey, 2015-16 (NFHS-4), International Institute for Population Studies (IIPS), Mumbai (IIPS & ICF, 2017).
	V2	Wasting	Children whose weight-for-height Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are considered thin (wasted), or acutely undernourished.	
	V3	Underweight	Children whose weight-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are classified as underweight.	
Prevalence of pre-existing morbidities	**V4**	Acute Respiratory Infection (ARI)	Percentage of children had ARI in the last two weeks preceding the survey.	
	V5	Cold & Cough	Percentages of children had cold & cough in last two weeks preceding the survey.	
	V6	Fever	Percentage of children who had a fever in the last two weeks preceding the survey.	
Poor household environmental conditions	**V7**	Use smoky cooking fuel	Percentage of children's families use smoky cooking fuel or solid biomass.	
	V8	Unimproved sources of drinking water	Percentage of children's families use unimproved sources of drinking water.	
	V9	Unimproved toilet facilities	Percentage of children families use unimproved toilet facilities.	
	V10	Rudimentary roof material	Percentage of children families use rudimentary roof material.	
	V11	Unclean floor material	Percentage of children families use unclean floor material.	
COVID-19 factors	**V12**	Active Case Rate (ACR)	ACR is calculated as the rate of the total figure of active cases of COVID-19 to the total figure of confirmed cases of COVID-19.	The Ministry of Health and Family Welfare (MoHFW), Government of India, New Delhi (MoHFW, 2020).
	V13	Case Fatality Rate (CFR)	CRF is calculated as the rate of the total figure of deaths due to COVD-19 to the total figure of confirmed cases of COVID-19.	

calculated as the root mean square deviation from the mean. The composite vulnerable score also be calculated for the identification of the vulnerable zone of COVID-19 using the following formula-

$$\mathrm{Z-Score} = \frac{Individual\ value - Mean\ value}{Standard\ deviation(\sigma)} \quad (1)$$

All the Z-score values of all indicators for each state and UT have been calculated the mean was calculated using the total Z-score value divide by the number of variables to get a composite vulnerability score. A high Z-score value indicates the high-risk zone of COVID-19 among under-five children and vice versa.

Hot spot analysis (Getis-Ord Gi*): To identify COVID-19 vulnerable zones, hot spot analysis has been used. The hot spot analysis tool calculates the Getis-Ord Gi* statistic (pronounced G-i-star) for each characteristic in a dataset. Hot spot analysis using spatial statistics produces maps, which show the spatial concentration of events. The resultants Z-scores inform us where features with either high (hot spot) or low values (cold spot) cluster spatially (Nelson & Boots, 2008). This tool works by looking at each feature within the context of neighboring features. A feature with a high value is interesting but may not be a statistically significant hot spot (Prasannakumar et al., 2011). To be a statistically significant hot spot, a feature will have a high value and be enclosed by other features with high values as well (Jana & Sar, 2016). The local sum for a characteristic and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum, and when that difference is too large to be the result of random chance, a statistically significant Z-score result. The Getis-Ord local statistics is given as-

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (2)$$

Where, x_j is the attribute value for future j, $w_{i,\ j}$ is the spatial weight between future i and j, n is equal to the total number of features and the G_i^* statistics is a z-score, so no additional calculations are required.

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j^2}{n}$$

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j^2}{n} - (\overline{X})^2$$

3. Results

3.1. Prevalence of malnutrition, pre-existing morbidities, poor household environmental conditions among under-five children, and active case rate and case fatality rate of COVID-19 in India

Table 2 represents the percentage of under-five children with the prevalence of malnutrition, pre-existing morbidities, poor household environmental conditions, and current COVID-19 factors in India. The prevalence of stunting in children under age five is highest in Bihar (48.38%), Uttar Pradesh (46.27%), Jharkhand (45.54%), and Meghalaya (43.94%), and lowest in Kerala (19.99%). Jharkhand has the highest percentage of wasting (28.9%) and underweight (47.85%) under-five children. Symptoms of ARI was higher in the states like Meghalaya (5.8%), Jammu and Kashmir (5.4%), Uttar Pradesh (4.7%), Uttarakhand (4.6%), Punjab (4.1%), West Bengal (3.3%), Jharkhand (3.2%), Haryana (3.2%) compared to other states and UTs of India. The highest prevalence of cold & cough (22.15%) and fever (24.5%) has been observed in Uttrakhand among children under age five.

About 53% of households in India use some type of solid fuel for cooking, with virtually all being wood or dung cakes. In India, 9.97% of

Table 2
Percentage of under-five children with the prevalence of malnutrition, pre-existing morbidities, poor household environmental conditions, and COVID-19 factors in India.

States and union territories	Prevalence of malnutrition (%)			Prevalence of pre-existing morbidities (%)			Poor household environmental conditions (%)					COVID-19 factors	
	Stunting	Wasting	Underweight	ARI	Cold & Cough	Fever	Use smoky cooking fuel	Unimproved sources of drinking water	Unimproved toilet facilities	Rudimentary roof material	Unclean floor material	ACR	CFR
Andaman & Nicobar Islands	23.27	18.98	21.11	1.50	12.89	8.62	25.83	5.75	14.09	4.91	14.34	34.34	0.00
Andhra Pradesh	31.44	17.35	32.19	0.50	5.38	8.33	41.02	27.69	44.57	13.17	6.87	45.89	1.17
Arunachal Pradesh	29.30	16.93	19.44	2.10	10.54	11.45	59.41	15.12	14.00	31.03	15.99	62.02	0.52
Assam	36.25	16.98	29.77	1.00	8.77	8.97	81.68	16.53	15.68	7.03	76.36	34.96	0.21
Bihar	48.38	20.87	43.93	2.50	10.33	12.24	88.18	1.67	74.42	23.95	77.90	30.53	0.89
Chandigarh	29.22	9.93	24.46	2.80	10.35	9.69	10.08	1.02	4.65	2.26	5.61	26.70	1.36
Chhattisgarh	37.60	23.10	37.69	2.20	12.49	13.35	80.77	10.16	63.13	3.66	58.84	23.62	0.45
Dadra and Nagar Havel	41.84	27.57	38.76	1.90	5.53	5.63	49.62	19.43	52.76	11.58	46.42	45.66	0.20
Daman and Diu	23.12	24.34	26.19	0.60	5.43	6.57	11.11	8.25	6.69	1.61	1.62	45.66	0.20
Delhi	32.11	15.48	27.30	2.40	10.80	13.40	2.77	25.06	6.14	12.44	0.60	16.72	3.00
Goa	20.00	21.83	23.66	1.40	14.07	16.20	17.39	1.59	12.33	7.22	8.52	39.72	0.66
Gujarat	38.31	26.51	39.36	1.40	9.02	8.94	55.74	10.18	38.76	3.94	22.74	25.51	4.81
Haryana	34.00	21.23	29.53	3.20	8.87	9.24	55.69	9.91	15.14	12.98	19.47	22.76	1.41
Himachal Pradesh	26.40	13.90	21.56	1.60	10.78	11.84	71.87	3.47	17.07	2.98	14.57	23.49	0.88
Jammu and Kashmir	27.70	12.23	16.77	5.40	14.97	13.87	51.66	14.10	27.76	10.02	29.22	41.98	1.73
Jharkhand	45.54	28.90	47.85	3.20	10.42	12.62	86.94	23.99	76.36	4.91	65.88	38.84	0.85
Karnataka	36.28	25.89	35.08	1.20	5.76	7.05	47.57	10.44	42.55	16.89	9.55	59.10	1.82
Kerala	19.99	15.68	16.23	0.80	8.59	10.54	47.96	6.23	0.65	3.78	0.97	48.45	0.40
Lakshadweep	26.55	14.07	23.53	0.90	12.97	13.87	59.04	9.83	0.00	1.24	0.00	-	-
Madhya Pradesh	41.94	25.81	42.83	2.10	10.45	11.36	76.03	16.92	64.59	18.11	58.35	23.82	3.64
Maharashtra	34.23	25.52	35.91	2.40	9.24	12.62	42.53	9.44	35.67	3.66	21.88	40.60	4.02
Manipur	28.78	6.93	13.69	0.70	12.80	8.25	60.99	60.79	2.03	5.54	59.90	40.34	0.00
Meghalaya	43.94	15.04	28.88	5.80	20.21	23.29	83.67	29.24	13.31	11.04	25.81	78.62	0.63
Mizoram	27.86	5.96	11.91	2.20	19.46	11.42	37.69	9.22	1.40	9.77	1.99	35.19	0.00
Nagaland	28.51	11.33	16.81	1.40	8.55	7.13	75.44	20.20	2.64	17.58	56.51	59.76	0.00
Odisha	34.08	20.39	34.30	2.40	12.73	12.86	84.10	11.93	73.66	27.04	52.87	32.12	0.51
Puducherry	23.79	23.77	22.09	3.00	14.50	11.81	13.69	5.10	30.03	15.20	4.13	45.30	1.23
Punjab	25.75	15.69	21.65	4.10	13.18	13.36	39.31	0.82	8.34	5.81	17.88	29.20	2.49
Rajasthan	39.08	22.97	36.57	2.10	8.53	9.82	74.61	16.28	53.62	13.93	31.39	23.18	2.11
Sikkim	29.42	14.26	14.06	0.30	3.41	3.80	46.46	2.42	0.19	2.48	14.38	55.21	0.00
Tamil Nadu	27.16	19.66	23.82	2.80	14.37	10.75	25.91	9.79	40.87	14.16	7.19	33.75	1.42
Telangana	27.61	17.89	27.90	2.00	13.89	16.59	30.07	21.53	32.70	5.37	12.06	33.62	1.01
Tripura	23.98	16.72	23.98	2.60	12.88	11.67	70.76	17.76	5.92	3.99	68.12	28.99	0.10
Uttar Pradesh	46.27	17.93	39.49	4.70	14.26	19.67	73.48	3.27	59.55	21.11	64.62	34.02	2.50
Uttarakhand	33.87	19.50	26.82	4.60	22.15	24.50	57.39	6.78	20.17	14.25	28.84	19.48	1.36
West Bengal	32.72	20.18	31.56	3.30	11.00	12.57	78.09	5.63	34.63	9.78	54.38	35.87	3.04
India	38.37	21.04	35.73	2.31	11.38	11.77	53.18	9.97	49.39	14.19	43.78	34.36	2.62

households haven't access to an improved source of drinking water and about half of the Indian households (49.39%) use unimproved toilet facilities, which are non-shared. About 14% of children living in houses having an unclean floor and 43.78% in houses having rudimentary roof material. In Odisha, the highest percentage (27.04%) of children living in houses having rudimentary roof material. In Bihar, the highest percentage (77.9%) of children living in houses having an unclean floor. The case fatality rate of COVID-19 is higher in Gujarat (4.81%), Maharashtra (4.02%), Madhya Pradesh (3.64%), West Bengal (3.04%), Delhi (3%) compared to other states and UTs of India. The active case rate is higher in Meghalaya (78.62%), Arunachal Pradesh (62.02%), Nagaland (59.76%), Karnataka (59.10%) compared to the other states and UTs of India (Table 2).

From the above maps, it is clear that in case of stunting the states like Jharkhand, Madhya Pradesh are showing high prevalence, and Jammu and Kashmir, Kerala states are showing low prevalence. In contrast, the states like Gujarat, Rajasthan are showing moderate stunting among under-five children of India. In the case of wasting and underweight, the states like Gujarat, Rajasthan, and Maharashtra are showing high whereas Jammu and Kashmir, Himachal Pradesh states are showing low prevalence. Contradictorily Jammu and Kashmir, Punjab, Uttar Pradesh, and Uttrakhand states are showing high, and Gujarat, Rajasthan are showing low acute respiratory infections. Uttarakhand is showing high, whereas Gujarat, Rajasthan, and Karnataka are showing low both in case of cold & cough and fever among under-five children in India. The use of smoky cooking fuel and unimproved sources of drinking water map states are quite contradictory to each other, states like Rajasthan, Madhya Pradesh, and Jharkhand are showing high percentages in case of use of smoky cooking fuel and a low percentage in case of unimproved sources of drinking water. In the case of unimproved toilet facilities, Rajasthan, Madhya Pradesh and Jharkhand are showing a high percentage, and Himachal Pradesh and Uttarakhand are showing a low percentage. Rudimentary roof materials and unclean floor materials are showing quite similar to each other in Uttar Pradesh and Bihar with a high percentage and Maharashtra and Telangana showing a low percentage. The active case rate is low in Gujarat and Madhya Pradesh, whereas high in Karnataka. In the case of CFR, states like Gujarat and Madhya Pradesh are showing high percentage and states like Kerala, Tamil Nadu, and Andhra Pradesh, etc., are showing a low percentage (Fig. 1).

3.2. Composite vulnerability score (CSV) aggravate susceptibility to Coronavirus disease (COVID-19) among under-five children in India

Table 3 represents the composite vulnerability score of various factors of the COVID-19 among under-five children in the states and UTs of India. The states and UTs which have a high composite vulnerability score of the COVID-19 among under-five children are Meghalaya (CVS = 1), Uttar Pradesh (CVS = 0.93), Jharkhand (CVS = 0.86), Bihar, (CVS = 0.74), Madhya Pradesh (CVS = 0.74), and Odisha (CVS = 0.55). The states and UTs which have low composite vulnerability score of the COVID-19 among under-five children are in Sikkim (CVS = -0.90), Daman & Diu (CVS = -0.76) Lakshadweep (CVS = -0.74), Kerala (CVS = -0.72), Chandigarh (CVS = -0.71).

The results of the analysis are shown in Fig. 2 which depicts state and union territory wise hot spot (vulnerable) and cold spot zone of COVID-19 among under-five children in India. Here, hot spots shown in red are statistically significant high clusters of events, random events are shown in yellow color and cold spots shown in blue color are statistically significant low clusters of events. The COVID-19 vulnerable/ risk zones (hot spot: 99% Confidence interval [CI]) were observed in Madhya Pradesh, Uttar Pradesh, Jharkhand, Bihar, and Meghalaya states of India, which are spatially high clustered, while comparatively high rates (hot spot: 95% CI) of COVID-19 vulnerable zones were observed in Chhattisgarh, Odisha, and West Bengal. The less vulnerable zones (cold spot: 95% CI) were observed in Kerala, Mizoram, and Sikkim, and comparatively less vulnerable zones (cold spot: 90% CI) were observed in Himachal Pradesh, Punjab, Delhi, Manipur, Nagaland, Tripura, Goa, and Andhra Pradesh.

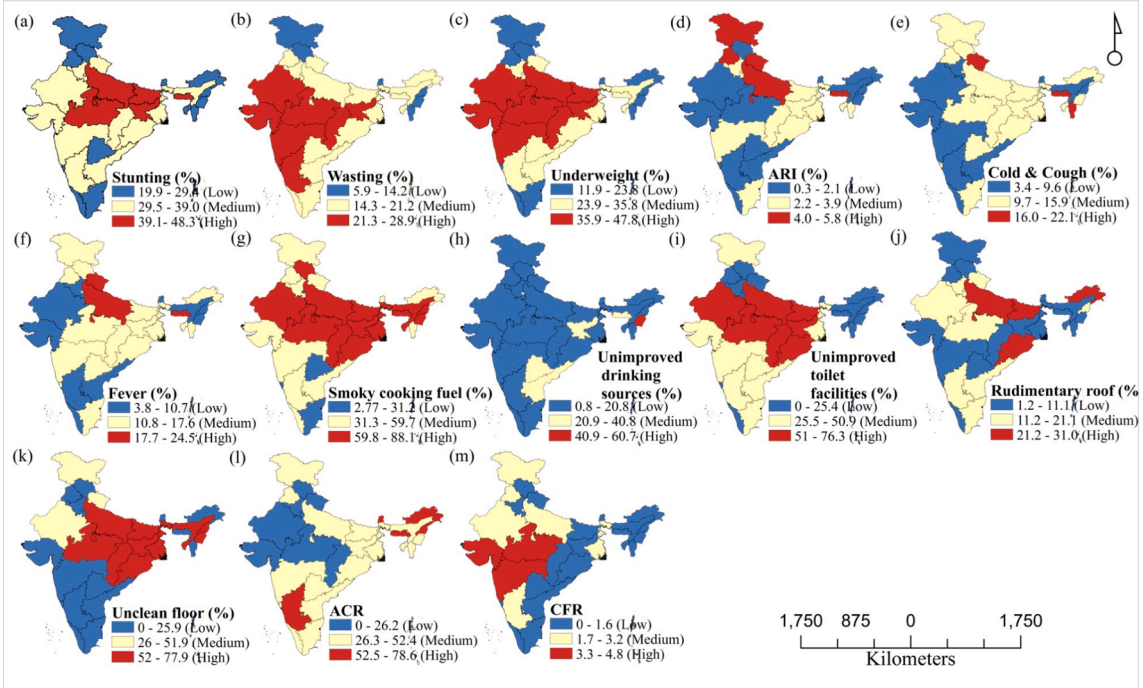

Fig. 1. Different indicators viz. **(a)** Stunting; **(b)** Wasting; **(c)** Underweight; **(d)** Acute Respiratory Infections (ARI); **(e)** Cold & cough; **(f)** Fever; **(g)** Use smoky cooking fuel; **(h)** Unimproved sources of drinking water; **(i)** Unimproved toilet facilities; **(j)** Rudimentary roof material; **(k)** Unclean floor material; **(l)** Active Case Rate (ACR); and **(m)** Case Fatality Rate (CFR) for identifying the COVID-19 vulnerable states and UTs of India.

Table 3
Composite vulnerability score of different indicators of the prevalence of malnutrition, pre-existing childhood morbidities, poor household environmental conditions, and current COVID-19 factors in the states and UTs of India.

States and union territories	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	Composite Vulnerability Score (CVS)
Andaman & Nicobar Islands	−1.18	0.06	−0.74	−0.60	0.37	−0.73	−1.12	−0.64	−0.57	−0.73	−0.60	−0.24	−1.02	−0.60
Andhra Pradesh	−0.09	−0.23	0.46	−1.34	−1.47	−0.79	−0.50	1.30	0.69	0.37	−0.90	0.61	−0.08	−0.15
Arunachal Pradesh	−0.38	−0.31	−0.92	−0.15	−0.21	−0.07	0.25	0.19	−0.58	2.76	−0.53	1.80	−0.61	0.10
Assam	0.55	−0.30	0.20	−0.97	−0.64	−0.65	1.16	0.31	−0.51	−0.45	1.87	−0.19	−0.85	−0.04
Bihar	2.17	0.39	1.73	0.14	−0.26	0.11	1.43	−1.00	1.93	1.81	1.94	−0.52	−0.31	0.74
Chandigarh	−0.39	−1.55	−0.38	0.36	−0.25	−0.48	−1.76	−1.06	−0.97	−1.09	−0.95	−0.80	0.07	−0.71
Chhattisgarh	0.73	0.79	1.05	−0.08	0.27	0.36	1.13	−0.25	1.46	−0.90	1.18	−1.03	−0.66	0.31
Dadra and Nagar Havel	1.30	1.59	1.17	−0.30	−1.43	−1.42	−0.15	0.57	1.03	0.16	0.68	0.59	−0.86	0.23
Daman and Diu	−1.20	1.01	−0.19	−1.27	−1.46	−1.20	−1.72	−0.42	−0.88	−1.18	−1.10	0.59	−0.86	−0.76
Delhi	0.00	−0.56	−0.07	0.07	−0.14	0.37	−2.06	1.07	−0.90	0.27	−1.15	−1.53	1.38	−0.25
Goa	−1.62	0.57	−0.47	−0.67	0.66	1.02	−1.46	−1.01	−0.65	−0.43	−0.83	0.16	−0.49	−0.40
Gujarat	0.83	1.40	1.24	−0.67	−0.58	−0.65	0.10	−0.25	0.45	−0.86	−0.26	−0.89	2.84	0.21
Haryana	0.25	0.46	0.17	0.66	−0.62	−0.58	0.10	−0.27	−0.53	0.35	−0.39	−1.09	0.11	−0.11
Himachal Pradesh	−0.76	−0.84	−0.69	−0.53	−0.15	0.02	0.76	−0.84	−0.45	−0.99	−0.59	−1.03	−0.31	−0.49
Jammu and Kashmir	−0.59	−1.14	−1.21	2.29	0.88	0.48	−0.06	0.10	−0.01	−0.05	0.00	0.32	0.36	0.11
Jharkhand	1.79	1.82	2.16	0.66	−0.23	0.19	1.38	0.97	2.01	−0.73	1.46	0.09	−0.34	0.86
Karnataka	0.56	1.29	0.77	−0.82	−1.38	−1.09	−0.23	−0.23	0.61	0.87	−0.79	1.58	0.44	0.12
Kerala	−1.62	−0.53	−1.27	−1.12	−0.68	−0.28	−0.21	−0.60	−1.13	−0.89	−1.13	0.80	−0.70	−0.72
Lakshadweep	−0.74	−0.81	−0.48	−1.04	0.39	0.48	0.24	−0.28	−1.16	−1.23	−1.17	−2.76	−1.02	−0.74
Madhya Pradesh	1.31	1.27	1.61	−0.15	−0.23	−0.10	0.93	0.35	1.52	1.03	1.16	−1.01	1.90	0.74
Maharashtra	0.28	1.22	0.86	0.07	−0.52	0.19	−0.43	−0.31	0.32	−0.90	−0.30	0.22	2.20	0.22
Manipur	−0.45	−2.08	−1.55	−1.19	0.35	−0.81	0.32	4.23	−1.07	−0.65	1.22	0.20	−1.02	−0.19
Meghalaya	1.58	−0.64	0.10	2.59	2.17	2.65	1.24	1.44	−0.61	0.09	−0.14	3.02	−0.52	1.00
Mizoram	−0.57	−2.25	−1.74	−0.08	1.98	−0.08	−0.63	−0.33	−1.10	−0.08	−1.09	−0.17	−1.02	−0.55
Nagaland	−0.48	−1.30	−1.21	−0.67	−0.69	−1.07	0.91	0.64	−1.05	0.96	1.08	1.63	−1.02	−0.18
Odisha	0.26	0.31	0.69	0.07	0.33	0.25	1.26	−0.09	1.90	2.23	0.94	−0.40	−0.61	0.55
Puducherry	−1.11	0.91	−0.64	0.51	0.77	0.01	−1.61	−0.70	0.09	0.64	−1.00	0.57	−0.04	−0.12
Punjab	−0.85	−0.53	−0.68	1.33	0.44	0.37	−0.57	−1.08	−0.81	−0.61	−0.46	−0.62	0.98	−0.24
Rajasthan	0.93	0.77	0.93	−0.15	−0.70	−0.45	0.87	0.29	1.06	0.47	0.08	−1.06	0.67	0.29
Sikkim	−0.36	−0.78	−1.51	−1.49	−1.95	−1.84	−0.27	−0.94	−1.15	−1.06	−0.60	1.30	−1.02	−0.90
Tamil Nadu	−0.66	0.18	−0.45	0.36	0.73	−0.24	−1.11	−0.28	0.54	0.50	−0.88	−0.28	0.12	−0.11
Telangana	−0.60	−0.13	−0.01	−0.23	0.62	1.11	−0.94	0.76	0.20	−0.67	−0.69	−0.29	−0.21	−0.08
Tripura	−1.09	−0.34	−0.43	0.22	0.37	−0.02	0.72	0.42	−0.91	−0.86	1.55	−0.63	−0.95	−0.15
Uttar Pradesh	1.89	−0.13	1.25	1.77	0.71	1.82	0.83	−0.86	1.31	1.43	1.41	−0.26	0.99	0.93
Uttarakhand	0.23	0.15	−0.12	1.70	2.64	2.93	0.17	−0.55	−0.32	0.52	−0.02	−1.33	0.07	0.47
West Bengal	0.08	0.27	0.39	0.74	−0.09	0.18	1.02	−0.65	0.28	−0.08	1.00	−0.13	1.42	0.34
Mean	32.12	18.65	27.96	2.31	11.38	11.77	53.18	12.99	27.95	10.40	29.33	37.57	1.27	
Standard deviation (σ)	7.49	5.63	9.22	1.35	4.08	4.34	24.50	11.30	24.11	7.47	25.09	13.61	1.25	

V_1 *= Stunting;* ***V_2*** *= Wasting;* ***V_3*** *= Underweight;* ***V_4*** *= Acute Respiratory Infections (ARI);* ***V_5*** *= Cold & cough;* ***V_6*** *= Fever;* ***V_7*** *= Use smoky cooking fuel;* ***V_8*** *= Unimproved sources of drinking water;* ***V_9*** *= Unimproved toilet facilities;* ***V_{10}*** *= Rudimentary roof material;* ***V_{11}*** *= Unclean floor material;* ***V_{12}*** *= Active case rate (ACR); and* ***V_{13}*** *= Case fatality rate (CFR).*

4. Discussion

Globally, stunting, wasting, and underweight are health risks for various diseases also the COVID-19. This study has identified the risk zones of COVID-19 among children under age five in India. As the Coronavirus has been associated with malnutrition, so, there has a relationship between malnutrition and COVID-19 (Fore et al., 2020; Headey et al., 2020). Children's malnutrition in vulnerable zones could intensify the effects of COVID-19 among children under age five. In the same way, more children under age five are becoming undernourished due to the weakening of health systems, disrupting routine services, interruptions in nutrition and supplementary necessary services, and the socio-economic alter happened by the COVID-19 pandemic in India. Our finding showed that children under age five with high malnutrition have a moderate to high risk of COVID-19 and these states and UTs are susceptible to COVID-19 in India.

Pre-existing morbidities like acute respiratory infection, cold & cough, and fever among children under age five in India have risk factors of the COVID-19. In previous studies, it is found that pre-existing co-morbidities among children under age five are risk factors of the COVID-19 death and these zones are vulnerable to COVID-19 (Saha & Chouhan, 2020; Shekerdemian et al., 2020; Sinha et al., 2020). This finding is in agreement with another study conducted in India (Saha & Chouhan, 2020).

Uses of smoky cooking fuel or solid biomass gas are the risk factors of health disease among under-five children. The use of smoky cooking fuel directly associated with the respiratory health system of living children and dependence on hard biomass for cooking and burning or heating exposes respiratory health problems of under-five children in India. Those people living in an area with extremely high amounts of pollutants are, therefore, more likely to develop severe respiratory infections and also aggravate susceptibility to COVID-19 (Conticini et al., 2020; Tobías et al., 2020). For its likelihood to increase the vulnerability of COVID-19 through smoky cooking fuel-related health effects among children under-five age and from the household air pollutants as such, the accessible public health challenge of indoor air pollution (IAP) in India (Saha & Chouhan, 2020) warrants concern and demands immediate and specific measures.

The spread of COVID-19 is directly related to the unimproved water and sanitation conditions of households. In developing countries, many

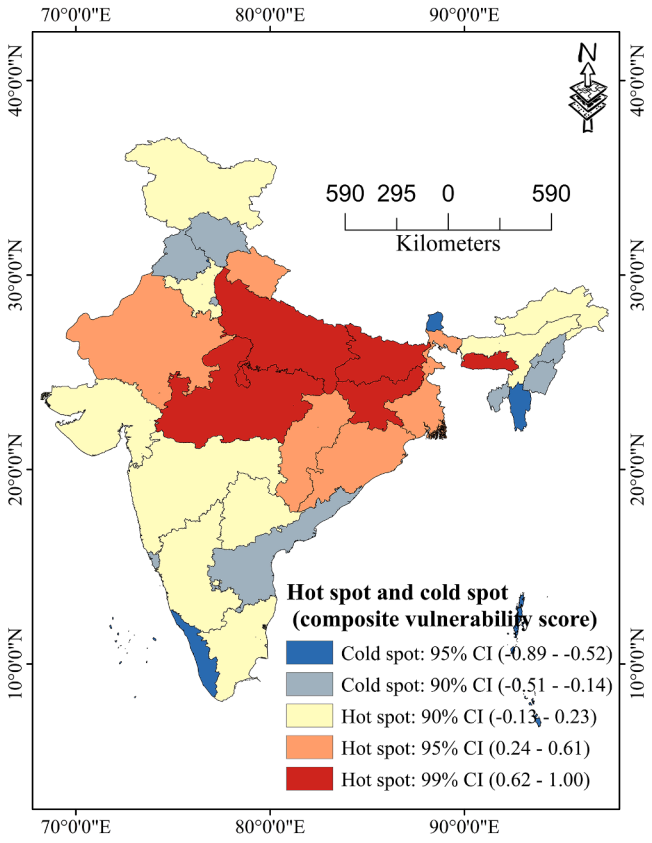

Fig. 2. State and union territory wise hot spot (vulnerable) and cold spot areas of COVID-19 among under-five children in India.

people have lack of access to improved sources of drinking water and sanitation facilities at present (Cox & Piccolo, 2020). In India, the risk of developing the COVID-19 was higher among those under-five children who are using unimproved drinking water sources and unimproved toilet facilities compared to those children who are using improved sources of drinking water and sanitation. The risk of developing the COVID-19 was higher in children from poor household environment having rudimentary roof materials and unclean floor materials than those from households having metal or concrete roof materials and clean floor materials. This could be because the unclean floor and rudimentary roof materials of the dwelling cause the transmission of the virus, which may aggravate susceptibility to Coronavirus disease. The states and UTs with high case fatality rates are vulnerable areas of the COVID-19 in India. This study is consistent with the study in the People's Republic of China (Cui et al., 2003) and Northern Italy (Conticini et al., 2020).

5. Limitations

The measurement of CFR amid the COVID-19 outbreak is very difficult, due to to under-reporting. In some places, patients might even die being tested. A major challenge with the exact calculation of the CFR is the denominator: the number of COVID-19 positive people. Asymptomatic cases of COVID-19, patients with mild symptoms, or individuals who are misdiagnosed could be left out of the denominator, leading to its underestimation and overestimation of the CFR. Surveyed women have self-reported about their children's pre-existing childhood morbidities, so there is a possibility of recall bias during the collection of information about children.

6. Conclusion

In the vulnerable states and UTs of India, under-five children being underprivileged of nutrition sustain, and also to a load of families because of not capable to meet ends due to loss of job and wages and alarming poverty due to the COVID-19 lockdown in India. So, there is a requirement to make stronger the existing food availability and supply along with ample counselling on mask wearing, hand-washing, and social isolation. If don't this, there is a likelihood of an increase in the number of malnourished under-five children who are susceptible to Coronavirus due to be deficient in immunity level. This possibly will have a negative boost in long-lasting health among under-five children and socio-economic and demographic impact in the vulnerable states and UTs of India. Access to clean drinking water and toilet facilities is key for public health and dropping the transmission of infectious diseases like COVID-19 in the vulnerable zones. For developing countries like India improving access to these facilities be supposed to be a top main concern to reduce this infectious disease.

CRediT authorship contribution statement

Jay Saha: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Pradip Chouhan:** Conceptualization, Formal analysis, Investigation, Supervision, Validation, Visualization, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.childyouth.2021.105962.

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