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Original Article

Public Health Section

Spatial and Space-time Clustering of Diarrhoeal Cases among Under-five Children in Karkala, Karnataka: A Geospatial Analysis

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ABSTRACT

Introduction: Globally, India tops by contributing the maximum number of diarrhoeal fatality. Forecasting the path and spread of diarrhoeal disease is critical due to its multifactorial cause, which needs robust spatial analysis and experiential investigations of communicable disease.

Aim: To investigate purely spatial, purely temporal, and space-time clusters of diarrhoea among under-five children using a Geographic Information System (GIS) in Karkala taluk of the Udupi district of Karnataka, India.

Materials and Methods: A retrospective longitudinal study was conducted involving all the primary health centres of Karkala taluk by the investigators, from the Department of Public Health, KS Hegde Medical Academy, Nitte (DU), Mangalore, Karnataka, India. The data on diarrhoea among under-five children was collected for three years, i.e., from 1st April 2015 to 31st March 2018, at the Udupi district health office. The data from 49 villages were obtained, and 3894 under-five childhood diarrhoea were reported during the study period. The annual incidence of childhood diarrhoea at the taluk level was calculated using excel. The spatial, temporal and space-time diarrhoeal clusters were identified using Kulldorff SaTScan software. Geographic Information System, QGIS 3.20.2 software was used to plot the maps.

Results: The analysis of the spatial cluster using SaTScan software for three years in the study area identified eight high-risk areas (p-value <0.0001), covering 17 villages. The most likely spatiotemporal cluster region was located at the northern Karkala, and the most-at-risk period was 1st April 2016 to 30th September 2017 {Log Likelihood Ratio (LLR)=114.67 and p-value <0.00001}. The analysis of purely temporal cluster showed that one most likely cluster happened in all villages (LLR=73.89, p-value <0.001) from 1st April 2017 to 3rd March 2018.

Conclusion: The diarrhoea among under-five children at Karkala taluk was not randomly distributed over space and time.

Keywords: Geographic information system, Healthcare facility, SaTScan, Udupi district

INTRODUCTION

According to World Health Organisation (WHO) report 2017, worldwide around 2.1 billion people have no access to clean drinking water [1]. Every year, it is estimated that around four billion diarrhoea cases occur globally, and it is one of the severe problems in the developing world [2]. Poor quality of water, sanitation, and hygiene are some of the leading cause of diarrheal incidence, and most deaths occur among under-five children due to diarrhoea [3]. India is responsible for 13% of under-five death due to diarrhoea, killing almost 3,00,000 children every year [4]. In 2015, India accounts largest number of under-five deaths among all countries [5]. Diarrhoea among under-five children not only varies across nationsbut also among different states of a given nation. These variations can be the result of climatic, environmental, behavioural, socio-economic, and spatial factors.

An epidemiological study on infectious disease helps us identify the root of the disease, its progression, the role of the environment in the development of disease, and the outspread. Whenever the disease cause is multi-factorial and infectious, forecasting its spread becomes critical, which requires robust spatial analysis. Various aetiological hypotheses can be stated and tested by geographical mapping of the disease, which would help identify hotspot areas and policy advocacy. The spatial analysis also helps in identifying the spatial-temporal cluster of the particular geographic area [6,7].

Udupi district is located in the Karnataka state of Indian nation has also contributed to diarrheal disease among Under-five children. According to District Health office sources, Udupi district (unpublished source) out of 84,246 under-five children, 8486 children had a diarrheal episode. According to District Level Household and faciltiy Survey-4 (DLHS-4), the burden of diarrheal disease in the Udupi district has doubled (4.2%) more than twice compared to that of DLHS-3 (1.9%) [8]. The primary aim of the study was to investigate purely spatial, purely temporal, and space-time clusters of diarrhoea among under-five children using GIS in Karkala taluk of Udupi district.

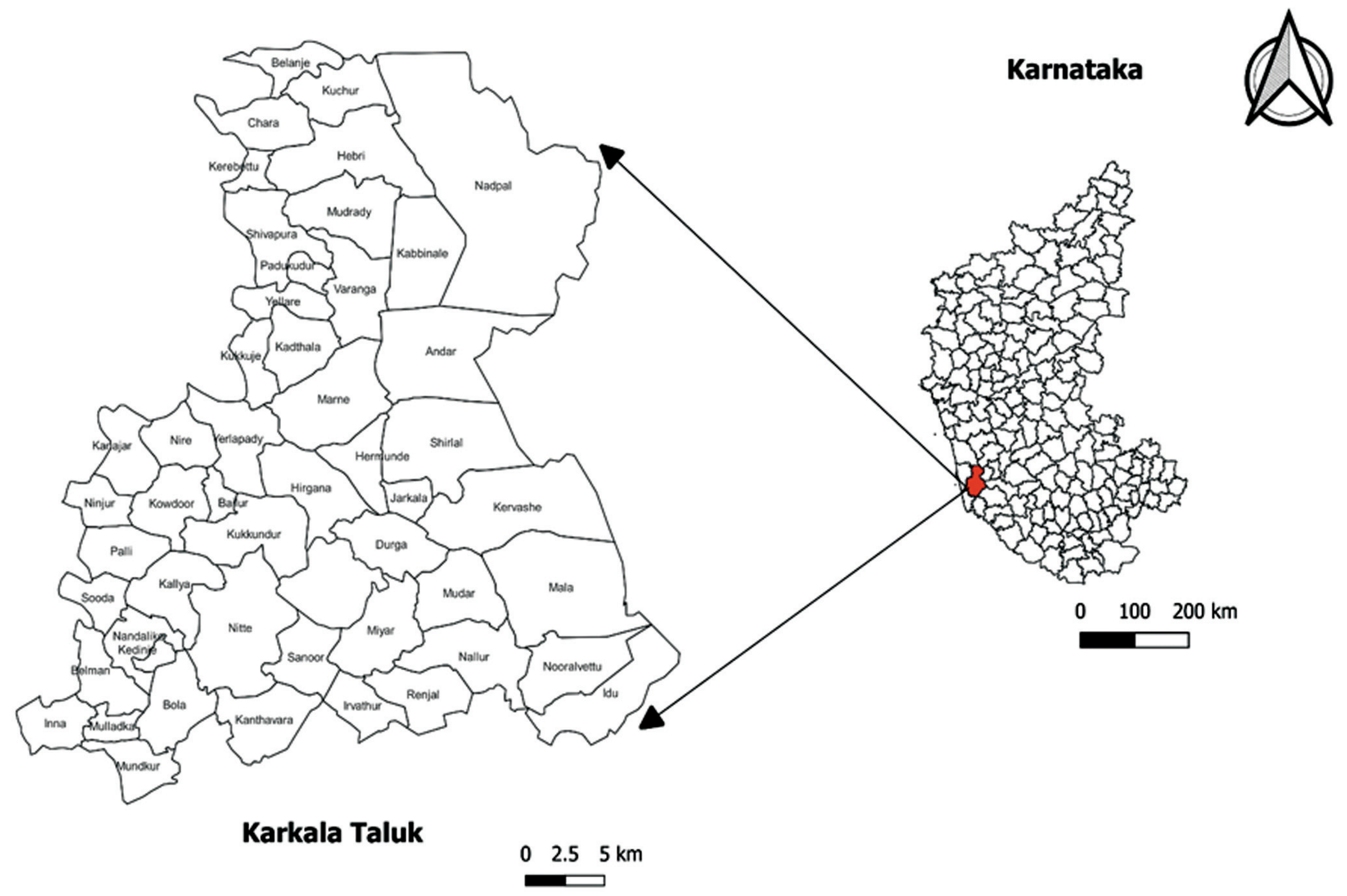
MATERIALS AND METHODS

A retrospective longitudinal study was conducted in Karkala block/taluk of the Udupi district in the year 2019-2020. The study area is located in the south-west part of the country between 13011’60” North latitude and 74058’48” East longitude. A geographic location represented each village by the geo-coordinates taken from a village’s representative site. Geo-coordinates were précised by means of a standard Cartesian coordinate system. The Karkala block has three seasons: summer, monsoon and winter. The warm season starts from March to May, monsoon from June to August and winter from September to February. In this region of study, the average highest and lowest temperatures are 26°C and 11°C, respectively [Table/Fig-1].

The study was approved by the Central Ethics Committee {Ref: NU/CEC/2019/0212, Date of approval: 30.01.2019}. In addition, formal approval was also taken from the District Health Officer (Udupi), and informed consent from participant and the guardians who participated in the study was undertaken.

Study Procedure

The cases were operationally defined as the number of under-five children identified with diarrhoea in all study villages healthcare facility. The data on diarrhoea among under-five children was collected for three years, i.e., from 1st April 2015 to 31st March 2018, at the district health office by reviewing monthly reports made to the regular surveillance system. To validate the information among under-five children at the village level, the researcher implemented a top to bottom approach, i.e., District level-taluk level, primary



[Table/Fig-1]: Study location (Map of Karnataka projected to show map of Karkala taluk).

health centre, subcentre. The demographic data of 49 villages were extracted from the subcentre, and the validation was done at it at each village panchayath. Two trained data collectors in public health collected the data.

STATISTICAL ANALYSIS

The annual under-five children diarrhoea incidences per 1000 under-five population at risk in each village from April 2015 to March 2018 were calculated using MS excel. The excess hazard ratio {Standard Morbidity Ratio (SMR) >1} for every village was estimated by dividing the observed cases by expected cases. The expected number of cases in each village was estimated by E(c)=p*C/P, where c is the number of expected cases, and p is the population of the study village, C is the total number of observed cases, and P is the total population in study taluk [9].

Cluster Analysis

The Spatiotemporaland cluster analysis was conducted in 49 villages using the Kulldorff scan statistic (SaTScan v9.6.1). The SaTScan software was used to detect the randomness of diarrhoea distribution over space and time among under-five children. By considering the number of observed and expected cases inside the window, the software identifies and assesses the statistical significance of spatial or space-time clusters. The scanning window in SaTScan software considers time (interval), space (circle/ellipse) and space-time (a cylinder with an elliptical or circular base). A discrete Poisson-based model was used to analyse the monthly reported diarrhoeal cases following Poisson distribution [10].

Purely Spatial Clusters

For identifying spatial clusters of under-five children with diarrhoea, a purely spatial analysis was performed using SaTScan software without taking time into account. For analysing the spatial statistics, the SaTScan software uses a circular window that scans the entire study area. The circle radius takes different values ranging from zero to the mentioned largest size. This fixed highest size determines the total population of under-five children at risk within the scanning window. It is recommended that the largest size is not beyond 50%, i.e., the identified cluster to have no more than 50% of the under-five children at risk [11]. The spatial scan statistic's null hypothesis states that diarrhoea among under-five children is randomly distributed throughout the villages and that the expected event count is proportional to the population at risk. If the null hypothesis is statistically rejected for any circular window, then the scan window's geographic area can be considered a spatial cluster.

SaTScan software uses a Monte Carlo simulation to test the assumption for each location and size of the scanning window. The null hypothesis states that there is no significant difference in observed cases inside and outside the scanning window for each circle. The likelihood ratio is calculated within each process, assuming Poisson distribution. The likelihood function for a specific window was calculated using:

$$\left[\frac{c}{E(c)}\right] \left[\frac{C-c}{C-E(c)}\right] I[c>E(c)]$$

Where 'c' is the number of under-five children with diarrhoea observed inside the window (village), and E(c) is the indirectly age-adjusted expected number of under-five children with diarrhoea inside the window (in that village), C is the total number of under-five children in the study area, C-c and C-E(c) are proportional to the age-standardised incidence ratios within and outside the window respectively, and I is an indicator function, I=1, when the window has more diarrhoeal cases than expected.

The most likely cluster is identified by the likelihood ratio having a higher value and with p-value significance. The Monte Carlo simulations (999) technique is used to estimate the p-value [11]. The significant cluster was identified with a p-value <0.05.

Spatiotemporal and Temporal Clusters

To detect temporal clusters with high rates of diarrhoea, a purely temporal cluster analysis was performed. The upper limit size of the cluster was set to 50% of the population at risk within the study period. The most likely cluster was identified by the likelihood ratio having the highest value. The p-value ≤0.05 was considered to be significant.

Space-time scan statistic was used to detect clusters both in space and time. The space-time scan statistic uses a cylindrical window with a circular (or elliptic) geographic base and height related to time to determine spatiotemporal clusters. The purely spatial scan statistic is reflected by the geographic base of the cylindrical window, while the height of the cylindrical window reflects the time period. For each possible geographical location and size, the cylindrical window is moved in both space and time; it also visits each possible time interval. For each space-time window, the likelihood ratio is calculated to determine the rate of observed cases and expected cases. The Monte Carlo simulations (999) technique is used to estimate the p-value [12].

RESULTS

The data from 49 villages were obtained, and 3894 under-five childhood diarrhoea were reported from 1st April 2015 to 31st March 2018. The total under-five population of villages in Karkala taluk for 2015-2016, 2016-2017 and 2017-2018 were 12,038, 12,116 and 11,848, respectively. In Karkala taluk, the combined incidence rate of diarrhoea was 123.6 cases per 1000 under-five population at risk. The overall incidence rate of diarrhoea among girl children was 385.7 per 1000 girl child, while the incidence rate for boys was 362.5 per 1000 boys. The maximum incidence of diarrheal cases (672 per 1000 population) was seen in the second year (13 to 24 months), while the least (148.6 per 1000) was seen in children below six months of age. The highest incidence of diarrhoea was seen in the month of April (650 per 1000 population) followed by July (350 per 1000 population), and the least was seen in November (15.8 per 1000 population at risk) [Table/Fig-2].

The SMR was determined by the number of observed cases over the number of expected cases. Almost 50% of villages had SMR >1, seven villages had >2, while 15 villages had SMR >1 [Table/Fig-3].

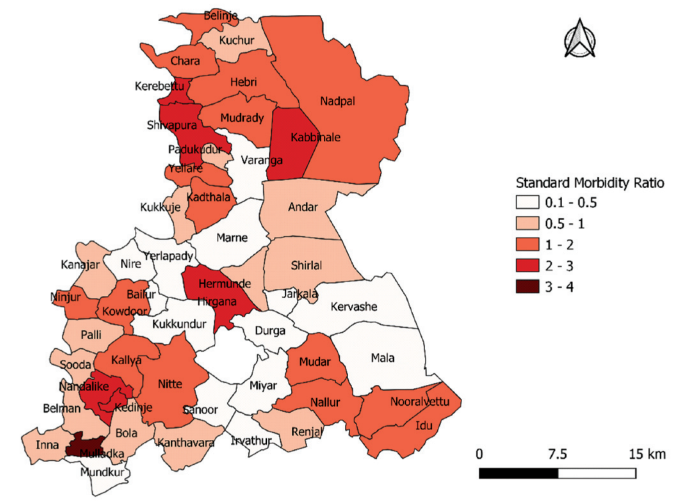
The diarrhoea among under-five children varied considerably across the villages. Overall, 24 villages had incidence rates of 100 or more cases per 1000 under-five children at risk. The Mulladka village witnessed the highest incidence rate (652.2 cases per 1000 children) in 2017-2018, while the lowest incidence was seen in Sanoor village (6.8 per 1000 children) in 2015-2016. The Mulladka village saw the overall highest incident cases (360.5 per 1000 under-five children at risk) and the least cases (19.5 per 1000 under-five children at risk) in Sanoor village.

Throughout the three-year study period, one primary cluster and seven secondary cluster were identified, covering a total of 17 villages. Likely, the Global Moran I values ranged from 0.016 to 0.351 for the study area, with a significant p-value suggesting positive spatial autocorrelation. The primary cluster for diarrhoea (LLR=187.817, p-value <0.0001) was centred at 13.489810 N, 75.001120 E with a radius of 11.45 km and relative risk of 2.04. The cluster covers nine villages, namely Kuchur, belinje, Hebri, Chara, Kerebettu, Mudradi, Nadpal, and Kabbinale. The secondary clusters were located at Kedenje, Nandalike, Hirgana, Idu, Norralavettu, mulladka, Nallur, and Nitte, which were statistically significant (p-value <0.0001), and one nonsignificant secondary cluster was found at Ninjur village with p-value 0.818 [Table/Fig-4].

One most likely cluster and three secondary clusters were identified by keeping the maximum spatial cluster size as 50% of the total population. The most likely spatio-temporal cluster area was located at the northern Karkala, and the high-risk period was 1st April 2016 to 30th September 2017 (LLR=114.67 and p-value <0.00001). The centre of the most likely cluster was in Kuchur village, 13.489810 N, 75.001120 E, covering nine villages: Kuchur, Belinje, Hebri, Chara,

Variables	Incidence rate per 1000 under-five population							
	2015-2016		2016-2017		2017-2018		Overall	
	Mean±SD	Maximum	Mean±SD	Maximum	Mean±SD	Maximum	Mean±SD	Maximum
Overall	100.6±75.5	294.1	114.2±82.1	299.2	159.3±116.9	652.2	123.6±83.1	360.5
Gender								
Male	96.4±82.1	407.4	110.1±83.4	333.3	167.9±123.4	666.7	123.2±82.9	362.5
Female	106.1±85.3	307.7	120.0±90.0	327.9	152.5±117.4	636.4	125.0±86.8	385.7
Age (in months)								
≤6	28.4±62.5	272.7	35.6±84.2	388.9	20.7±57.2	333.3	25.4±40.7	148.6
7-12	109.5±131.2	428.6	169.6±170.5	533.3	146.4±197.9	750.0	142.5±124.2	473.7
13-24	281.5±217.8	857.1	255.7±187.7	705.9	266.7±202.7	1000	272.1±128.5	672.1
25-36	254.5±197.3	1000	232.4±171.9	666.7	222.2±151.7	692.3	232.6±109.5	487.8
37-48	231.1±212.1	857.1	211.5±197.7	666.7	194.0±194.9	1000	201.8±135.3	631.6
49-60	95.0±141.5	666.7	95.1±117.3	407.4	150.0±221.5	1000	125.5±121.4	526.3
Month								
January	78.7±95.8	333.3	38.4±49.9	222.2	61.7±69.3	250	57.1±50.3	194.4
February	77.6±95.6	333.3	59.6±89.6	333.3	69.9±81.9	333.3	64.0±47.7	216.7
March	156.5±242.8	1000	122.4±159.7	687.5	98.6±106.9	500	115.2±80.1	371.4
April	95.1±122.6	500	113.1±161.7	1000	140.9±192.0	1000	124.6±122.7	650.0
May	73.2±101.6	500	74.8±78.9	333.3	78.7±91.3	391.3	78.8±52.8	250.0
June	132.9±145.5	666.7	87.3±147.3	1000	62.7±67.5	304.4	88.0±55.2	258.1
July	91.9±80.2	350.0	116.9±155.3	666.7	125.6±129.9	684.2	116.5±80.0	350.0
August	65.7±75.9	285.7	115.2±128.4	750.0	87.2±75.1	333.3	88.2±42.45	210.5
September	52.5±56.2	181.8	69.0±63.1	166.7	65.7± 68.6	312.5	67.9±41.8	161.3
October	61.9±83.5	428.6	62.8±66.6	285.7	69.7±69.3	333.3	66.3±51.8	210.5
November	44.9±60.2	250	67.8±81.5	363.6	71.6±82.8	366.7	62.4±43.8	153.8
December	69.1±74.2	333.3	72.7±98.3	476.2	67.8±65.9	233.3	70.9±59.9	266.7

[Table/Fig-2]: Distribution of diarrhoeal incidence among under-five children in Karkala Taluk.



[Table/Fig-3]: Excess risk of under-five diarrhoea from April 2015 to March 2018 in villages of Karkala Taluk, Udupi District.

Purely Temporal Clusters of Childhood Diarrhoea

All villages witnessed one most likely cluster in the month of 1st April 2017 to 3rd March 2018, 2018 (LLR=73.89, p-value <0.001). The overall RR within the cluster was 1.49 (p-value <0.0001), with an observed number of 1661 and 1296.4 expected cases. There were no secondary clusters identified.

DISCUSSION

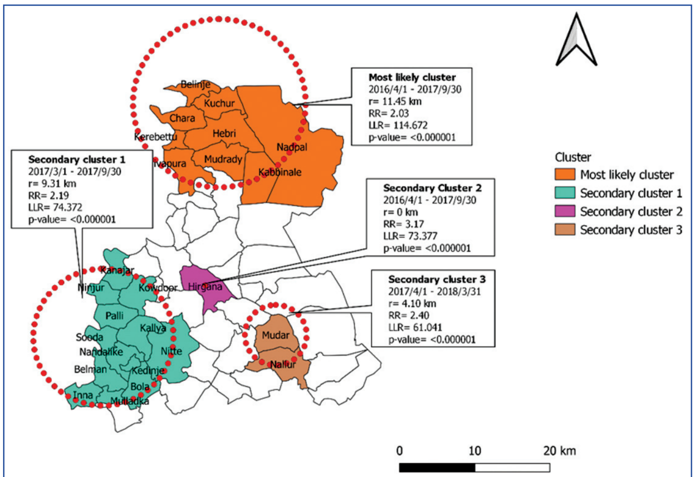
The study analysed the spatial and space-time distribution of under-five diarrhoea in Karkala taluk from April 2015 to March 2018 using Kulldorff's scan statistical analysis. The study established significant space-time clustering of diarrhoea incidents among under-five in Karkala taluk.

The study exhibited seasonal variation of diarrhoea among under-five children. The incidence rate was highest in Mulladka village for the year 2017/18. The high-risk space-time spots of diarrhoea were observed in south-west Karkala. The findings were consistent with the study conducted in Chennai, showing that climatic factors like high temperature and heavy rainfall were significantly associated with childhood diarrhoea [13-16]. The high temperature helps in bacterial growth and favours its survival in the external environment [15,17,18]. The flooding and surface run water will enhance drinking water source contamination during the rainy season [19]. The dry seasons lead to increase consumption of water because of high temperatures. Unhygienic drinking water practices and water scarcity leads to the transmission of diarrhoea [19,20]. Most of the household wells and bore wells will be dried out during the summer season, making households use unimproved water sources [19]. The extended analyses on rotavirus from the Global Burden of Disease report show that diarrheal episodes and death among under-five children could have been saved if full rotavirus vaccination coverage had been achieved [21]. While in Kakarla taluk, the rotavirus vaccination was involved in the routine immunisation schedule in 2021.

Cluster type	Coordinates/Radius	Cluster village	Observed cases	Expected cases	RR	LLR	p-value
Primary cluster	13.489810 N, 75.001120 E/11.45 km	Kuchur, Belinje, Hebri, Chara, Kerebettu Mudradi, Shivapura, Nadpal, Kabbinale	1185	688.14	2.04	187.867	<0.00001
Secondary cluster	13.170210 N, 74.893430 E/1.44 km	Kedenje, Nandalike	201	76.2	2.73	72.21	<0.00001
Secondary cluster	13.265440 N, 74.983880 E/0 km	Hirgana	226	103.98	2.25	55.41	<0.00001
Secondary cluster	13.149560 N 75.159090 E/2.93 km	Idu, Nooraletttu	259	139.01	1.92	43.11	<0.00001
Secondary cluster	13.130840 N, 74.867320 E/0 km	Mulladka	53	16.14	3.32	26.32	<0.00001
Secondary cluster	13.170060 N 75.079280 E/0 km	Nallur	204	133.85	1.55	16.47	0.00001
Secondary cluster	13.186290 N 74.942300 E/0 km	Nitte	274	209.18	1.33	9.716	0.0018

[Table/Fig-4]: Spatial clustering of diarrhoea among under-five children in Karkala taluk, India, 2015-2018.

Kerebettu, Mudradi, Shivapura, Nadpal, Kabbinale with a radius of 11.45 km. During this period, a total of 641 diarrhoeal cases among under-five children were reported with a relative risk of 2.03. The first spatiotemporal secondary cluster area was located at the south-west of Karkala. The increased risk period for diarrhoea among under-five was 1st March 2017 to 30th September 2017 (LLR=74.372, p-value <0.00001). The first secondary cluster centre was in Sooda village, 13.203370 N, 74.858880 E, covering 13 villages, namely Sooda, Palli, Nandalike, Kallya, Belman, Kedenje, Ninjur, Kowdoor, Mulladka, Bola, Inna, Nitte and Kanajar. Altogether 325 diarrhoeal cases were reported during the high-risk period with a relative risk of 2.19. In Karkala taluk, March to May and June to September are hot weather periods and south-west monsoons [Table/Fig-5].



[Table/Fig-5]: Spatiotemporal clustering of diarrhoeal incidence among under-five children at village level in Karkala taluk, Udupi district, 2015-2018.

One of the critical findings of this study is the non random spatial distribution of diarrhoea in Karkala village. In the northern zone of Karkala taluk, a purely spatial cluster was identified. The spatiotemporal models indicated the most likely cluster was located in the northeast area of Karkala taluk. The first secondary clusters were found in thirteen villages of the southwest zone and others in the southeast zone of Karkala taluk. The spatiotemporal clusters witnesses' relatedness in geographical parameters like climate conditions, altitude and socio-demography. In epidemiology, cluster analysis's importance is to detect cases' aggregation and eventually find the evidence of risk factors. Disease prevention, protection, and health promotion activities can be planned using cluster analysis [22].

The excess risk places of diarrhoea cases in the study area are seen within a defined place and time. The most likely spatiotemporal cluster was found in all northern Karkala and the south-west region between 1st April 2016 and 30th September 2017. This might be due to the precipitation changes over India's years, leading to climate change [23]. Significant high rates of purely temporal under-five diarrhoea cases were detected in all villages from 1st April 2017 to 3rd March 2018. This could be due to the decreasing trend in southwest monsoon rainfall and a slight increase in northeast monsoon in the year 2017/18 [24,25].

The strength of the study is the complete line listing of cases day-wise was obtained for all the villages from the district health office and validating at the sub-centre level. The other strength was on-time reporting of diarrhoea cases by the Accredited Social Health Activist (ASHA) by conducting house to house visits. SaTScan software's use helped us detect local clusters with good accuracy and evaluate statistical significance without any trouble.

Limitation(s)

The limitation of the study would be incompleteness and under-reporting of diarrhoea among under-five children, as the data might reflect only those who availed of healthcare services. This limitation would be minimal as this is anticipated to be uniform across all villages over the study period. The other limit of this study is the failure to test the association between the incidence of diarrhoea among under-five children and environmental factors like humidity, temperature and rainfall due to the unavailability of data.

CONCLUSION(S)

There was significant spatial and spatiotemporal clustering of diarrhoeal cases among under-five children in Karkala taluk. The Karkala taluk also saw the seasonal distribution of under-five diarrhoea cases during 2015-2018. The prevention, control and health promotional activities can be planned using advanced spatial statistical methods. The spatial information will help the program planners have equity in resource distribution, such as horizontal equity and vertical equity. The health authorities should ensure the execution of specific intervention like potable water supply, healthy environment and hygienic practices, drainage facility, and good food safety and water treatment practices for appropriate locations.

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REFERENCES

[1] World Health Organization, Geneva. Progress on Drinking Water, Sanitation and Hygiene. World Health Organization and the United Nations Children's Fund (UNICEF). 2017 Jul:22-4. [cited 2022 Jan 10]. Available from: https://www.who.int/mediacentre/news/releases/2017/launch-version-report-jmp-water-sanitation-hygiene.pdf.
[2] Lakshminarayanan S, Jayalakshmy R. Diarrheal diseases among children in India: Current scenario and future perspectives. J Nat Sci Biol Med. 2015;6(1):24-28.
[3] Bessong PO, Odiyo JO, Musekene JN, Tessema A. Spatial distribution of diarrhoea and microbial quality of domestic water during an outbreak of diarrhoea in the Tshikuwi community in Venda, South Africa. J Health Popul Nutr. 2009;27(5):652.
[4] The Million Death Study Collaborators. Causes of neonatal and child mortality in India: A nationally representative mortality survey. Lancet. 2010;376(9755):1853-60.
[5] Liu L, Chu Y, Oza S, Hogan D, Perin J, Bassani DG, et al. National, regional, and state-level all-cause and cause-specific under-5 mortality in India in 2000-15: A systematic analysis with implications for the Sustainable Development Goals. Lancet Glob Health. 2019;7(6):e721-34.
[6] Saravana Kumar V, Devika S, George S, Jeyaseelan L. Spatial mapping of acute diarrheal disease using GIS and estimation of relative risk using empirical Bayes approach. Clin Epidemiol Glob Health. 2017;5(2):87-96.
[7] Waller LA, Carlin BP, Xia H, Gelfand AE. Hierarchical spatio-temporal mapping of disease rates. J Am Stat Assoc. 1997;92(438):607-17.
[8] District level household and faciltiy survey (DLHS-4). Mumbai: International Institute for Population Sciences. [cited 2022 Jan 3]. Available from: http://www.rchiips.org/DLHS4.htm.
[9] Reiner RC, Wiens KE, Deshpande A, Baumann MM, Lindstedt PA, Blacker BF, et al. Mapping geographical inequalities in childhood diarrhoeal morbidity and mortality in low-income and middle-income countries, 2000–17: Analysis for the Global Burden of Disease Study 2017. Lancet. 2020;395(10239):1779-801.
[10] Kulldorff M. A spatial scan statistic. Commun Stat-Theory Methods. 1997;26(6):1481-96.
[11] Kulldorff M, Nagarwalla N. Spatial disease clusters: Detection and inference. Stat Med. 1995;14:799-810.
[12] Kulldorff M. An isotonic spatial scan statistic for geographical disease surveillance. J Natl Inst Public Health. 1999;48:94-101.
[13] Mertens A, Balakrishnan K, Ramaswamy P, Rajkumar P, Ramaprabha P, Durairaj N, et al. Associations between high temperature, heavy rainfall, and diarrhea among young children in rural Tamil Nadu, India: A prospective cohort study. Environ Health Perspect. 127(4):047004.
[14] Bado AR, Susuman AS, Nebie EI. Trends and risk factors for childhood diarrhea in sub-Saharan countries (1990-2013): Assessing the neighborhood inequalities. Glob Health Action. 2016;9(1):30166.
[15] Zhou X, Zhou Y, Chen R, Ma W, Deng H, Kan H. High temperature as a risk factor for infectious diarrhea in Shanghai, China. J Epidemiol. 2013;23(6):418-23.
[16] Levy K, Woster AP, Goldstein RS, Carlton EJ. Untangling the impacts of climate change on waterborne diseases: A systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. American Chemical Society. 2016 [cited 2022 Jan 25]. Available from: https://pubs.acs.org/doi/pdf/10.1021/acs.est.5b06186.
[17] Bentham G, Langford IH. Environmental temperatures and the incidence of food poisoning in England and Wales. Int J Biometeorol. 2001;45(1):22-26.
[18] Islam MS, Sharker MAY, Rheman S, Hossain S, Mahmud ZH, Islam MS, et al. Effects of local climate variability on transmission dynamics of cholera in Matlab, Bangladesh. Trans R Soc Trop Med Hyg. 2009;103(11):1165-70.
[19] Hoque BA, Hallman K, Levy J, Bouis H, Ali N, Khan F, et al. Rural drinking water at supply and household levels: Quality and management. Int J Hyg Environ Health. 2006;209(5):451-60.
[20] Chou WC, Wu JL, Wang YC, Huang H, Sung FC, Chuang CY. Modeling the impact of climate variability on diarrhea-associated diseases in Taiwan (1996–2007). Sci Total Environ. 2010;409(1):43-51.
[21] Troeger C, Khalil IA, Rao PC, Cao S, Blacker BF, Ahmed T, et al. Rotavirus vaccination and the global burden of rotavirus diarrhea among children younger than 5 years. JAMA Pediatr. 2018;172(10):958-65.
[22] Odoi A, Martin SW, Michel P, Middleton D, Holt J, Wilson J. Investigation of clusters of giardiasis using GIS and a spatial scan statistic. Int J Health Geogr. 2004;3(1):11.
[23] Kulkarni A, Sabin TP, Chowdary JS, Rao KK, Priya P, Gandhi N, et al. Precipitation Changes in India. In: Krishnan R, Sanjay J, Gnanaseelan C, Mujumdar M, Kulkarni A, Chakraborty S, editors. Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India. Singapore: Springer. 2020:47-72. [cited 2021 Dec 28]. Available from: https://doi.org/10.1007/978-981-15-4327-2_3.
[24] Annual Rainfall-2018.pdf. [cited 2021 Feb 28]. Available from: https://des.kar.nic.in/sites/Annual%20Rainfall-2018.pdf.
[25] Pai MS. A descriptive study to assess the knowledge and practice regarding water, sanitation and hygiene among women in selected villages of Udupi district. Nitte Univ J Health Sci. 2016;6(1):21.

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