Detection of High Risk Clusters of Diarrhoea, Fever and Cough in Tanzania: Results from Tanzania Demographic and Health Surveys, 1999 to 2016

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Abstract

Demographic and health surveys provide useful nation-wide data for assessing the impact of maternal and child health in developing countries. Using Tanzania demographic and health survey data for the period of 1999 to 2016, the current study aimed at assessing the spatial distribution of childhood illnesses in Tanzania. The Kulldorff's Spatial Scan Statistic was applied to identify clusters with the high risk of childhood diarrhoea, fever and cough. Results indicate that one cluster has been identified for any of the childhood illnesses (diarrhoea, fever and cough) in 1999. The identified clusters with the high risk of childhood illnesses (diarrhoea, fever and cough) showed a decrease of sample points with time specifically in high risk clusters for 2004-05, 2009-10 and 2015-16 Tanzania Demographic and Health Surveys. Also, the radii of high risk clusters were decreasing with increase in time. These results suggest improvements in child health status and indicate narrow concentration of childhood illness to some specific areas in the country. The small area estimation is required to guide interventions effectively in order to alleviate common risk factors within the location.

Keywords: Childhood illnesses, spatial scan statistic, high risk clusters, Tanzania demographic and health surveys

Introduction

Childhood morbidity is a great public health problem due to its contribution to childhood mortality. Despite increasing commitment to support prevention and treatment of infectious diseases, diarrhoea, malaria, fever and acute respiratory infections remained the leading causes of childhood morbidity (Nataro, 2012, Mohammed, 2013, Okoro, 2016, Lugangira et al., 2017). Globally, diarrhoea was estimated as the second leading cause of death among under-five children (Walker et al., 2013). In Sub-Saharan countries, such as Malawi and Zambia, childhood death was associated with diarrhoea, respiratory diseases, particularly pneumonia and AIDS (Kandala et al., 2006). Khatab & Fahrmeir (2009) indicated that diarrhoea, respiratory infectious diseases and fever were the leading causes of childhood morbidity in Egypt. In Tanzania, like in many other sub-Saharan countries, malaria,

diarrhoea and pneumonia are among the leading morbidities (Mashoto et al. 2014 & Lugangira et al. 2017). Further, Kuate-Defo & Diallo (2002), Anderson et al., (2014), and Xu et al., (2015) have shown that the risk of childhood illnesses varies across space.

Demographic and Health Surveys (DHSs) are being continuously used to analyze childhood morbidity in the developing world (Manesh et al., 2007; Mustafa et al., 2017; Lungu et al., 2018). The DHSs provide large-scale data on childhood illnesses, including diarrheoa, fever and acute respiratory infection, as well as adjusted geographical locations. Current health intervention strategies stimulate the development of spatial statistical methods whereby many statistical methods have been suggested and applied to estimate the risk of diseases over space. The Kulldorff's Scan approach is been increasingly used in testing the hypothesis of no spatial clustering (Kulldorff, 2005, Anderson et al., 2014, Xu et al., 2015 & Mclafferty, 2015). To enhance our understanding about clustering of childhood diarrhoea, fever and cough in Tanzania, Kulldorff's Scan Statistic was used to (i) detect high risk clusters of childhood diseases and (ii) examine spatial pattern of childhood diseases in four national-wide surveys.

Methodology

This study utilizes secondary data from 1999 TRCHS, 2004-05 TDHS, 2009-10 TDHS and 2015-16 TDHS-MIS. The 1999, 2004-05, 2009-10 and 2015-16 are the 3, 4, 5 and 6 rounds of surveys in the series of DHS conducted in Tanzania since 1991. TDHS was implemented by the Tanzania National Bureau of Statistics (NBS) and the Office of the Chief Government Statistician Zanzibar (OCGS), in collaboration with the Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDEC). The DHSs was designed to provide national estimates on issues related to demography and health status. The samples were based on multi-stage stratified sampling, considering urban and rural settings are the main sampling strata. The data for children aged 6-59 months were extracted and processed for the analysis.

Three reported illnesses of live births were extracted and used for analysis. These outcomes were obtained through memories "if the child had fever, symptoms of ARI/cough and diarrhoea" at any time in the last two weeks before the survey. The binary responses were then generated as one (1) if the child had the disease or zero (0) if not diseased at any time two weeks before the interview. These responses were used as the outcome variable independently. For the purpose of this study, the children and GPS datasets were merged using cluster identification number. The number of children diseased and live births for each cluster were summarized separately for each survey. The summary of data extracted from the surveys is presented in Table 1.

Table 1: Sample Size

Target Group	Survey Year			
	1999 TRCHS	2004-05 TDHS	2009-10 TDHS	2015-16 TDHS-MIS
Children under five years	3,215	8,564	8,023	10,233
Number of live births	2,839	7,852	7,526	9,430
Cluster/Sample Points	357	475	475	608

The interest of this study was to study the prevalence of childhood diarrheoa, fever and cough. The study focused on children under five years who were surviving at the time of interview for all four surveys. Children under the age of five years who were not surviving at the time of interview were deleted, and the remaining sample for 1999 RCHS, 2004-05 TDHS, 2009-10 TDHS and 2015-16 TDHS-MIS were 2,839; 7,852; 7,526 and 9,430 children respectively.

This study utilizes STATA version 14 and SaTScan version 9.3.1. Data processing and descriptive analysis were performed in STATA. SaTScan was used to identify high risk clusters of childhood illnesses. This study applied Kulldorff's Spatial Scan Statistics to identify clusters with a high risk of childhood diarrhoea, fever and cough. The Satscan method assumes that disease events were randomly distributed under the null hypothesis. The alternative hypothesis claim elevated the risk inside a region as compared to the outside region. The spatial scan test used a moving circle of varying size to find a set of regions or points that maximize the likelihood ratio test for the null hypothesis for a purely random Bernoulli process. The number of live births in the household was included as the control variable. A critical, max-size parameter sets an upper bound on the percentage of the total population at risk that was contained by an identified field cluster. The default max-size, 50 percent of the total population was used for this study. Statistically significant ($P<0.05$) clusters with a high risk of childhood illness clusters were identified. These clusters were used to assess the spatial patterns of childhood morbidity. Quantum GIS (QGIS) was used to present maps and identified clusters.

Levels of childhood diarrhoea, fever and cough

Figure 1 presents the percentage of children under five years who had diarrhoea, fever and cough two weeks preceding the survey for 1999 TRCHS, 2004-05, 2009-10 and 2015-16 TDHS. Results showed that childhood fever and childhood cough have decreased significantly over the years. Childhood fever decreased from 36.9 percent in 1999 TRCHS to 17.9 percent in 2015-16 TDHS. A childhood cough decreased from 39.6 percent in 1999 TRCHS to 3.7 percent in 2015-16 TDHS. On the other hand childhood, diarrhoea increased slightly from 1999 to 2010. Childhood diarrhoea decreased from 13.0 percent in 1999 TRCHS to 11.8 percent in 2015-16, respectively.

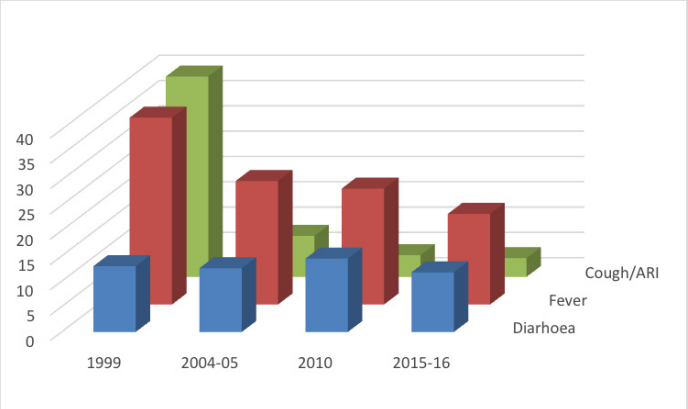

Figure 1: Bar Graph showing the percentage of children under five years who had diarrhoea, fever and cough in the two weeks preceding the survey

Spatial Cluster Analysis

The analysis was based on sample points (locations) where data for TRCHS and TDHS were collected. A total of 307 sample points for 1999 TRCHS, 472, 459 and 608 sample points for 2004-05, 2009-10 and 2015-16 TDHS respectively were analyzed for all three diseases (diarrhoea, fever and cough). The first large significant cluster was considered as the most likely cluster while the next significant clusters were considered as secondary clusters.

Identified Clusters with High Risk of Childhood Diarrhoea

One significant cluster with the high risk of childhood diarrhoea was identified in 1999 TRCHS. Three, six and four significant clusters with the high risk of childhood diarrhoea were identified for 2004-05, 2009-10 and 2015-16 TDHSs. The results of identified clusters are shown in Table 2 and Figure 2.

Significant cluster identified in 1999 TRCHS was centralized at the sample point with coordinate (-9.585175^{o} S, 34.65539^{o} E) in Njombe Region. The cluster had a radius of 549.055km and covers sample points from Katavi, Tabora, Singida, Dodoma, Morogoro, Pwani, Lindi, Mtwara, Ruvuma, Iringa, Njombe, Mbeya, Manyara, Tanga, Dar es Salaam and Rukwa Regions. The most likely cluster detected in 2004-05 TDHS with 65 sample points was centralized at the sample point with coordinate (-11.1791^{o} S, 36.3512^{o} E) in Ruvuma region. The cluster had a radius of 375.64 km and covers sample points from Ruvuma, Morogoro, Lindi, Mtwara, Iringa and Njombe Regions. For 2009-10 TDHS, most likely cluster with 36 sample points was centralized at the sample point with coordinate (-6.28196^{o} S, 36.28404^{o} E) in Dodoma Region. The cluster had a radius of 178.22 km and covered sample points from Dodoma, Iringa, Manyara, Morogoro and Singida Regions. For 2015-16 TDHS, most likely cluster with 25 sample points was centralized at the sample point with coordinate (-8.16845^{o} S, 30.950238^{o} E) in Rukwa region. The cluster had a radius of 178.22 Km and covered sample points from Rukwa and Katavi Regions.

The identified clusters revealed a reduction of sample points with time for 2004-05, 2009-10 and 2015-16 TDHS. For 2004-05 TDHS, 117 sample points out of 472 sample points were in high risk

clusters, for 2009-10 98 sample points out of 459 sample points were in high risk clusters and for 2015-16 86 sample points out of 608 sample points were in high risk clusters. This suggests improvements of the health status of under-five year's children in Tanzania. It also suggests clustering of childhood diarrhoea in Kigoma and some areas around Lindi, Mtwara and Ruvuma.

Table 2: Clusters Identified with High Risk of Childhood Diarrhoea

Survey Year	Cluster type	Centroid	Latitude	Longitude	Radius	Sample point	p-value	Relative risk	Region with Centroid
1999	Most likely	184	-9.58517	34.65539	549.05	58	0.003	1.69	Njombe
2004-05	Most likely	276	-11.1791	36.35125	375.64	65	0.000	1.79	Ruvuma
	Secondary	87	-4.18439	30.48486	114.26	20	0.000	1.86	Kigoma
	Secondary	383	-5.95217	35.30823	169.21	32	0.000	1.77	Dodoma
2009-10	Most likely	9	-6.28196	36.28404	178.22	36	0.000	1.77	Dodoma
	Secondary	278	-4.57269	30.0848	108.23	15	0.003	1.89	Kigoma
	Secondary	317	-1.62662	31.15338	72.28	11	0.009	2.09	Kagera
	Secondary	150	-10.1209	38.91769	127.71	26	0.013	1.97	Lindi
	Secondary	37	-3.65188	37.44957	32.5	3	0.04	4.39	Kilimanjaro
	Secondary	465	-5.87436	39.32951	8.18	7	0.043	2.22	Kaskazini Pemba
2015-16	Most likely	314	-8.16845	30.950238	129.33	25	0.000	1.84	Rukwa
	Secondary	328	-4.81963	30.336719	58.73	5	0.000	2.33	Kigoma
	Secondary	425	-1.713962	33.796311	89.54	22	0.000	1.68	Mara
	Secondary	197	-11.142623	38.584472	177.22	34	0.033	1.79	Mtwara

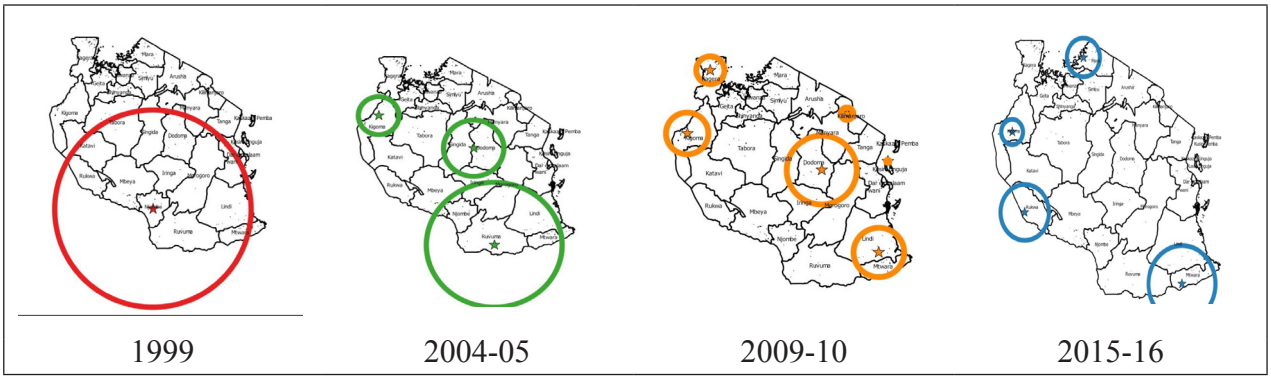

Figure 2: Clusters Identified with High Risk of Childhood Diarrhoea

Identified Clusters with High Risk of Childhood Fever

One significant cluster with the high risk of childhood fever was identified in 1999 TRCHS. For 2004-05 and 2009-10 TDHSs, three clusters while in 2015-16 TDHS-MIS , two clusters with the high risk of childhood fever were identified. The results of the identified clusters are shown in Table 3 and Figure 3. Significant cluster identified in 1999 TRCHS with the high risk of fever had 25 sample points. The cluster was centralized at the sample point with the following coordinates (5.0744^{o} S, 39.1011^{o} E) in Tanga region. It had a radius of 107.1462 Km and covered sample points from Tanga, Kaskazini Pemba, Kusini Pemba and Kaskazini Unguja Regions.

The most likely cluster identified in 2004-05 TDHS had 251 sample points and was centralized at the sample point with coordinates (10.0544^{o} S, 38.9869^{o} E) in Lindi region. That cluster had a radius of 584.6649 Km and covered sample points from Lindi region, all regions from Zanzibar, Tanga, Dodoma, Morogoro, Pwani, Mtwara, Ruvuma, Iringa and Dar es Salaam Regions. Most likely, cluster identified in 2009-10 TDHS consisted of 97 sample points and was centralized at the sample point with coordinate (10.6651^{o} S, 39.5037^{o} E) in Mtwara Region. It had a radius of 466.8390 Km and included sample points from Lindi, Morogoro, Ruvuma, Mtwara, Pwani and Dar es Salaam Regions. Most likely cluster identified in 2015-16 TDHS consisted of 123 sample points and was centralized at the sample point with coordinate (-1.329993^{o} S, 31.821584^{o} E) in Kagera region. It had a radius of 327.533 km and included sample points from Kagera, Geita, Mwanza, Shinyanga, Simiyu and Mara Regions.

The identified clusters revealed a reduction of sample points with time for 2004-05, 2009-10 and 2015-16 TDHS. For 2004-05 TDHS, 272 out of 472 sample points were in high risk clusters, for 2009-10 97 out of 459 sample points were in high risk clusters and for 2015-16 123 out of 608 sample points were in high risk clusters. This suggests that improvement of the health status of the under-five children in Tanzania. It also suggests clustering of childhood fever to Lake and southern zones.

Table 3: Identified Clusters with High Risk of Childhood Fever

Survey Year	Cluster type	Centroid	Latitude	Longitude	Radius	sample points	p-value	Relative Risk	Region with Centroid
1999	Most likely	50	-5.07436	39.10114	107.15	25	0.00051	1.43	Tanga
2004-05	Most likely	133	-10.0544	38.98691	584.66	251	0.00000	1.74	Lindi
	Secondary	80	-4.56793	30.09066	123.21	15	0.00002	1.68	Kigoma
	Secondary	153	-1.2398	34.3924	42.42	6	0.03500	1.68	Mara
2009-10	Most likely	169	-10.6651	39.50367	466.84	97	0.00000	1.63	Mtwara
	Secondary	39	-3.34484	37.35028	81.33	28	0.00148	1.8	Arusha
	Secondary	353	-1.25297	34.3385	65.88	11	0.04800	1.6	Mara
2015-16	Most likely	379	-1.329993	31.821584	327.533	123	0.00000	1.652	Kagera
	Secondary	170	-10.468108	37.970543	239.973	46	0.00146	1.585	Lindi

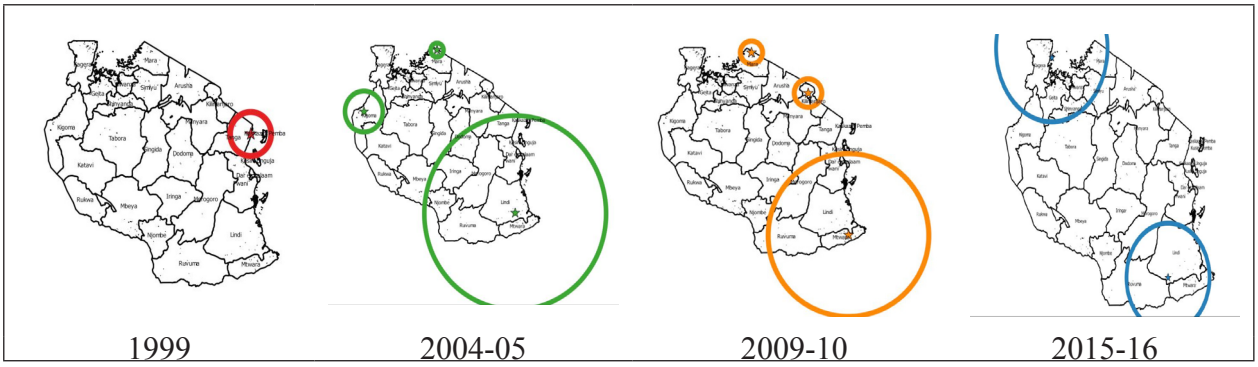

Figure 3: Clusters Identified with High Risk of Childhood Fever

Identified Clusters with High Risk of Childhood Cough/ARI

There was only one significant cluster with the high risk of a childhood cough for 1999 TRCHS. For 2004-05, 2009-10 and 2015-16 TDHS two, three and five significant clusters with the high risk of a childhood cough were identified respectively. Results of identified clusters are presented in Table 4 and Figure 4.

Significant cluster identified in 1999 TRCHS had 50 sample points with its centre at the sample point with coordinate (5.8681° S, 39.2978° E) in Kaskazini Unguja Region. The cluster had a radius of 120.7628 Km, and it included sample points from all Zanzibar regions, Tanga, Pwani and Dar es Salaam. The most likely cluster with 261 sample points identified in 2004-05 TDHS was centralized at the sample point with coordinate (9.7497° S, 39.2978° E) in Lindi region. The cluster had a radius of 632.6974 Km, and it included sample points from Lindi, all regions from Zanzibar, Mtwara, Ruvuma, Iringa, Njombe, Mbeya, Morogoro, Dodoma, Singida, Manyara, Tanga, Kilimanjaro, Pwani and Dar es Salaam. For 2009-10 TDHS, most likely cluster with 140 sample points was identified with a centroid at the sample point with coordinate (6.3094° S, 36.9871° E) in Morogoro Region. The cluster had a radius of 264.8045 Km, and it included sample points from Morogoro, Dodoma, Manyara, Singida, Pwani, Kilimanjaro, Tanga and Dar es Salaam Regions. For 2015-16 TDHS-MIS, most likely cluster with 85 sample points was identified with a centroid at the sample point with coordinate (-6.370009° S, 39.566090° E) in Kusini Unguja Region. The cluster had a radius of 71.48 Km, and it included sample points from Kusini Unguja, Kaskazini Unguja, Dar es Salaam and Pwani Regions.

Generally, the identified clusters with the high risk of a childhood cough showed the decrease of sample points with time specifically in most likely clusters for 2004-05, 2009-10 and 2015-16 TDHS. Also, the radii of most likely clusters were decreasing with increase in time. These results suggest improvements in child health status and concentration of a childhood cough to some specific areas in the country.

Table 4: Identified Clusters with High Risk of Childhood Cough

Survey Year	Cluster type	Centroid	Latitude	Longitude	Radius	sample points	p-value	Relative Risk	Region with Centroid
1999	Most likely	338	-5.868128	39.297812	120.76	50	0.000	1.44	Kaskazini Unguja
2004-05	Most likely	122	-9.749736	39.529359	632.70	261	0.000	1.80	Lindi
	Secondary	80	-4.567926	30.090662	123.21	15	0.000	1.58	Kigoma
2009-10	Most likely	81	-6.309380	36.987136	264.80	140	0.000	1.53	Morogoro
	Secondary	330	-2.782015	30.493698	159.48	15	0.000	1.83	Kagera
	Secondary	51	-3.206508	37.301296	84.09	28	0.000	1.92	Kilimanjaro
2015-16	Most likely	552	-6.370009	39.566090	71.48	85	0.000	1.91	Kusini Unguja
	Secondary	411	-1.627655	34.599284	108.15	19	0.000	1.76	Mara
	Secondary	24	-3.454100	37.019346	60.50	23	0.000	2.00	Arusha
	Secondary	329	-4.493844	29.752603	190.08	21	0.003	1.61	Kigoma
	Secondary	344	-3.678012	33.416342	3.29	2	0.029	3.35	Shinyanga

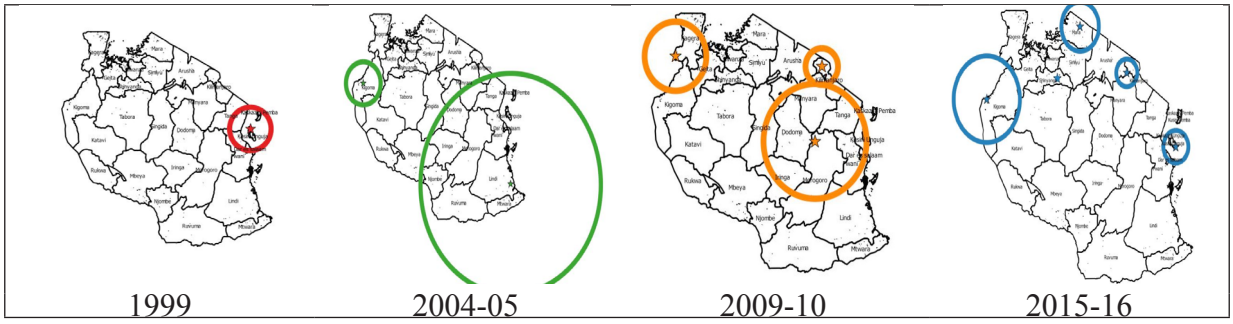

Figure 4: Clusters Identified with High Risk of Cough by Survey Year

Demographic and health surveys are conducted to obtain information about the prevalence of diseases, individual related characteristics as well as the utilization of health services. The statistical models fitted were aiming at identifying clusters with the high risk of childhood illness; examine factors associated with childhood morbidity and assessing differences of association between explanatory and multiple outcomes.

Clusters with the high risk of childhood diarrhoea, fever and cough were identified for the four surveys. Dynamic spatial patterns of childhood illnesses for most likely clusters were observed. For diarrhoea, significant clusters which were identified with the high risk of diarrhoea were one, three, six and four for 1999 TRCHS, 2004-05 TDHS, 2009-10 TDHS and 2015-16 TDHS-MIS respectively. The spatial patterns showed that Njombe, Ruvuma, Dodoma and Rukwa are the regions with the centroid sample point for the most likely cluster of childhood diarrhoea. These results are in agreement with 2004-05, 2009-10 and 2015-16 TDHS reports. TDHS reported substantial differences in diarrhoea prevalence by regions in Tanzania Mainland, with Kigoma showing highest level. The results indicate that Kigoma is a Secondary cluster from 2004-05 to 2015-16. Surprisingly, while Kigoma and Shinyanga are in the same zone, Shinyanga had the lowest level of diarrhoea prevalence (NBS and Macro, 2005; 2011). This difference is an indicator of unequal distribution of health-related resources or the existence of problems specific to some households or communities (Kandala et al., 2008).

For fever, significant clusters which were identified with the high risk of fever were one, three, three and two for 1999 TRCHS, 2004-05 TDHS, 2009-10 TDHS and 2015-16TDHS-MIS respectively. The spatial patterns showed that Tanga, Lindi, Lindi and Mara are the regions with the centroid sample point for the most likely cluster of childhood diarrhoea. The childhood fever can be an indicator of malaria among children in Sub-Saharan Africa (Filmer, 2005). TDHS reported that fever is a major manifestation of malaria. Most likely clusters with the high risk of childhood fever were consistently centralized in Southern and Lake Zone, including Lindi and Mara for 2004-05 TDHS, 2009-10 TDHS and 2015-16 TDHS-MIS (MoHCDGEC, MoH, NBS, OCGS & ICF Macro, 2016). The results suggested a significant reduction of sample points in the most likely clusters from 251out of 457 in 2004-05 TDHS to 123 out of 608 sample points in 2015-16 TDHS-MIS. This reduction and improvements can be due to interventions and efforts made to combat malaria among pregnant women and under-five children. These efforts included two doses of SP for pregnant women, free Insecticide Treated Nets (ITNs) and spraying of DDT at homes (MoHSW, 2008).

A childhood cough is one of the symptoms of Acute Respiratory Infection (ARI) which is the leading cause of childhood morbidity in Tanzania (NBS and Macro, 2011). One, two, three and six significant clusters with the high risk of a childhood cough were identified for 1999 TRCHS, 2004-05 TDHS, 2009-10 TDHS and 2015-16 TDHS-MIS respectively. Most likely clusters were decreasing in size and sample points from 2004-05 to 2015-16 TDHS. The most likely clusters were centralized in Kaskazini Unguja, Lindi, Morogoro and Kusini Unguja. These spatial patterns suggest disaggregation of clusters with a high risk of cough into small clusters with time.

Conclusion

In this study, an attempt was made to analyze childhood morbidity in Tanzania. Significant clusters with a high risk of child morbidity were identified. The identification of significant clusters with a high risk of childhood diarrhoea, fever and cough indicated the spatial variation of childhood morbidity in Tanzania between 1999 and 2016. Identified significant clusters decreased in size and sample points over time and indicated clustering to some specific areas. This implies the existence of specific problems to some households or communities/areas. Therefore it was essential to identify localized factors which increased or decreased childhood morbidity risks. Thus, any strategy aiming at reducing childhood morbidity should directly intervene in specific areas with a high risk of diseases namely diarrhoea, fever, and cough.

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