Master's Thesis of Public Health

Spatial Inequalities and Socio-Economic Factors of Acute Respiratory Infections among Under-Five Children in Rwanda: The 2014-15 Rwanda Demographic Health Survey

트완다 5 세 미만 아동의 급성 호흡기 감염에 대한 공간적 불균형과 사회경제적 요인: 2014-15 년 트완다 인구 건강 설문조사

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보건학 석사 학위논문

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Theos Dieudonne BENIMANA

Abstract

Spatial Inequalities and Socio-Economic Factors of Acute Respiratory Infections among Under-Five Children in Rwanda: The 2014-15 Rwanda Demographic Health Survey

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Introduction: Globally, ARIs commonly continue to endanger the health of the public and were acknowledged to be one of the three principal morbidity as well as mortality causes amongst under-five children. Despite the progress made, the rates of maternal, neonatal, and under-five mortality are still high in Rwanda and vary in space and time. To address remaining maternal, neonatal, and child health challenges, health policymakers should commendably grasp the spatial heterogeneity of maternal and childhood morbidities. This study aims to explore spatial inequalities and find out the socio-economic determinants of ARIs among under-five children in Rwanda.

Methods: A cross-sectional study used the most current nationally representative household survey data (The 2014-15 Rwanda Demographic Health Survey) by including all under-five children. Bivariate and multivariate analyses were performed.

A fixed and random effects multilevel model was employed to identify ARIs factors and Global Moran's I was calculated to display the ARIs patterns in the study area using SAS statistical software v9.4. SaTScan v9.6 software's spatial scan statistic was used to pinpoint the significant ARIs' spatial clusters.

Results: ARIs showed a clustered pattern and spatial cluster detection identified four statistically significant clusters across the country. History of diarrhea increased risks of developing ARIs (AOR=2.69, 95% CI: 2.21, 3.27). However, children aged between 24-59 months (AOR=0.73, 95% CI: 0.56, 0.95), and household members less or equal than five (AOR=0.81, 95% CI: 0.68, 0.98) were protective factors to ARIs.

Conclusion: ARIs displayed spatial inequalities across the country and the age of the child, household members, and history of diarrhea were significantly correlated factors. Strengthening is underscored in the Childhood Illness Integrated Management program, intensification of health Information, Education and Communication to mothers with under-five children, increase the community-based provision of oral rehydration solution as well as oral antibiotics for diarrhea and pneumonia treatment respectively, and safer environments establishment.

Keywords: Acute Respiratory Infections, Spatial Inequalities, Under-five, Children

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1. INTRODUCTION

Acute respiratory infections (ARIs) encompass serious heterogeneous mix of organisms (fungi, bacteria, or virus) infections of any part of the respiratory system and related organs that prevent normal breathing function. ARIs are contagious and characterized by coughing followed by complications in breathing and frequently cause death when concomitant with other diseases (Mirji, Shashank, & Shrikant, 2016). They are further categorized as upper respiratory system infections (J00-J06) for example common colds, certain types of influenza, sinus infections (Eccles et al., 2007) or lower respiratory system infections (J20-J22) like pneumonia and bronchitis (Nice, 2008).

ARIs commonly continue to endanger the health of the public and they were acknowledged to be one of the three principal morbidity as well as mortality causes (ARIs, diarrhea, and malaria) amongst under-five children across the globe in 2016 (WHO, 2018), however, children from developing world have tenfold to fiftyfold increased risks of dying from ARIs than their counterparts (Chatterjee, 2016).

Globally, almost 20% of the under-five mortality rate is ascribable to ARIs, and pneumonia alone accounts for 18% (Pinzón-Rondón, Aguilera-Otalvaro, Zárate-Ardila, & Hoyos-Martínez, 2016). Approximately 2 million deaths out of 150 million pneumonia cases occur yearly, translating to just about one in five under-five deaths globally (WHO & UNICEF, 2013). India being the first with 43 million cases, is followed by China and Pakistan with 21 and 10 million respectively. Bangladesh, Indonesia, and Nigeria augment 6 million each, Democratic Republic of Congo and Ethiopia add-on a share of 4 million each, Philippines and Vietnam 3 million each, and Afghanistan, Brazil, Myanmar, Sudan and United Republic of Tanzania 2 million each to cover 15 countries that share three-quarters of all under-five episodes of pneumonia globally (Rudan, Boschi-Pinto, Biloglav, Mulholland, & Campbell, 2008; UNICEF & WHO, 2006). Furthermore, an extra 4 million cases occur in the developed world (Rudan et al., 2008).

Lower airways infections are commonly severe and dangerous than upper airways infections. In 2015, there were about 291 million cases of lower airways infections (Vos et al., 2016) from which 2.74 million deceased, however, decreased from 3.4 million died in 1990 (Naghavi et al., 2015) compared to 17.2 billion upper airways infections cases (Vos et al., 2016) which caused about 3,000 deaths in 2014 decreased from 4,000 died in 1990 (Lozano et al., 2012). In 2016, lower airways infections were acknowledged to be the sixth major reason for deaths in all groups of age and the first the primary mortality cause in under-five as result of approximately 2.38 million deaths (Troeger et al., 2018). Approximately all of the lower airways infections cases (97%) are reported in developing countries from which 70% being recorded in regions of sub-Saharan Africa and South Asia (UNICEF, 2016). People living in families with lower socio-economic status, inadequate nutrition, insufficient access to immunization, unsafe cooking and sanitation facilities, immunosuppressed and/or immunocompromised bodies are more likely to develop or die from ARIs (WHO & UNICEF, 2013).

Rwanda is subdivided into Northern, Southern, Eastern, Western, and central (Kigali capital) geographically-centered provinces. They are further split into districts (30), sectors (416), cells (2,148), and villages (14,837) to cover 26,338 km^2 of surface (Annex 1: Administrative Map of Rwanda). Alike "Rwanda We Want" vision of the country (become upper-middle and high-income country in 2035 and 2050 respectively), the health sector of Rwanda aims to follow an incorporated and community-focused development progression by providing, in both geographically and financially, universal coverage of quality healthcare amenities to promote health, prevent and cure diseases as well as rehabilitation services thereby ensuring improved health state and productivity of Rwandans (MoH, 2019).

The Rwandan health sector is a pyramidal three-tiered structure (Annex 2) and consists of three levels namely the central level comprises of Ministry of Health, Rwanda Biomedical Center, and the national referral and teaching hospitals; the intermediary level made of provincial hospitals; and the peripheral level embodied by district hospitals, a network of health centers and health posts respectively at sector and cell level, plus Community Health Workers at the village level (Annex 3) (MoH, 2019).

Rwanda shrunk the mortality rate among under-five children to an estimate of 70% from 2000 to 2011 through various sustainable investments in the Rwandan health system, one of a few low-income countries to meet MDG4 (reduce by 2/3 under-five mortality rate by 2015) (WHO, 2015). Even though in 2015 the mortality rate in under-five dwindled to 50 from 152 deaths per 1,000 live births in 2005 (NISR, MOH, & ICF-International, 2015), there is still work to be done. In 2015, 6% of under-five children had been ill reported to have ARIs (NISR et al., 2015) increased from 4% in 2010 (NISR, MoH, & ICF-International, 2012).

Despite the progress made, maternal, neonatal and under-five mortality rates are still high in Rwanda. To address remaining maternal, neonatal, and child health challenges, health policymakers should commendably grasp the spatial heterogeneity of maternal and childhood morbidities.

Findings of studies done in Rwanda mostly dealt with the prevalence and determinants related to the outcome in question. Additionally, they are scarce and did not display the geographical distribution of the outcome. Thus, using spatial analysis methods, this study explored the spatial inequalities and found out the social as well as economic determining factors of ARIs among under-five children in Rwanda. Specifically, we hypothesized that ARIs are distributed unequally across the study area, that ARIs rates are highly displayed in urban than rural settings and that ARIs are associated with lower socio-economic status.

2. LITERATURE REVIEW

2.1. Operational definition

Acute respiratory infections (ARIs) cover serious fungal, bacterial, or viral infections that may obstruct with regular breathing. It affects either the upper airways which involve the respiratory organs from the external openings of the nasal cavity (nostrils) to the vocal folds in the voice box (larynx) or the lower airways that includes the airways extension to the lungs from the windpipe and bronchi (Simoes et al., 2006).

ARIs in children pose a substantial risk on life, and as the definition of ARIs, mothers or caregivers in our study were questioned if their under-five suffered from cough in the course of 14 days prior to the survey and, if yes, whether coughing had been followed by difficulties in normal breathing. Questions were formulated as follows: "Has (NAME) had an illness with a cough at any time in the last 2 weeks?" and "when (NAME) had an illness with a cough, did he/she breathe faster than usual with short, rapid breaths or having difficulty breathing?"

2.2. ARIs factors among under-five children

The review of the literature has shown various correlated determinants to ARIs. However, major disparities exist among these factors from the developing world to the developed world. The model of exposure and disease puts under-five children in concrete and social environments then reflects magnitude as well as strength of correlation to ARIs symptoms, considering a variety of social, economic, biological, and environmental constituents.

For example, Kumar et al., 2015 revealed that the ARIs prevalence was higher amongst urban areas dwellers children compared with children from rural areas and mentioned that overcrowding, living in urban areas, and second birth order were significant determinants of ARIs. Similarly, results by (Ramani, Pattankar, & Puttahonnappa, 2016) showed that overcrowded household was a significant predictor of ARIs, and additionally, underlined that family history of respiratory illness, poor housing status, firewood fuel, were significantly associated with ARIs. Other studies by (Bipin, Nitiben, & Sonaliya, 2011; Kinyoki et al., 2017; M. M. Rahman & Rahman, 1997; Savitha, Nandeeshwara, Pradeep Kumar, ul-Haque, & Raju, 2007; Sharma, Kuppusamy, & Bhoorasamy, 2013) reported that overcrowding was statistically correlated with ARIs.

Furthermore, evidence exist to show that other household factors namely type of cooking and toilet facilities (Akinyemi & Morakinyo, 2018; Mekuriaw, Kassahun, Sharma, Zemicheal, & Abera, 2014; Siziya, Muula, & Rudatsikira, 2009) can also forecast the likelihood of ARIs among children under-five. Not to forget household members and residence (Adesanya & Chiao, 2017; Akinyemi & Morakinyo, 2018; Al-Sharbatti & AlJumaa, 2012).

Ramani et al., 2016 also accentuated that age was negatively associated with the incidence of ARIs, finding similar in many studies viz. (Acharya, Prasanna, Nair, & Rao, 2003; Akinyemi & Morakinyo, 2018; Deb, 1998; Islam, Sarma, Debroy, Kar, & Pal, 2013; Siziya et al., 2009) which underscored that ARIs prevalence progressively declined as the children grew older. Al-Sharbatti & AlJumaa, 2012; Siziya et al., 2009 mentioned that the sex of the child can also be a predictive factor of ARIs. Moreover, Alemayehu, Kidanu, Kahsay, & Kassa, 2019; Chalabi, 2013 revealed a statistically significant relationship between the child’s odds of developing ARIs and nutrition status. Immunization status of the child also was found to be statistically one factor connected to the odds of developing ARIs (Jackson et al., 2013; Khalek & Abdel-Salam, 2016).

Adesanya & Chiao, 2017 revealed a significant dissimilarity between provinces vis-a-vis ARIs prevalence in Nigeria and that dry season and household poverty were significantly associated with increased risks of ARIs. Botelho, Correia, da Silva, Macedo, & Silva, 2003 also revealed that decreased relative humidity and dry season were linked to the rise of the rate of pediatric hospitalization from ARIs. Muthoni & Ngesa, 2017 indicated geographical heterogeneity and considerable disparity in the ARIs prevalence among under-five children which could be accredited to the dissimilarity in socio-economic status and geographical variations of regions in the study.

Other studies have shown other factors associated with ARIs. For example, Cardoso, Coimbra, & Werneck, 2013 showed that lower maternal age was significantly associated with children's hospitalization due to ARIs. Parental lower educational levels (Al-Sharbatti & AlJumaa, 2012), parental employment status (Cardoso et al., 2013; Fatmi & White, 2002; Geberetsadik, Worku, & Berhane, 2015) was also reported to be one of determining factors of ARIs among under-five children.

These findings call the attention of the health systems and public health institutions necessitating multi-sectoral involvement for policy implications for health programs design and interventions at various levels targeting the reduction of ARIs among under-five children. Aforesaid programs and interventions should particularly emphasis on poverty assuagement, and ameliorating households' sanitation conditions through enhanced facilities provision (safer environments), improvements in nutrition and strengthening mass vaccination, advancing health information, education and communication to mothers with under-five children, early diagnosis and treatment, and other intervention programs against under-five ARIs (Simoes et al., 2006).

2.3. Conceptual framework

After reviewing the variables defined in the 2014-15 Rwanda Demographic Health Survey dataset and relevant literature, our study followed the below constructed conceptual framework from Mosley and Chen modified version (Mosley & Chen, 2003) and illustrated factors correlated with ARIs among under-five children.

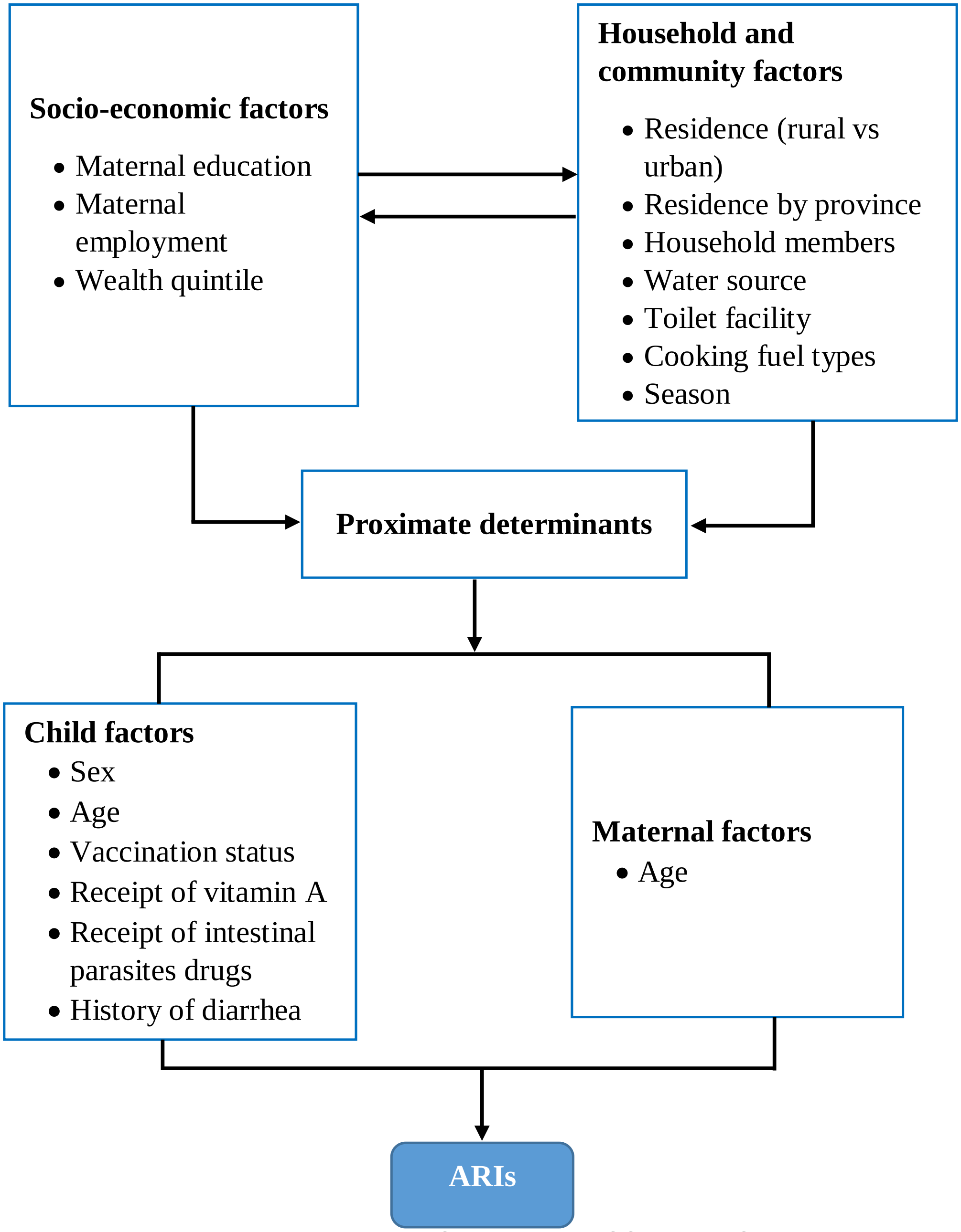

Figure 1. Conceptual framework of factors of ARIs

3. MATERIALS AND METHODS

3.1. Population and Sample

All under-five children included in the 2014-15 RDHS were eligible. After excluding children whose mothers did not mention their employment status (n=6), drinking water source (n=118), cooking facility type (n=4), toilet facility type (n=20), child's vaccination status (10) diarrhea status (n=39), child's receipt of vitamin A (n=337) and drug for intestinal parasites (n=11) study analysis included 7311 under-five children.

A two-stage stratified cluster sampling procedure was employed for the 2014-15 RDHS using the enumeration areas list formed during the 2012 Rwanda Population and Housing Census as source material of the sample. The initial stage was used to select sample units (clusters) consisting of a total of 113 clusters in urban settings and 379 clusters in rural settings (492 clusters) while the next stage helped in households systematic sampling. A total sample size of 12,793 households was selected from household lists of the selected enumeration areas of which 12,699 households were surveyed from which, in turn, 13,564 women in reproductive age (15-49) participated in the survey interview.

The Kid Recode File, used for our analysis holding household, maternal, and child-related variables was created from women individual interviews regarding their under-five children. The sampling process is well detailed in the 2014-15 RDHS report (NISR et al., 2015).

The spatial units used in analyses were districts (n=30). Districts are the most important administrative regions of Rwanda's decentralization system and subdivided into sectors. They were chosen due to the lack of data for further local administrative regions like sectors, cells or villages.

3.2. Variables

3.2.1. Outcome variable

Acute respiratory infection was considered as the study outcome variable and it was modeled as a binary variable. As the definition of ARIs, mothers or caregivers in our study were queried if their under-five suffered from cough in the course of 14 days prior to the survey and, if yes, whether coughing had been followed by difficulties in normal breathing.

3.2.2. Explanatory variables

The indices which were used in the study were categorized as child factors including sex, age, vaccination status, receipt of vitamin A, and intestinal parasites drugs in the latest 6 months; parent factors comprising of mother's age, employment status, in addition to educational level; and household and community factors encompassing residence (rural vs. urban), residence by province, household members, water source modeled as improved (piped into dwelling, piped to yard/plot, public tap/standpipe, tube well or borehole, protected well, protected spring, bottled water) or unimproved (unprotected well, unprotected spring, rainwater, cart with small tank river/dam/lake/ponds/stream /canal/irrigation channel), toilet facility modeled as improved (flush to piped sewer system, flush to septic tank, flush to pit latrine, flush to somewhere else, flush don't know where, ventilated improved pit latrine, pit latrine with slab, composting toilet) or unimproved (pit latrine without slab/open pit, no facility/bush/field), and cooking fuel types labeled also as improved (electricity, liquid petroleum gas, natural gas, biogas, kerosene, coal, lignite, charcoal) or unimproved (wood, agricultural crop, animal dung, straw/shrubs/grass), and household wealth quintile.

The interview season was modeled as the dry season (June to August and December to February) and the rainy season (March to May and September to November), and comorbidity conditions included history of diarrhea. The variables were selected according to the variables defined in the RDHS dataset and related literature (Jackson et al., 2013; Harerimana, Nyirazinyoye, Thomson, & Ntaganira, 2016; Seidu et al., 2019).

3.3. Statistical analysis

3.3.1. Analytical analysis

To identify the ARIs determining factors among under-five children, a fixed and random effects multilevel model was applied due to the consideration of the between-cluster variability. Both Generalized Linear Mixed Models (GLMM) and Logistic regression were fitted due to the binary outcome variable. Akaike Information Criteria (AIC), and Bayesian information Criteria (BIC) values were used to contrast the quality of statistical models and the model with the lowest AIC and BIC values was considered as the best model. All bivariate analysis variables were added in the multivariate analysis. We used Adjusted Odds Ratio (95% CI, $p<0.05$) in the multivariate analysis to justify the statistically significant association with ARIs. SAS statistical software version 9.4 was used for descriptive analysis.

3.3.2. Spatial autocorrelation analysis

Global Moran's I was employed to quantify the degree to which similar features cluster and where such clustering occurred across the study area using SAS statistical software version 9.4. Clustering, dispersion, and randomness tendency was designated by a positive, negative, and zero global Moran's I value with $p<0.05$ respectively.

The spatial autocorrelation was present after the rejection of the stated null hypothesis that ARIs patterns were randomly dispersed among under-five children in Rwanda.

3.3.3. Spatial scan statistical analysis

We employed Kulldorff's SaTScan v9.6 software's spatial scan statistic to pinpoint significant ARIs spatial clusters, and to prove if the geographic ARIs clustering existed due to random distribution or not among under-five children across the area. A scanning window circulating across the area was employed and the Bernoulli model was used for scanning since children with ARIs against their counterparts were considered as cases and controls respectively. Primary clusters were pinpointed by the window with the maximum likelihood while secondary clusters were determined by significant log-likelihood ratios.

The default to look for clusters covering up to half the population at risk using the upper limit of < 50% was used, letting to detect high clusters, and clusters with exceeding maximum limit windows were ignored. To assess whether ARIs observed cases inside clusters were higher than the expected cases or vice versa outside clusters, the likelihood ratio test statistic was used. Besides, clusters' relative risks were computed to analyze the risk of developing ARIs within the area of clusters. The p-values of the log-likelihood ratio test were significant at $p < 0.05$ and were calculated through 9999 Monte Carlo simulations (Kulldorff, 1997).

3.4. Ethical issues

The Institutional Review Board of Seoul National University approved our study (IRB No. E2004/001-002). Data for this study was downloaded after permission was granted from the DHS International Program website https://dhsprogram.com/. The 2014-15 RDHS was conducted by the Government of Rwanda through the Ministry of Health and the National Institute of Statistics with the members of the national steering committee to the DHS and the technical assistance of ICF International with the aiming at data collection for keeping track of health indicators improvements of Rwandans.

4. RESULTS

4.1. Descriptive analysis and Factors of ARIs

A total of 7,311 under-five children from the 2014-15 RDHS were included in analysis. Participants' socio-demographic, household and community, and comorbid characteristics are abridged in table 1.

The average age of the children was 28.5 (SD ± 17) months with about more than half of them aged two years and above, and no big difference about their sex distribution. Slightly more than half of the mothers varied from 25 to 34 years of age, the majority with primary schooling level, and working. The majority of households are rural dwellers, about half from the poor wealth index category, and about two-thirds having a family size of up to 5 household members. In addition, the majority of households used improved water sources as well as improved toilet facilities, however, the majority used unimproved cooking facilities. The majority of the children got vitamin A supplement and took intestinal parasites drugs in the latest 6 months, and had no history of diarrhea. The ARIs' overall prevalence amongst under-five children in Rwanda was 11.6%.

Table 1. Summary of socio-demographic, household and community, and comorbid characteristics of the study participants

Variable	N = 7321	%
Socio-demographics		
Sex of child		
Male	3690	50.5
Female	3621	49.5
Age of child (months)		
0 – 11	1584	21.6
12 – 23	1502	20.5
24 – 59	4225	57.9
Age of the mother		
15 – 19	136	1.9
20 – 24	1218	16.7
25 – 29	2168	29.6
30 – 34	1958	26.8
35 – 39	1142	15.6
40 – 44	551	7.5
45 – 49	138	1.9
Mother's employment status		
Not working	1054	14.4
Working	6257	85.6
Mother's education level		
Non-formal (<6 years)	1050	14.4
Primary (6 years)	5235	71.6
Secondary (12 years)	830	11.3
Higher (>12 years)	196	2.7
Wealth index quintile		
Lowest	1743	23.8
Second	1534	21.0
Middle	1396	19.1
Fourth	1246	17.0
Highest	1393	19.1
Season		
Dry	4757	65.1
Rainy	2554	34.9

Residence		
Rural	5727	78.3
Urban	1584	21.7
Residence (Province)		
Kigali (Capital)	861	11.7
South	1795	24.6
West	1840	25.2
North	1021	14.0
East	1794	24.5
Household and community		
Household members		
0 – 5	4443	60.8
6-10	2798	38.2
Above 10	70	1.0
Source of drinking water		
Improved	5221	71.4
Unimproved	2090	28.6
Type of cooking facility		
Improved	1233	16.9
Unimproved	6078	83.1
Type of toilet facility		
Improved	5202	71.1
Unimproved	2109	28.9
Comorbid		
Vaccination status		
Complete	2020	27.6
Incomplete	5291	72.4
Vitamin A supplement		
Yes	5846	80.0
No	1465	20.0
Had diarrhea		
Yes	878	12.0
No	6433	88.0
Drugs for intestinal parasites		
Yes	5369	73.4
No	1942	26.6
ARI		
Yes	851	11.6
No	6460	88.4

In the bivariate analysis, the age of the child, season, residence by province, type of toilet facility, vaccination status, history of diarrhea, receipt of vitamin A supplement, and intestinal parasites drugs in the previous 6 months were significant at $p<0.05$. Nevertheless, all variables were fitted in the multivariate analysis (Table 2).

Both generalized linear mixed model and logistic regression were fitted. AIC and BIC were examined in model comparison, and the generalized linear mixed model was selected due to its relative smallest values (Table 3).

In multivariate mixed-effect analysis, the child's age, household members, and diarrhea history were significantly correlated factors of ARIs (Table 4). Children with a history of diarrhea had nearly 3 times increased odds of having ARIs (AOR=2.69, 95% CI: 2.21, 3.27) compared with their counterparts. However, children aged between 24-59 months had 27% decreased likelihoods of having ARIs (AOR=0.73, 95% CI: 0.56, 0.95) in comparison with those younger than six months. Additionally, the odds of ARIs among children who had household members less or equal than five were 19% (AOR=0.81, 95% CI: 0.68, 0.98) lower than those with family members above ten.

Table 2. ARIs proportions' bivariate analysis among under-five children

Variable	Children in the study	Children suffering from ARI		p-value
	N=7321	N	%	
Sex of child				0.5345
Male	3690 (50.5)	421	11.4	
Female	3621 (49.5)	430	11.8	
Age of child (months)				<.0001
0 – 11	1584 (21.6)	226	14.3	
12 – 23	1502 (20.5)	222	14.8	
24 – 59	4225 (57.8)	403	9.5	
Age of the mother				0.1482
15 – 19	136 (1.9)	15	10.9	
20 – 24	1218 (16.7)	158	12.9	
25 – 29	2168 (29.6)	254	11.7	
30 – 34	1958 (26.8)	220	11.2	
35 – 39	1142 (15.6)	131	11.4	
40 – 44	551 (7.5)	60	10.9	
45 – 49	138 (1.9)	13	9.4	
Mother's employment status				0.4250
Not working	1054 (14.4)	115	10.9	
Working	6257 (85.6)	736	11.8	
Mother's education level				0.7634
Non-formal (<6 years)	1050 (14.4)	110	10.5	
Primary (6 years)	5235 (71.6)	623	11.9	
Secondary (12 years)	830 (11.3)	101	12.2	
Higher (>12 years)	196 (2.7)	17	8.7	

Wealth index quintile				0.0799
Lowest	1742 (23.8)	216	12.4	
Second	1534 (21.0)	187	12.2	
Middle	1396 (19.1)	164	11.7	
Fourth	1246 (17.0)	133	10.7	
Highest	1393 (19.1)	151	10.8	
Season				0.0123
Dry	4757 (65.1)	521	10.9	
Rainy	2554 (34.9)	330	12.9	
Residence				0.4453
Rural	5727 (78.3)	658	11.5	
Urban	1584 (21.7)	193	12.2	
Residence (Province)				<.0001
Kigali (Capital)	861 (11.7)	105	12.2	
South	1795 (24.4)	266	14.8	
West	1840 (25.2)	192	10.5	
North	1021 (14.0)	120	11.7	
East	1794 (24.5)	168	9.3	
Household members				0.0737
0 – 5	2798 (38.2)	293	10.5	
6 – 10	4443 (60.8)	546	12.3	
Above 10	40	12	17.1	
Source of drinking water				0.3218
Improved	5221 (71.4)	620	11.9	
Unimproved	2090 (28.6)	231	11.0	
Type of cooking facility				0.9828
Improved	1233 (16.9)	144	11.7	
Unimproved	6078 (83.1)	707	11.6	

Type of toilet facility				<.0001
Improved	5202 (71.1)	554	10.7	
Unimproved	2109 (28.9)	297	14.1	
Vaccination status				0.0088
Complete	2020 (27.6)	203	10.1	
Incomplete	5291 (72.4)	648	12.3	
Vitamin A supplement				0.0406
Yes	5846 (80.0)	658	11.3	
No	1465 (20.0)	193	13.1	
Had diarrhea				<.0001
Yes	878 (12.0)	216	24.6	
No	6433 (88.0)	635	9.9	
Drugs for intestinal parasites				<.0001
Yes	5369 (73.4)	577	10.7	
No	1942 (26.6)	274	14.1	

Table 3. Generalized linear mixed effect and logistic regression model comparison

Recommended models	**AIC**	**BIC**
Logistic regression	5261.391	5268.288
Generalized linear mixed effect	4970.84	5113.58

Table 4. Logistic regression and mixed-effect logistic regression analysis of ARIs factors among under-five children

Variable	Logistic AOR (95% CI)	Mixed-effect AOR (95% CI)
Sex of child		
Male	1	1
Female	1.08 (0.93, 1.25)	1.09 (0.94, 1.28)
Age of child (months)		
0 – 11	1	1
12 – 23	1.07 (0.83, 1.39)	1.08 (0.82, 1.43)
24 – 59	*0.75 (0.59, 0.96)*	**0.73 (0.56, 0.95)**
Age of the mother		
15 – 19	1	1
20 – 24	1.30 (0.73, 2.30)	1.36 (0.74, 2.50)
25 – 29	1.25 (0.71, 2.20)	1.29 (0.70, 2.35)
30 – 34	1.28 (0.72, 2.27)	1.37 (0.75, 2.52)
35 – 39	1.32 (0.74, 2.37)	1.37 (0.74, 2.54)
40 – 44	1.37 (0.74, 2.56)	1.45 (0.75, 2.80)
45 – 49	1.22 (0.54, 2.74)	1.36 (0.58, 3.20)
Mother's employment status		
Not working	1	1
Working	1.12 (0.90, 1.40)	0.98 (0.77, 1.25)
Mother's education level		
Non-formal (<6 years)	1	1
Primary (6 years)	1.13 (0.90, 1.41)	1.11 (0.87, 1.41)
Secondary (12 years)	1.21 (0.87, 1.68)	1.17 (0.82, 1.66)
Higher (>12 years)	0.92 (0.52, 1.65)	0.99 (0.53, 1.86)

Wealth index quintile		
Lowest	1	1
Second	1.08 (0.87, 1.35)	1.15 (0.91, 1.45)
Middle	1.10 (0.88, 1.39)	1.04 (0.81, 1.33)
Fourth	0.99 (0.77, 1.28)	0.98 (0.74, 1.28)
Highest	0.89 (0.62, 1.27)	0.88 (0.60, 1.30)
Season		
Dry	1	1
Rainy	1.23 (1.06, 1.43)	1.23 (0.99, 1.54)
Residence		
Rural	1	1
Urban	1.19 (0.94, 1.52)	1.14 (0.82, 1.60)
Residence (Province)		
Kigali (Capital)	1	1
South	1.18 (0.88, 1.59)	1.34 (0.87, 2.70)
West	0.79 (0.58, 1.07)	0.82 (0.53, 1.29)
North	0.94 (0.68, 1.30)	1.06 (0.66, 1.69)
East	*0.71 (0.52, 0.96)*	0.74 (0.47, 1.15)
Household members		
Above 10	1	1
6 – 10	1.65 (0.86, 3.18)	1.21 (0.58, 2.50)
0 – 5	*0.84 (0.71, 0.99)*	**0.81 (0.68, 0.98)**
Source of drinking water		
Unimproved	1	1
Improved	1.07 (0.90, 1.27)	0.99 (0.82, 1.21)
Type of cooking facility		
Unimproved	1	1
Improved	1.05 (0.78, 1.42)	1.10 (0.79, 1.53)

Type of toilet facility		
Unimproved	1	1
Improved	0.77 (0.65, 0.91)	0.86 (0.71, 1.04)
Vaccination status		
Incomplete	1	1
Complete	0.86 (0.72, 1.03)	0.85 (0.69, 1.04)
Vitamin A supplement		
No	1	1
Yes	1.02 (0.80, 1.30)	1.00 (0.77, 1.30)
Had diarrhea		
No	1	1
Yes	*2.80 (2.34, 3.36)*	**2.69 (2.21, 3.27)**
Drugs for intestinal parasites		
No	1	1
Yes	0.85 (0.66, 1.10)	0.88 (0.67, 1.15)

4.2. ARIs spatial distribution

The ARIs' spatial distribution among under-five children was positive. The clustered pattern found was statistically significant with Global Moran's I of 0.03 ($p<0.001$) with a z-score of 9.51 which showed that the chance of the clustered pattern found was less than 1% to be caused by a random chance. With the rejection of the null hypothesis of spatial randomness across the study area, our study found a low but statistically significant spatial autocorrelation.

4.3. Spatial scan statistical analysis

Spatial cluster detection identified four statistically significant clusters, covering a total of 175 enumeration areas. The primary clusters were located in the south-central part and centered at 2.068247 S, 29.999843 E with a 7.30 km radius (LLR=28.4, $p<0.001$). The risk of ARIs among children within the area was 4 times (RR=4.08) than their counterparts living exterior the region. The first secondary clusters were positioned in the south-eastern part and centered at 2.189899 S, 30.454163 E with 14.11 km radius, and 2.4 times high risks of ARIs among children within the area than their counterparts.

The following secondary clusters were found in the south-western part at 2.647015 S, 29.465716 E with a radius of 70.34 km and 1.5 times increased risks of ARIs. The third secondary clusters were traced in the central part at 1.973543 S, 30.045271 E with a 2.01 km radius, and 2.4 times higher risks of ARIs (Table 5).

The red-colored circles designated the significant spatial windows of the detected ARIs high clusters and children within every cluster had higher risks of developing ARIs than children outside the cluster (Figure 2).

Table 5. ARIs spatial clusters

Clusters	**Detected enumeration areas**	**Coordinates/Radius**	**Obs. cases**	**Exp. cases**	**RR**	**LLR**	**p-value**
1	5	2.068247S, 29.999843E / 7.30km	35	8.85	4.08	28.4	<0.001
2	14	2.189899S, 30.454163E / 14.11km	61	26.53	2.40	20.3	<0.001
3	146	2.647015S, 29.465716E / 70.34km	334	254.45	1.51	19.2	<0.001
4	10	1.973543S, 30.045271E / 2.01km	43	18.6	2.38	14.3	<0.001

Spatial Scan Statistics of ARIs in Rwanda, 2015

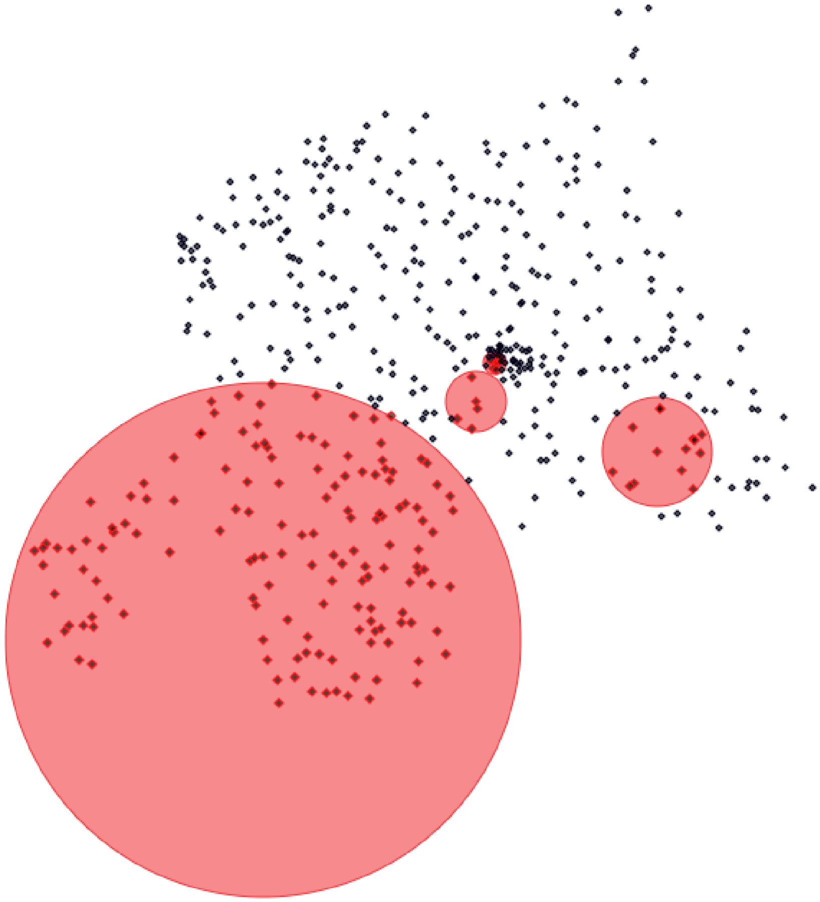

Figure 2. High clusters of ARIs among under-five children

5. DISCUSSION

Using 7311 under-five children from the current RDHS, the study sought to investigate the spatial inequalities and find out the socio-economic ARIs factors among under-five children in Rwanda. The ARIs prevalence was 11.6% and the multivariate mixed-effect model revealed that a child's age, household members, and history of diarrhea were significantly correlated determinants of ARIs.

Children in the age brackets of 24–59 months had decreased odds of developing ARIs than those younger than 11 months, similar result with the study done by (Andrade et al., 2017) that found the greatest burden of ARIs among less than one year children compared to those of two to five years of age. Similar studies by (Amsalu, Akalu, & Gelaye, 2019; Nair et al., 2013; Walker et al., 2013) also emphasized this association. This could be from the development of the immune system over time empowering them to fight against infectious pathogens including ARIs and additionally, this result accentuates the significance of ARIs preventive measures in the first 12 months of lifespan which is vital for the healthy growth and immune system's effective development.

Our finding of the association of history of diarrhea of the child and ARIs is consistent with previous work. Dadi, Kebede, & Birhanu, 2014; Schmidt, Cairncross, Barreto, Clasen, & Genser, 2009 reported that diarrhea contributed substantially to the risk of ARIs. S. Rahman, 2014 also stated that children with diarrhea episodes had high odds of developing ARIs. This is explained by the fact that children are exposed to heavy pathogens and also having a comorbid disease like diarrhea weakens their immature immunity systems making them likely prone to other diseases including ARIs.

Regarding family size, our study revealed that children living with less or equal than five household members had a lower risk of developing ARIs compared with children whose family members were above ten, a result similar to the study by (Vijayan, L, & Johnson, 2019) revealed that nuclear families are significant independent protective factors for ARIs. The results of this study are also in conformity with various literature that publicized overcrowded households to be a significant predictor of ARIs (Bipin et al., 2011; Kinyoki et al., 2017; Kumar et al., 2015; Ramani et al., 2016).

Dissimilarly to the findings by (Kumar et al., 2015) which indicated that living in an urban area was a significant determining factor of ARIs, our findings did not find that association. However, proportions of ARIs were high in urban areas than in rural areas. Similarly to the study by (Adesanya & Chiao, 2017) reported a significant dissimilarity between provinces vis-a-vis ARIs prevalence in Nigeria, our findings showed a clustered pattern and spatial inequalities in the ARIs distribution across the country's districts, the high risk being central (Nyarugenge and Kamonyi districts), south-eastern (Ngoma District) and south-western (Rusizi, Nyaruguru, Gisagara districts) parts of the country which could be ascribed to the dissimilarity in socio-economic status and geographical variations of regions in question.

The present study used data from a recent countrywide survey countenancing the findings to be inferred to all under-five children in Rwanda. Additionally, being the first study, to our knowledge, carried out in Rwanda capturing geographic patterns of the disease in question using spatial analysis methods to pinpoint ARIs clusters makes it more appealing. Nevertheless, it is important to note that precise ARIs cases' locations were not identified because values of location data were 1 – 2km and 5km shifted for urban and rural settings correspondingly for confidentiality motives.

Despite its strengths, these findings should be inferred considering that causal relationship was not identified as a result of the cross-sectional study design. Furthermore, the ARIs cases' definition in RDHS is based on mothers' or caregivers' self-reports not clinically confirmed data which increases the chance of potential recall bias which could be lessened due to the short period of reference of 14 days.

The results of the present study present inestimable health policy connotations at different levels by the health systems and public health institutions necessitating multi-sectoral involvement in aiming at reducing ARIs among under-five children in Rwanda. Such programs and interventions should specifically focus on Childhood Illness Integrated Management by equipping healthcare providers especially community health workers in each village with clinical knowledge, skills, and materials to expand the capacity for early detection and treatment of ARIs, intensify Health Information, Education and Communication (IEC) to mothers with under-five children to increase knowledge and skills on ARIs and promote healthcare-seeking behavior, increase the community-based provision of oral rehydration solution as well as oral antibiotics for diarrhea and pneumonia treatment respectively, establish safer environments through electrification of rural areas and distribution of modern stove as well as promoting and supporting breastfeeding and complementary feeding, vitamin A supplementation and mass vaccination.

6. CONCLUSION

This study underscored the public health burden of ARIs amongst under-five children in Rwanda. ARIs presented spatial inequalities across the country's districts, the high-risk clusters were located in central, south-eastern, and south-western parts. Child's age and household members were protective factors to ARIs whereas a history of diarrhea increased the likelihood of developing ARIs. However, the present study did not discover a statistically significant correlation between socio-economic status and the odds of having ARIs among under-five children in Rwanda.

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Abstract in Korean

서론: 급성 호흡기 감염(Acute Respiratory Infections)은 지속적으로 공중보건에 위협을 끼치고 있으며, 전 세계 5 세 미만 아동들의 질병이환과 사망의 3 대 주요 원인 중 하나이다. 최근의 의료 발전에도 불구하고, 르완다에서는 다양한 시간과 장소에 걸쳐 임산부, 신생아 및 5 세 미만 영유아의 사망률이 여전히 높게 발생되고 있다. 이러한 보건 문제를 해결하기 위해, 보건 정책 입안자들은 임산부와 영유아 질환의 공간 이질성(spatial heterogeneity)을 잘 파악할 필요가 있다. 따라서, 본 연구에서는 르완다 5 세 미만 아동의 급성 호흡기 감염에 대한 공간적 불균형과 사회경제적 결정요인을 다루고자 한다.

방법: 본 연구는 단면연구이며 르완다의 국가 대표 가구 조사 자료 중 가장 최신자료(2014-15 년 르완다 인구 건강 설문조사)를 사용하였다. 조사대상으로는 15~49 세의 모든 여성의 5 세 미만 아동이다. 본 연구에서는 급성 호흡기 감염의 위험요인을 식별하기 위해 고정 효과와 무작위 효과 다변량 모형을 사용하였으며, SAS 통계 소프트웨어 v9.4.로 Global Moran's I 통계를 사용하여 질병의 공간적 패턴을 평가하였다. 또한, SaTScan v9.6 소프트웨어의 공간 스캔 통계 분석을 사용하여 통계적으로 유의한 급성 호흡기 감염의 공간 군집을 탐지하였다.

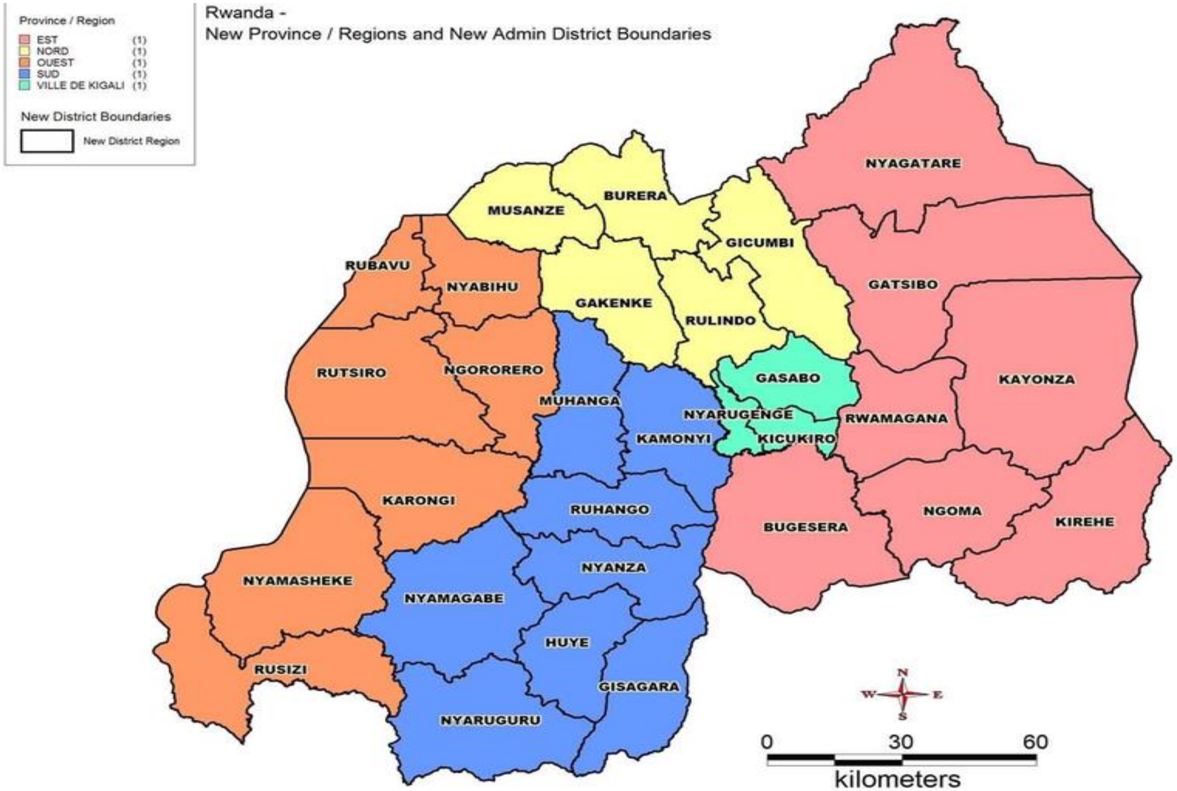
결과: 급성 호흡기 감염에 대한 군집 패턴을 보였으며, 통계적으로 유의한 네 개의 군집을 확인하였다. 설사의 경험 유무는 급성 호흡기 감염의 발생을 유의하게 증가시키는 것으로 나타났다(AOR=2.69, 95% CI: 2.21, 3.27). 반대로, 24-59 개월 아동(AOR=0.73, 95% CI: 0.56, 0.95)과 5 인 이하 가구(AOR=0.81, 95% CI: 0.68, 0.98)는 급성 호흡기 감염의 보호 요인으로 나타났다.

결론: 급성 호흡기 감염은 전국에 걸쳐 공간적 불균형을 보였으며, 아동의 연령, 가구원, 설사의 경험 유무가 급성 호흡기 감염과 유의한 상관관계가 있었다. 안전한 환경 제공과 더불어 아동 질환의 통합관리 프로그램 강화, 건강 정보 구축, 5 세 미만 아동이 있는 여성에게 적절한 교육과 소통을 하는 것, 지역사회에 설사를 예방하기 위한 경구 수분 보충제와 폐렴을 예방하기 위한 항생제를 보급하는 것이 필요하다.

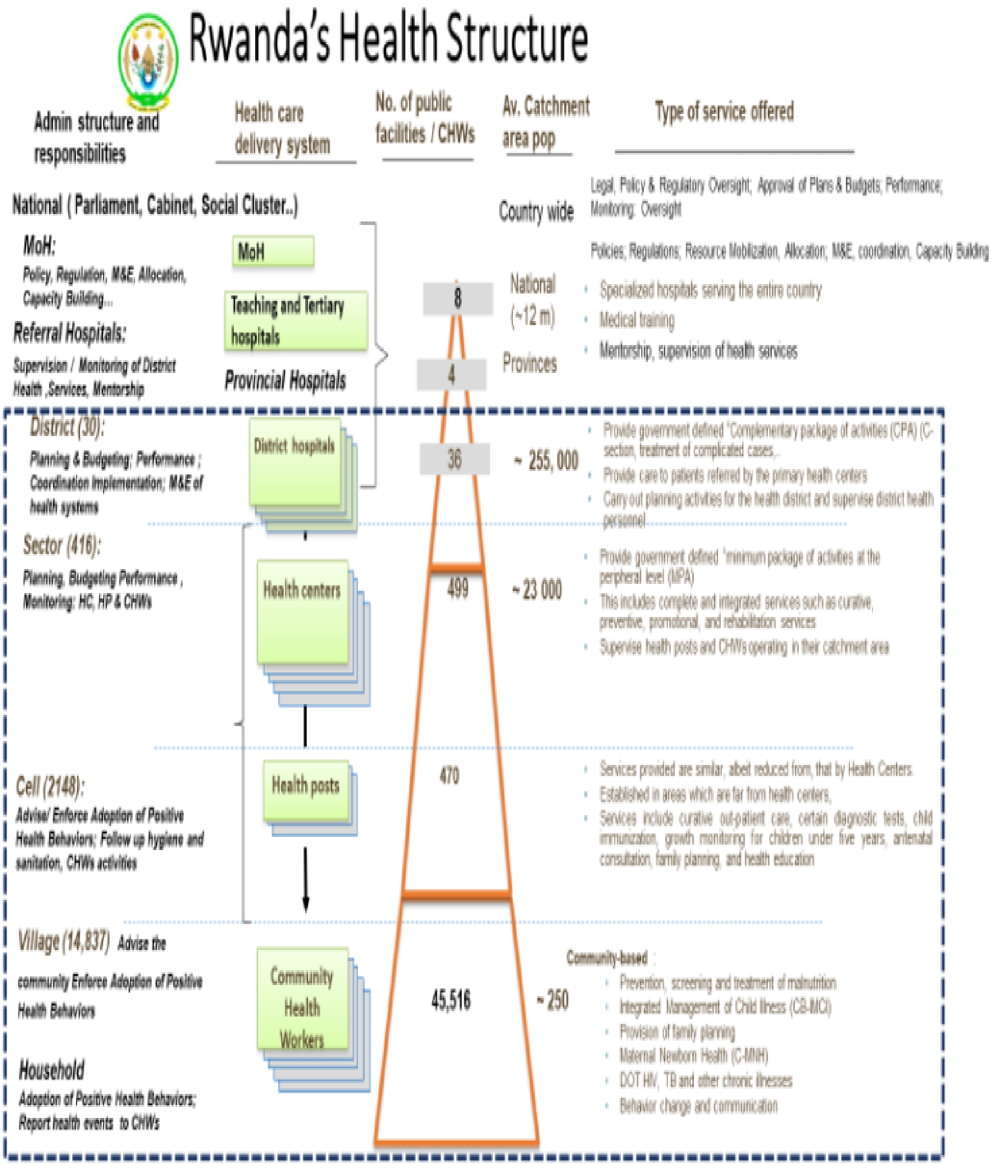
키워드: 급성 호흡기 감염(ARIs), 공간적 불균형, 5 세 미만, 아동

학번: 2018-24419

Annex 1. Map of Rwandan Provinces and Districts



Annex 2. Rwanda Health System Structure



Annex 3. Existing administrative structures and related health facilities

Administrative level/structures	Number	HSS Structures	Number
Villages	14,837	CHW	45,516
Cells	2,148	Health Posts	476
Sectors	416	Health Centers	499
Districts	30	District Hospitals	36
		District Pharmacies	30
Provinces	5	Provincial Hospitals	4
National		National Referral and Teaching Hospitals	8
Referral systems		Ambulances/SAMU	255
Registered private HFs	250		

Source: **HMIS 2016-2017**