Impacts of Climate Variables on Respiratory Diseases in Infants and Children in Kigali City.

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Abstract

Acute respiratory diseases are amongst the common illness in infants and children under 5 years old. These diseases are often suspected to be associated with climate variables. This study aimed to analyze the relationship between climate variables and Acute Respiratory Infection (ARI) and pneumonia prevalence in infants and children under 5 years old in Kigali city, during the period of 2014-2018. Spearman correlation followed by Generalized Linear Models (GLM) was used to determine the relationship between total monthly rainfall, average humidity and temperature and respiratory diseases. Before quantitatively estimate the relationship between climate variables and respiratory diseases using GLM, we checked the linearity between these groups using the Generalized Additive Models. Correlations analysis showed that rainfall had a moderate positive correlation with Pneumonia (coefficient of correlation, ρ, ranged between 0.395 and 0.747) and a weak positive correlation with ARI (coefficient of correlation varied between 0.274 and 0.579). Relative humidity also demonstrated a moderate positive correlation to both diseases with the coefficient of correlation varying between 0.497 and 0.730. The study found that treated ceases of ARI increased by 0.10% to 0.55% and 2.90% to 8.55% for each millimeter increase in rainfall and each percentage increases in humidity, respectively. While pneumonia cases increased by 0.29% to 0.91% and 0.35% to 6.47% for each millimeter increase in rainfall and each percentage increase in relative humidity, respectively. This study concludes that climate variables have to be considered as possible factors impacting the prevalence of Pneumonia and ARI cases in infants and children under 5 years old in Kigali city, and this should be considered by local public health authorities when providing health education for people preparing them for higher risk seasons.

Keywords: Acute Respiratory Infection, pneumonia, climate variables, Kigali city.

1. Introduction

The climate change harms human health both directly and indirectly. Direct effects include changes of earth system, such as rising temperatures, change in rainfall intensity and frequency or snowfall in some areas, and drought. Indirectly, climate-related ecosystem changes increase the range, seasonality, and infectivity of some vector-borne diseases, directly threaten respiratory health by promoting or aggravating respiratory diseases or indirectly by increasing exposure of risk factors for respiratory diseases (Budiyono et al., 2017).

Many studies confirmed the relationship between climate variability and respiratory diseases (Akachi et al., 2009; D'Amato et al., 2016; De Souza et al., 2012; Santos et al., 2017; Sheffield & Landrigan, 2011). The World Health Organization (WHO) estimated that climate change contributed to more than 150,000 deaths and 5.5 million lost disability-adjusted life years worldwide, in year 2000 alone, and more than 88% of this burden occurs in children under the age of 5 years (Xu et al., 2012). Temperature, humidity, and rainfall can influence the occurrence of diseases, including ARI and pneumonia which are the leading causes of mortality of the children under 5 years of age (Kim et al., 2016). In low- and middle-income countries, 6.9 million children died in 2011 and about one in five of these deaths was caused by an Acute Lower Respiratory Infection (ALRI) (Harerimana et al., 2016). According to WHO in its world health statistics report, the lower respiratory infections are classified as the first of the top 10 conditions contributing most to the life expectance reduction in low-income countries with the life expectance reduced by 2.09 years attributed to lower respiratory infections and, more than 808 thousand deaths of children under age of 5 years were caused by ARI in year 2017 alone (World Health Organization, 2019). Children under 5 years are the most population at risk for pneumonia because their immune is weak (Liu et al., 2016). Cold and/or damp weather also increases the incidence of pneumonia due to being favorable for breeding of various micro-organisms (D'Amato et al., 2016). Both ARI and pneumonia are infectious diseases transmitted by person-to-person route and are quite widespread and closely associated with climate variability in their development (Kim et al., 2016), and their incidence demonstrated high seasonality (Santos et al., 2017). Increased opportunity of contact with infected person from increased indoor activity, divergence of the survival and stability of pneumococci in the air, decreased host immunity and behavioral changes of individuals are suggested factors in the air (Kim et al., 2016).

Changes in meteorological factors mainly affect the respiratory system and, in particular, are thought to be substantial causes of induced bronchial asthma, trachealis, bronchitis, pneumonia, ARI and other respiratory diseases (Liu et al., 2016; Santos et al., 2017). Climate variables are considered to affect the respiratory system by lowering the resistance of the human body to infections and by affecting the way in which these infections spread (du Prel et al., 2009). Rwanda third communication report under United Nations Framework Convention on Climate Change (UNFCCC) showed that the mortality rate due to respiratory infections was increasing from 7,115 cases in 2009 to 11,085 deaths in 2014 due to climate variability and the report says that children under 5 years are the most affected (Republic of Rwanda, 2018). The objective of this study is to assess the relationship between the climate variables and Acute Respiratory Infection (ARI) and pneumonia in infant and children under 5 years old in Kigali city.

2. Methodology

2.1 Study Area

This study was conducted in Kigali city. Kigali, the capital of Rwanda, is located between 29°43'E-29°44'E and 2°35'S-2°37'S (Jiwaji, 2016). It is divided into three districts, namely: Gasabo, Kicukiro and Nyarugenge. Nyarugenge district as the city center is dominated by commercial and administrative activities, while Gasabo district counts more in administrative and residential activities whereas Kicukiro district is almost residential area. Besides this classification, each district has a suburban area dominated by residential and agricultural activities. In this study we randomly selected two health centers in each district.

Kigali city counts inhabitants of approximately 1.2 million as 2017 on an area of 730 km^2 of which 30% is urban area and 70% rural. The city's population growth rate is 6.2 per cent per annum (UN Environment Programme, 2018). Rwanda, Kigali within, as the equatorial country, experiences a temperate tropical climate, characterized by two distinguishable dry and wet seasons. The long dry season spans between the months of June and August, and the short one between Midi-December and February. The long rainy season is observed during the months of March to May, while the short rainy season spans between September and Midi-December (King, 2007; Muhire & Ahmed, 2015). Kigali is located in central plateau region of Rwanda characterized by rainfall between 1100 mm and 1300 mm in 90 to 150 days a year with mean temperature between 18 °C and 20 °C (Republic of Rwanda, 2018).

Data of ARI, pneumonia and climate parameters for 5 years (2014-2018), used in this study, were acquired from two different public institutions. We collected data for respiratory diseases from Rwanda Biomedical Center (RBC). These data were recorded in six health centers: Muhima and Biryogo in Nyarugenge District, Kicukiro and Gikondo in Kicukiro District, and Bweramvura and Gihogwe in Gasabo District. Meteorological data were acquired from Rwanda Meteorology Agency (Meteo Rwanda) for three meteorological stations: namely, Gitega, Kigali Airport and Kabuye stations located in Nyarugenge, Kicukiro, and Gasabo districts respectively.

2.2 Data Analysis Methods

The data analysis was conducted firstly by looking over descriptive analysis of the data in terms of the dependent variables (respiratory diseases) and independent variables (climate variables). Raw climate data in Kigali city, as independent variables, were aggregated to monthly mean values of temperature, humidity and total rainfall. ARI and pneumonia, as dependent variables, were brought to total cases per month. In addition to mean values, the correlation of respiratory diseases and climate variables were examined by calculating the Spearman correlation coefficient (ρ).

The variance inflation factor (VIF) was used to assess the degree of collinearity between the climate variables as independent variables. Before quantitatively estimating the risk of ARI and pneumonia as dependent variables (predictands) versus independent variables (predictors) using Generalized Linear Models (GLM), we checked the relationship (linearity) between the meteorological variables and the respiratory diseases using Generalized Additive Models (GAM) as non-parametric estimator. The disease incidences are commonly assumed to follow a Poisson process (Guisan et al., 2002; Kim et al., 2016), so we used log function as a link function for GLM. Furthermore, time series plots were used to look at possible seasonal variation of respiratory diseases. In that regard, we twin-plotted ARI and pneumonia with rainfall. Equations used for GLM (Equation (1)) and GAM (Equation (2)) are shown below:

$$log(\mu_i) = \beta_0 + \beta_1 \times rainfall_i + \beta_2 \times Tmin_i + \beta_3 \times Tmax_i + \beta_4 \times RH_i + \epsilon_i \quad (1)$$

$$\log(\mu_i) = \beta_0 + s(rainfall_i) + s(Tmin_i) + s(Tmax_i) + s(RH_i) + \epsilon_i \quad (2)$$

where β_0: intercept, β_i: ith coefficient, s: the smoothing function, and ϵ_i: error term.

While the VIF for ith predictor variable was calculated using Equation (3).

$$VIF_i = \frac{1}{1-R_i^2}, \quad i = 1, \dots, p \quad (3)$$

where R_i^2 is the multiple correlation coefficient of regression between x_i and the remaining $\boldsymbol{p-1}$ predictors.

3. Results and Discussion

3.1. Descriptive Statistics

Descriptive statistics of ARI, pneumonia is shown in Table 1. High monthly number of pneumonia cases was 567 cases, registered at Gihogwe health center, while the highest monthly number of ARI cases was 547 cases, recorded at Bweramvura health center. The low number of cases for ARI and pneumonia were both zero, and respectively recorded at Bweramvura and Kicukiro health centers. During the study period, Gihogwe health center averaged the highest cases of pneumonia cases with 123.63 cases, while Gikondo has the highest average of ARI cases of 144.45 cases. The lowest cases of pneumonia were averaged at Bweramvura (91.10 cases) while the lowest cases of ARI were averaged at Gihogwe health center (90.25 cases).

Table 1: Descriptive Statistics of Pneumonia and ARI cases per month at six selected health centers during the period of 2014-2018

		Biryogo	Muhima	Kicukiro	Gikondo	Gihogwe	Bweramvura
Pneumonia	mean	105.25	108.72	91.32	92.72	123.63	91.10
	std	99.38	116.99	86.73	103.12	118.83	100.37
	min	3	10	0	7	3	8
	max	417	519	406	511	567	467
ARI	mean	128.25	104.72	92.87	144.45	90.25	107.33
	std	94.37	89.87	58.73	137.24	68.28	93.76
	min	10	12	8	11	19	0
	max	465	395	263	500	363	547

***std**: Standard deviation, **min**: Minimum Value, **max**: Maximum Value*

Table 2: Averaged total monthly rainfall, average minimum and maximum temperature and average relative humidity in Kigali city during the period of 2014-2018

	Nyarugenge				Gasabo				Kicukiro			
	Rain	Tmax	Tmin	RH	Rain	Tmax	Tmin	RH	Rain	Tmax	Tmin	RH
Jan	67	27.8	17.1	72	114	27.8	12.5	70	58	28.1	17.0	70
Feb	80	27.8	17.1	72	175	27.2	13.3	75	75	27.8	17.0	76
Mar	151	26.9	17.3	76	205	28.3	13.8	75	99	27.2	16.8	76
Apr	194	25.4	17.3	82	182	27.7	13.1	82	122	26.0	17.0	79
May	85	25.7	16.8	77	57	28.0	13.4	75	56	26.1	17.1	75
Jun	33	26.0	16.7	69	30	28.1	12.8	63	19	26.7	16.5	62
July	3	27.0	16.6	56	9	28.3	12.2	54	3	27.7	16.3	53
Aug	44	27.5	17.7	63	98	28.2	12.8	57	27	28.0	17.3	57
Sep	77	27.8	17.5	71	99	27.9	12.5	66	53	27.2	17.0	67
Oct	113	27.3	17.3	75	139	27.8	12.9	75	69	27.8	17.0	76
Nov	149	26.1	16.7	80	127	27.3	13.0	81	82	26.3	16.6	83
Dec	114	26.6	17.0	74	71	27.7	12.2	76	71	26.8	16.5	77

Table 2 gives the values of average monthly total rainfall, monthly mean temperature and relative humidity for the study period. The month of July recorded the lowest average total rainfall with the mean values of 3 mm, 9 mm and 3 mm averaged in Nyarugenge, Gasabo and Kicukiro districts respectively.

The highest averages of total monthly rainfall were averaged for the April in Nyarugenge and Kicukiro districts, with respective values of 194 mm and 122 mm, and for the month of March in Gasabo district (205 mm). During the study period, the temperature fluctuated between the monthly averages of 12.2 ºC and 28.3 ºC with the highest and lowest values both averaged in Gasabo district.

The relative humidity was low in July with average values of 56%, 54% and 53%, and high in April with average values of 82%, 82% and 79 % in Nyarugenge, Gasabo and Kicukiro districts respectively.

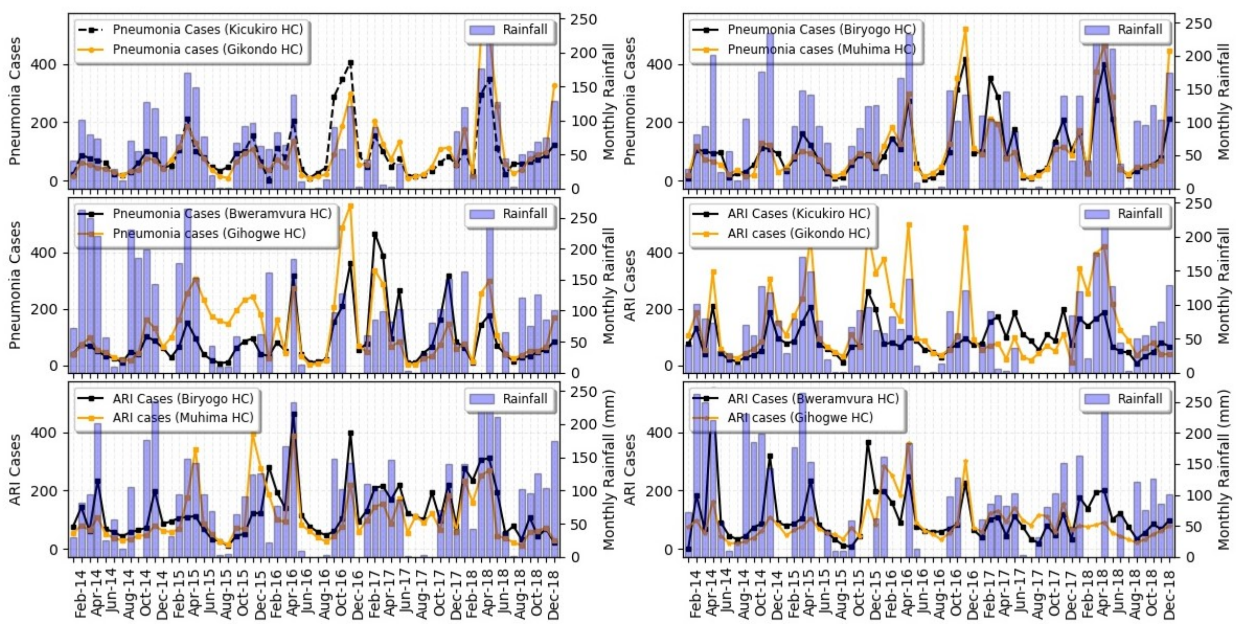

Figure 1: The patterns of monthly total rainfall, ARI and Pneumonia Cases in six health centers for the period of 2014-2018.

The timeseries of pneumonia and ARI cases are twin-plotted with rainfall for the total monthly cases of treated diseases and total monthly rainfall (Figure 1) and for monthly averaged data of rainfall, ARI and pneumonia over study period (Figure 2). Both pneumonia and ARI present strong seasonality patterns with the higher values observed during the rainy months (Figure 2). The seasonality behavior of respiratory diseases was also reported by Althouse et al. (2018); Chan et al.(2002); Kim et al. (2016) and Lin et al. (2009) in their respective studies.

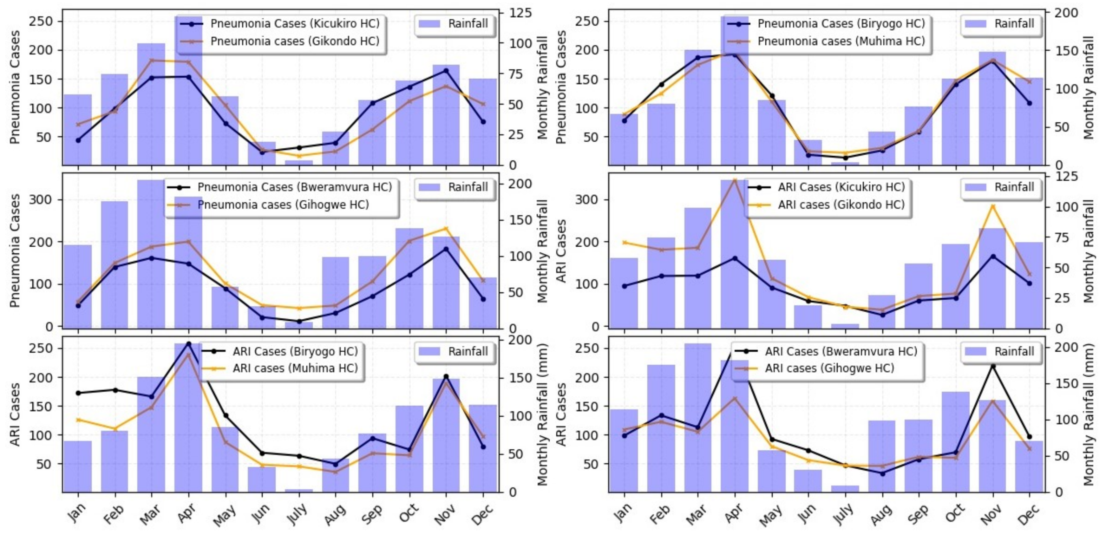

Figure 2: Twin plots of monthly averages of pneumonia and ARI cases versus rainfall at selected Health Centers (HC) in Kigali City (2014-2018).

Table 3: Spearman Correlation coefficients for climate variables and respiratory diseases cases in children under five years of age during the study period of 2014-2018

	Health Centers	Rainfall	Tmin	Tmax	RH
Pneumonia	Biryogo	0.735	0.053	-0.237	0.643
	Muhima	0.747	0.069	-0.167	0.665
	Kicukiro	0.746	0.034	-0.293	0.542
	Gikondo	0.685	-0.041	-0.397	0.497
	Gihogwe	0.395	-0.091	-0.042	0.569
	Bweramvura	0.590	0.024	-0.421	0.574
ARI	Biryogo	0.393	0.139	-0.203	0.683
	Muhima	0.400	0.310	-0.179	0.577
	Kicukiro	0.284	-0.017	-0.232	0.511
	Gikondo	0.545	0.176	-0.239	0.654
	Gihogwe	0.274	-0.142	-0.295	0.526
	Bweramvura	0.579	0.159	-0.418	0.730

We calculated the Spearman's coefficient of correlation between respiratory diseases and meteorological variables as given in Table 3. Pneumonia cases presented a strong positive correlation with rainfall at Muhima, Kicukiro and Biryogo Health centers (ρ = 0.747, 0.746 and 0.735 respectively), a moderate positive correlation at Gikondo and Bweramvura Health Centers (ρ = 0.685 and 0.590 respectively) and a weak positive correlation at Gihogwe health center (ρ = 0.395).

Rainfall and ARI were found to be moderately correlated at Bweramvura, Gikondo and

Muhima Health Center (ρ = 0.579, 0545 and 0.400 respectively) and weakly correlated at other health centers with ρ = 0.393, 0.284 and 0.274 at Biryogo, Kicukiro and Gihogwe Health centers, respectively. Relative humidity has also presented a moderate correlation with both pneumonia ($0.497 \leq \rho \leq 0.665$) and ARI ($0.511 \leq \rho \leq 0.730$), while minimum and maximum temperatures found to be weakly correlated with respiratory diseases with a positive correlation for the minimum temperature and a negative correlation for the maximum temperature in general. A positive correlation of ARI and relative humidity and a no correlation between temperature and respiratory diseases were also reported by Budiyono et al. (2017), but our findings are in contradiction with their results for rainfall and respiratory diseases correlations.

3.1. Variance Inflation Factor, Generalized Additive Models and Generalized Linear Models

Before performing a GLM analysis, we checked the relationship between the meteorological variables (independent variables) and the respiratory diseases (response variables) using GAM. The figures that summarize the results of GAM models are given in the appendices (Figure 4 - 7). After examining the results, the linearity assumption was concluded. Furthermore, we checked the multicollinearity between meteorological parameters as predictors using the VIF. Based upon the results, VIF varies between 3.2 and 1.1. These values of VIF demonstrate a weak multicollinearity between predictors and, so a little effect on parameter estimation results.

The GLM parameter estimates are given in Table 4, and the relative risks of ARI and pneumonia versus climate variables were plotted in Figure 3. Recorded cases of both ARI and pneumonia generally increased with an increase in rainfall and relative humidity, and they decreased with the increase in maximum temperature and the increase of minimum temperature (Figure 3). Taking Biryogo health center as an example; coefficients related to minimum temperature were -0.057 for ARI and -0.092 for pneumonia, where negative sign indicates a decrease in recorded disease cases as a function of average minimum temperature increase, that is, there is inverse relationship between the variables under analysis. Therefore, it is expected that, for the months with lowest temperature records, the higher rates of ARI and pneumonia are observed. Thus, exp (-0.057) = 0.945, and exp (-0.092) = 0.912, it is estimated that the average number of ARI and pneumonia decreases by approximately 5.52% and 8.91% at Biryogo health center respectively for each increase in 1^{o}C above the monthly average value of minimum temperature.

Table 4: GLM parameter estimates for occurrence of Pneumonia and ARI during the period of 2014-2018 at six selected health centers in Kigali city

		Acute Respiratory Infections						Pneumonia					
HC		coef	std	z	P>|z|	LCI*	UCI**	coef	std	z	P>|z|	LCI*	UCI**
Biryogo	Intercept	-3.578	0.662	-5.405	0.000	-4.876	-2.281	-3.668	0.808	-4.540	0.000	-5.252	-2.085
	Rainfall	0.001	0.000	2.967	0.003	0.000	0.002	0.004	0.000	9.022	0.000	0.003	0.005
	Tmin	-0.057	0.024	-2.362	0.018	-0.104	-0.01	-0.092	0.027	-3.359	0.001	-0.146	-0.038
	Tmax	0.166	0.021	8.072	0.000	0.126	0.207	0.181	0.024	7.490	0.000	0.134	0.228
	RH	0.067	0.004	16.768	0.000	0.059	0.074	0.063	0.005	12.864	0.000	0.053	0.072
Muhima	Intercept	-4.279	0.744	-5.753	0.000	-5.737	-2.822	-6.796	0.869	-7.819	0.000	-8.499	-5.092
	Rainfall	-0.002	0.000	-4.061	0.000	-0.002	-0.001	0.006	0.000	13.057	0.000	0.005	0.006
	Tmin	0.168	0.026	6.474	0.000	0.117	0.219	0.096	0.026	3.649	0.000	0.044	0.148
	Tmax	0.009	0.023	0.372	0.710	-0.037	0.054	0.172	0.025	6.886	0.000	0.123	0.221
	RH	0.082	0.004	18.262	0.000	0.073	0.091	0.061	0.005	11.620	0.000	0.051	0.071
Bweramvura	Intercept	2.960	0.755	3.918	0.000	1.479	4.44	8.399	0.898	9.353	0.000	6.639	10.158
	Rainfall	0.001	0.000	4.658	0.000	0.001	0.002	0.003	0.000	9.785	0.000	0.002	0.003
	Tmin	0.089	0.015	5.896	0.000	0.059	0.118	-0.316	0.017	-18.589	0.000	-0.349	-0.283
	Tmax	-0.119	0.023	-5.197	0.000	-0.164	-0.074	-0.082	0.027	-2.989	0.003	-0.135	-0.028
	RH	0.050	0.002	23.724	0.000	0.046	0.054	0.030	0.002	14.218	0.000	0.025	0.034
Gihogwe	Intercept	3.922	0.881	4.453	0.000	2.196	5.648	-6.983	0.596	-11.707	0.000	-8.153	-5.814
	Rainfall	0.001	0.000	3.771	0.000	0.001	0.002	0.004	0.000	15.678	0.000	0.004	0.005
	Tmin	-0.229	0.018	-13.040	0.000	-0.264	-0.195	-0.280	0.015	-19.031	0.000	-0.309	-0.251
	Tmax	0.029	0.027	1.077	0.282	-0.024	0.082	0.452	0.019	24.279	0.000	0.415	0.488
	RH	0.035	0.002	15.894	0.000	0.031	0.039	0.031	0.002	17.053	0.000	0.027	0.034
Kicukiro	Intercept	7.001	0.555	12.620	0.000	5.914	8.089	3.728	0.571	6.529	0.000	2.609	4.847
	Rainfall	0.001	0.000	3.292	0.001	0.000	0.002	0.009	0.000	31.554	0.000	0.008	0.009
	Tmin	-0.136	0.030	-4.580	0.000	-0.194	-0.078	0.073	0.031	2.332	0.020	0.012	0.134
	Tmax	-0.069	0.015	-4.746	0.000	-0.098	-0.041	-0.050	0.015	-3.434	0.001	-0.078	-0.021
	RH	0.023	0.002	14.091	0.000	0.020	0.026	0.004	0.002	2.065	0.039	0.000	0.007
Gikondo	Intercept	0.682	0.464	1.470	0.142	-0.227	1.591	10.968	0.587	18.694	0.000	9.818	12.118
	Rainfall	0.006	0.000	25.008	0.000	0.005	0.006	0.009	0.000	33.740	0.000	0.009	0.010
	Tmin	0.215	0.023	9.233	0.000	0.169	0.261	-0.163	0.034	-4.870	0.000	-0.229	-0.097
	Tmax	-0.076	0.012	-6.488	0.000	-0.099	-0.053	-0.180	0.015	-11.712	0.000	-0.210	-0.150
	RH	0.031	0.001	22.604	0.000	0.029	0.034	0.006	0.002	3.113	0.002	0.002	0.009

CLI: Lower Confidence interval, UCI**: Upper Confidence Interval*

The coefficients related to relative humidity (retaking Biryogo health center as example) were 0.067 for ARI and 0.063 for pneumonia, were positive, indicating an increase of ARI and pneumonia cases due to increase in relative humidity, that is, there is a direct relationship between the variables under analysis. Thus, it is expected that, for the months with higher relative humidity records, the higher cases of ARI and pneumonia will be observed. Therefore, by taking exp (0.067) = 1.069 and exp (0.063) =1.065, so it is estimated that the average number ARI and pneumonia increases by approximately 6.89% and 6.47% at Biryogo health center respectively for each increase in 1% above the monthly average value of relative humidity. Other coefficient, presented in Table 4, may be interpreted the same way.

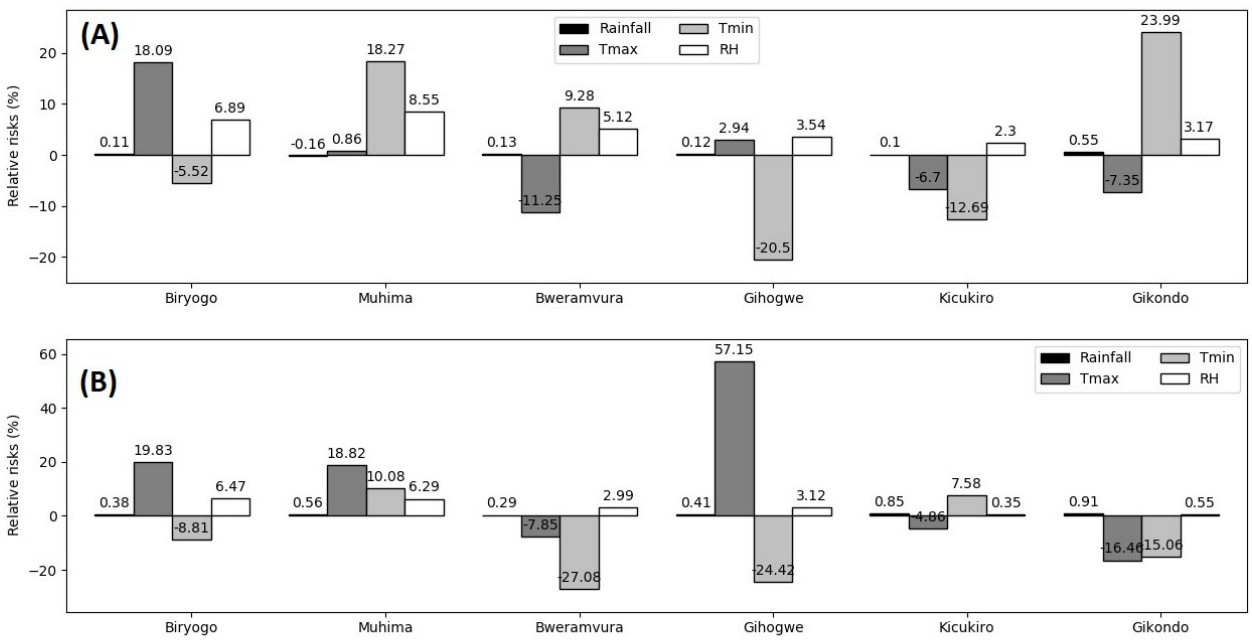

Figure 3: Relative impact of meteorological parameters on Acute Respiratory Infection (A)and Pneumonia (B) at selected health centers in Kigali City.

Figure 3 gives the relative risks of ARI and pneumonia versus climate variables. It can be seen from Figure 3 that rainfall and relative humidity are directly related with respiratory diseases at all health centers, except at Muhima health center which demonstrated an inverse relationship between ARI and rainfall. The risk of ARI varied between -0.16% and 0.55% for each mm increase in total monthly rainfall, while those of pneumonia varied between 0.29% and 0.95% for each mm increase in total monthly rainfall above the mean value. The increase in relative humidity demonstrated a higher risk of increase in respiratory disease with values of 2.30% to 8.55% increase in ARI and 0.35% to 6.47% increase in pneumonia cases for each increase in 1% of relative humidity above the mean value. The direct relationship between climate variables and acute respiratory diseases was also reported by Kim et al. (2016); Liu et al. (2016) and Paynter et al. (2010). Contrary to the findings of Budiyono et al. (2017) who reported a non-association between pneumonia and rainfall, temperature and relative humidity.

It can be seen from Figure 3 that the maximum temperature demonstrated a contradictory relationship. On some health centers they were found to be directly related with diseases, while in other health centers they were found to be inversely related. This contradiction in results was also found by different scholars. Lin et al. (2009) and Kim et al. (2016) found a positive association of pneumonia with maximum temperature, while Chan et al. (2002) and Paynther at al. (2010) reported a negative association. The cause of this contradiction may be coming from the factor that the temperature is adversely interacting with other environmental factors such as air pollutants, wind speed and solar radiation (Bernard et al., 2001; Jayamurugan et al., 2013) and, these factors are also known to affect the occurrence of infectious respiratory diseases like ARI and pneumonia, especially in urban areas (Tze-ming et al., 2007; WBK & Associates Inc., 2003; WHO, 2020).

4. Conclusion

Acute respiratory diseases are amongst the common illness in infants and children under 5 years of age. In this study we established a clear relationship between ARI and pneumonia in children under age of 5 years in Kigali city, we especially demonstrated that rainfall and relative humidity are more aggravating respiratory diseases at higher level. Cases of pneumonia and ARI in Kigali city from the six health centers were higher in the wet and humid months than in the dry ones. This study did not consider other factors such as solar radiation, and air pollution levels because of lack of data for those factors, but the information given in this study is important for the public health concern when planning appropriately for the measures against the respiratory diseases in infants and children.

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APPENDICES : Results (spline lines) of General Additive Models (GAM)

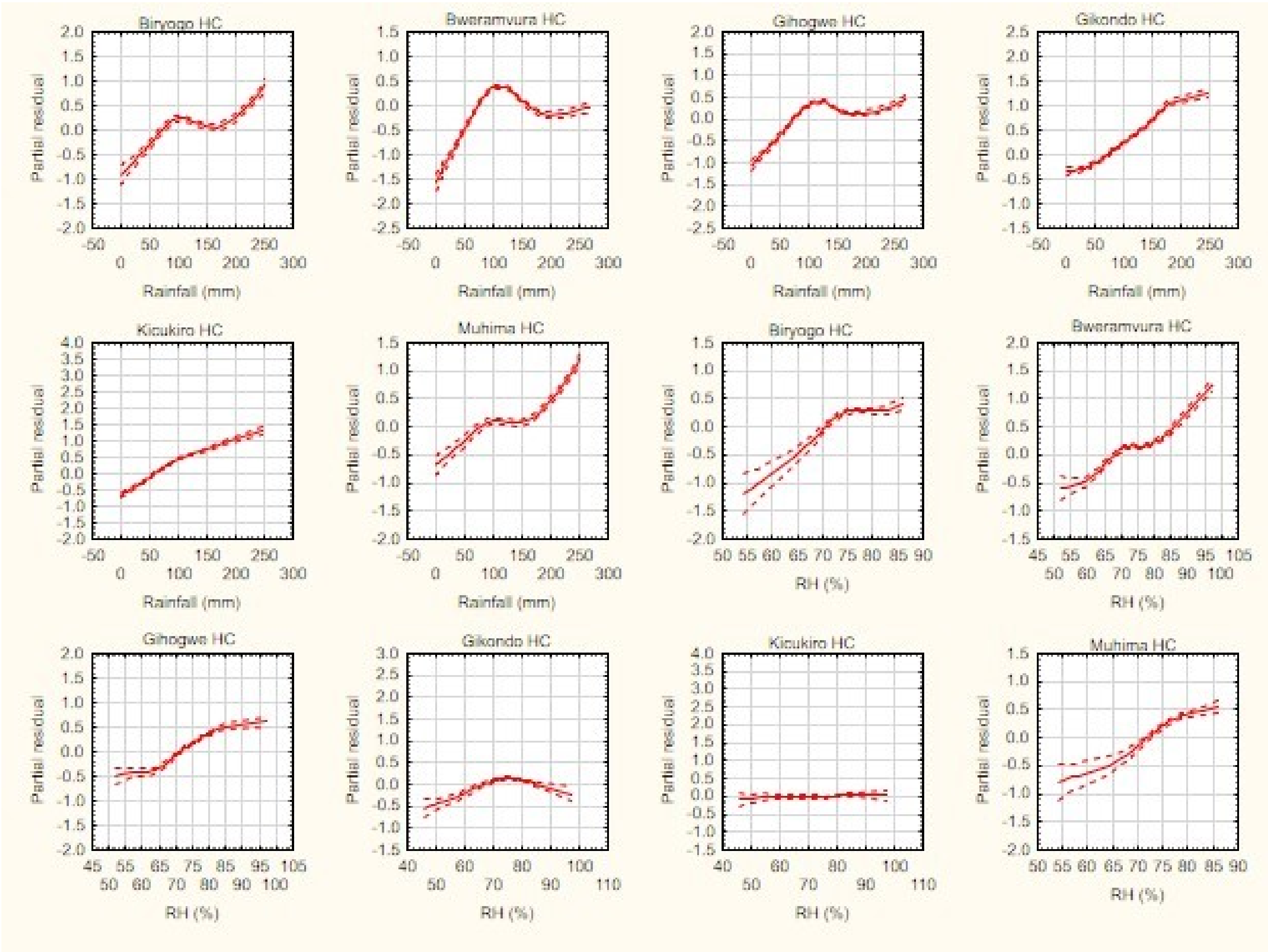

Figure 4: Spline lines (solid line) and 95% confidence band (dashed lines) of partial residuals for pneumonia responses to maximum rainfall and relative humidity in selected Health Centers (HC) in Kigali City.

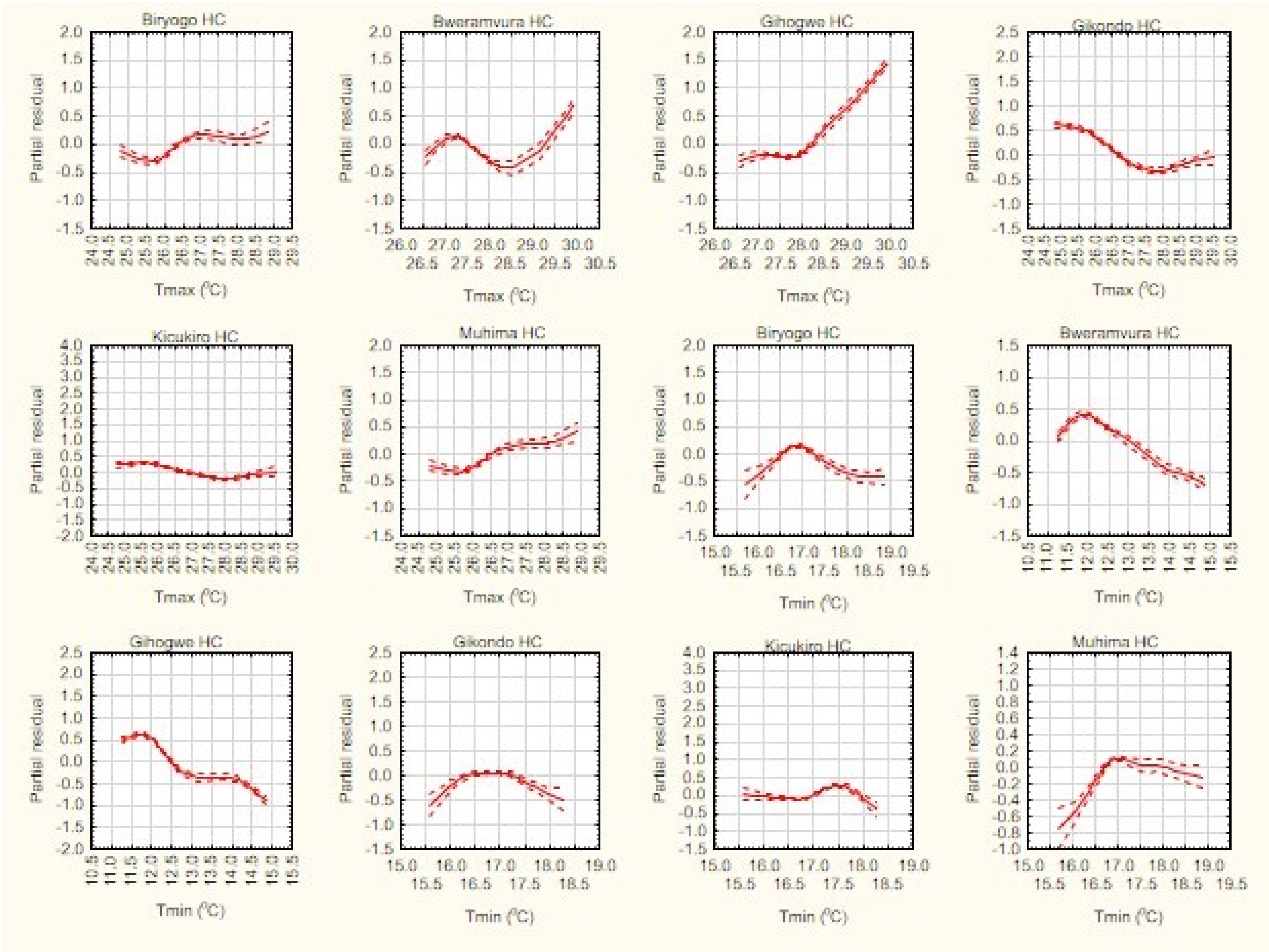

Figure 5: Spline lines (solid line) and 95% confidence band (dashed lines) of partial residuals for pneumonia responses to minimum and maximum temperature in selected Health Centers (HC) in Kigali City.

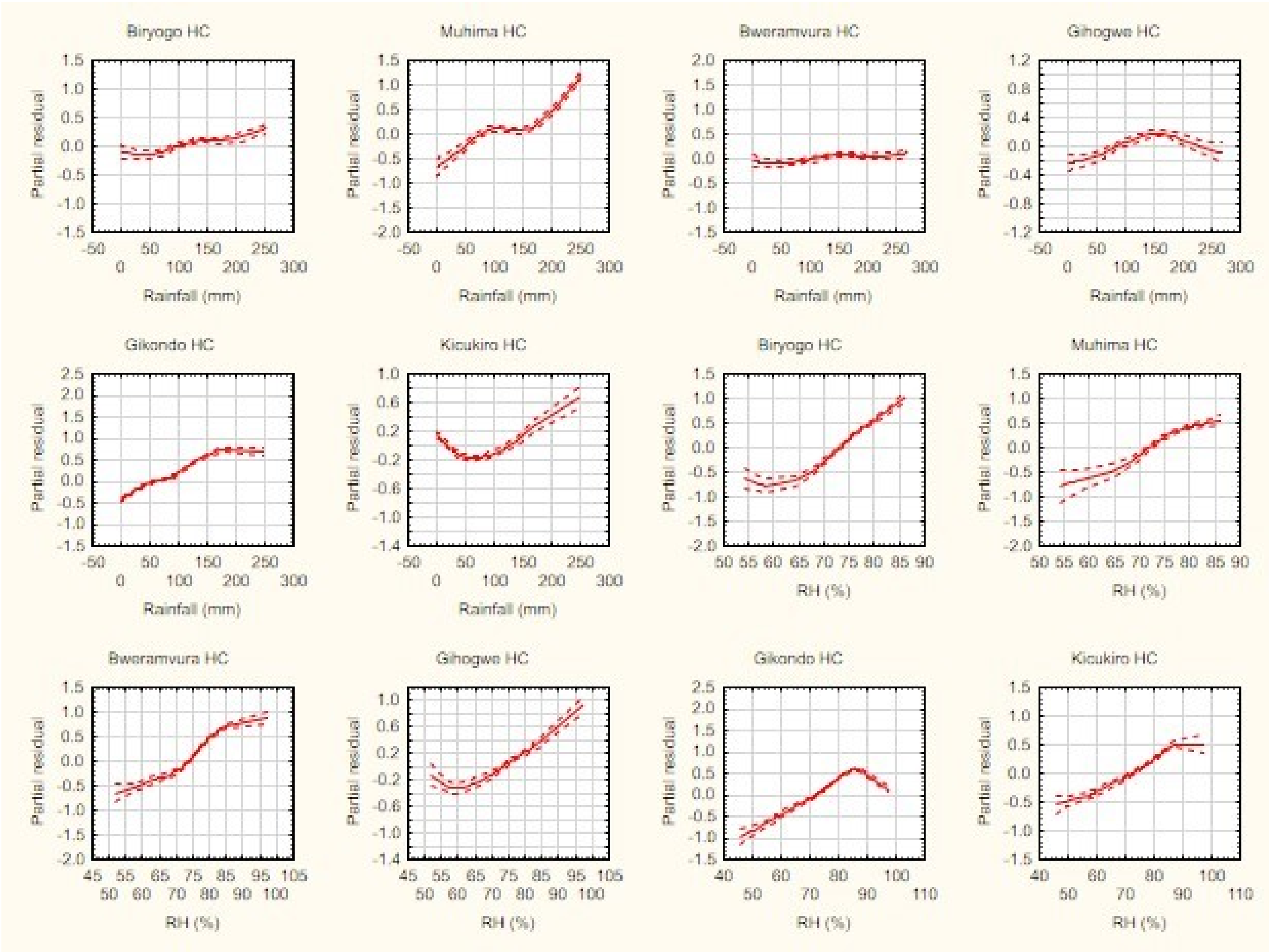

Figure 6: Spline line (solid line) and 95% confidence band (dashed lines) of partial residuals for ARI responses to rainfall and relative humidity in selected Health Centers (HC) in Kigali City.

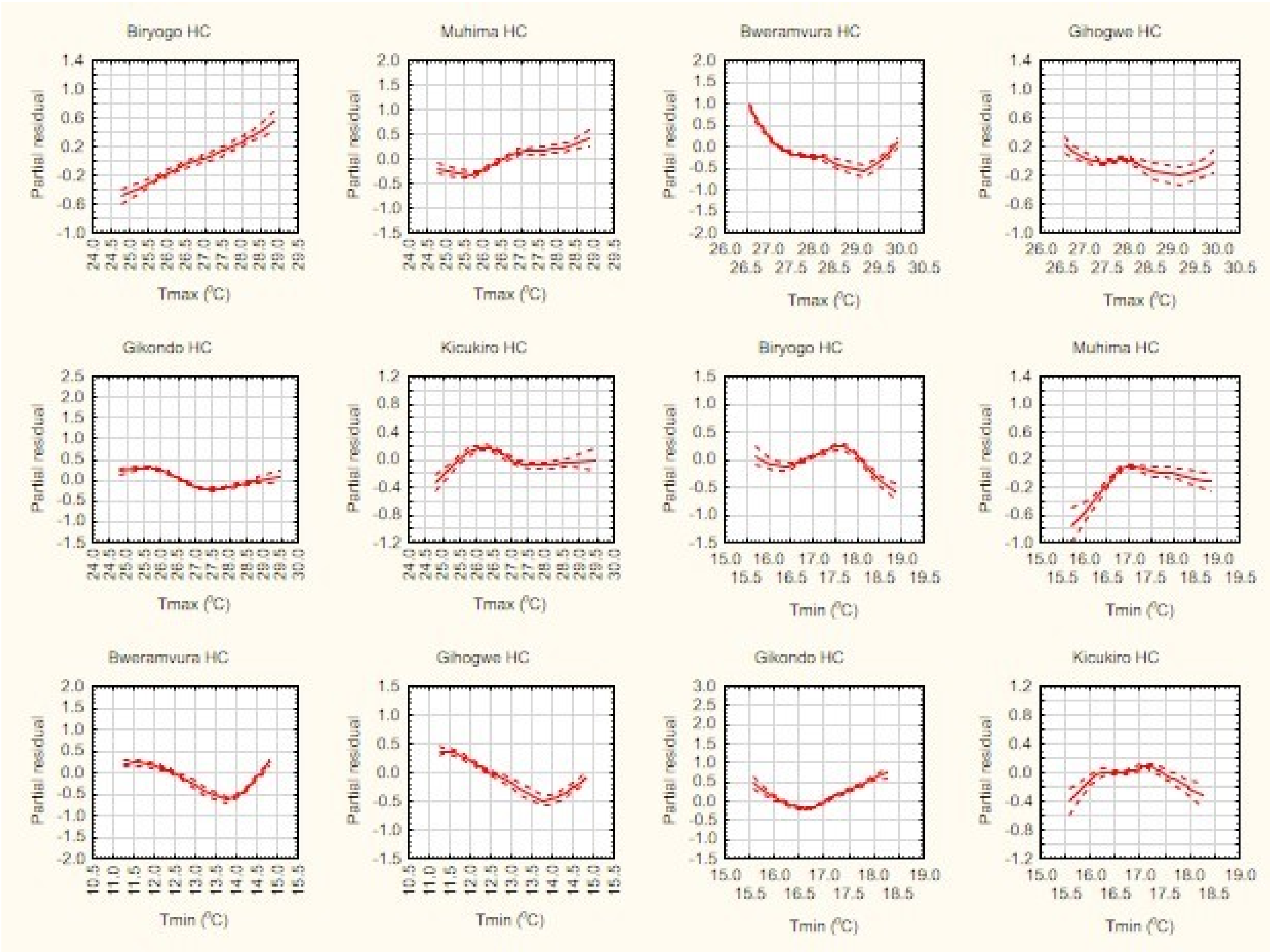

Figure 7: Spline line (solid line) and 95% confidence band (dashed lines) of partial residuals for ARI res ponses to minimum and maximum temperature in selected Health Centers (HC) in Kigali City.