Negative Binomial Model in Linking Water-borne and Vector-borne Disease Hospitalizations with Climate Sensitive Variables in Nepal

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ABSTRACT

Background: Several statistical models are built to associate climate sensitive variables such as temperature, rainfall, relative humidity and wind speed with selected water-borne (WB) diseases namely enteric fever, diarrhea and dysentery and vector-borne (VB) diseases namely malaria, encephalitis and leishmaniasis separately based upon daily time series data.

Objective: The objective of the paper is to associate climate sensitive variables with WB and VB diseases in the context of Nepal through building statistical models.

Materials and Methods: Analysis is based upon the ecological study design with five years of daily hospital inpatient data collected from 22 leading hospitals of 10 districts spread across all the three eco-belts of Nepal and corresponding meteorological data covering 16 stations of the selected districts collected from Department of Hydrology and Meteorology for the period 2009-2014. Negative binomial model is found suitable and used to account the over-dispersed count response variables.

Results: Temperature is found to be consistently and positively associated with the accounted disease hospitalizations with around 3-9% (95% CI: 1.3-10.1% combined) and 2-12% (95% CI: 0.3-15.1% combined) estimated increase in WB and VB diseases per 1^0C increase in average temperature, respectively. However, the same type and level of consistency are not detected in the remaining meteorological variables in the presence of confounders like annual trend, holiday effect and seasonality.

Conclusion: Under the climate change scenario of Nepal, WB and VB diseases that can be attributed to rise in temperature is expected to increase in future with substantial attributable burden of diseases. Consequently, Nepal needs to face the challenges of climate change by improving health facilities, reducing poverty among Nepalese people, implementing suitable adaptation and vulnerability related plans and policies, widespread use of eco-friendly energy and technology, etc. along with achieving the targeted sustainable development goals in years to come.

Keywords: Burden of diseases, climate change, Poisson-gamma model, temperature, water-borne and vector-borne diseases.

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INTRODUCTION

Many studies across the globe have shown that climate change is a real phenomenon characterized by increase in average surface air temperature and changes in nature, intensity and frequency of precipitation (Intergovernmental Panel on Climate Change [IPCC], 2001). Global warming with increase in greenhouse gas concentration, gradual melting of snow and icebergs, rise in sea levels, increased evidences of floods, landslides, drought and desertification, etc. are the main symptoms of climate change in the world and reported by the fifth report of Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change [IPCC], 2013). Many studies have also been conducted in Nepal in this context which showed increase in average surface temperature and shifts in rainfall pattern (Chaudhari & Aryal, 2009; Ebi, Woodruff, Von Hildebrand, & Corvalan, 2007; Shrestha, Wake, Mayewski, & Dibb, 1999; Shrestha, Wake, Mayewski, & Dibb, 2000; United Nations Environment Program [UNEP], 2002). However, the average surface air temperature rise per decade in Nepal has been reported with substantial variability between reports. For instance, Department of Hydrology Meteorology (DHM) in 2007 reported an increase of around 2^0 C temperature for Nepal projected for the period 2039-2069 compared to 1961-1990 based upon Regional Climate Model (RegCM3) which is equivalent to an average rise of 0.25^0C per decade (Department of Hydrology Meteorology [DHM], 2007). Similarly, according to World Bank Climate Change Knowledge Portal, an average increase of 0.55^0C temperature is estimated in the period 1990-2012 compared to 1960-1990 which is equivalent to an average increase of around 0.2^0C temperature per decade (Climate Change Knowledge Portal [CCKP], 2016). Other studies have indicated that from 1977-1994, mean annual maximum temperature in Nepal increased by 0.06^0 C and average temperature rise is estimated at 0.5^0C per decade (Ebi et al., 2007; Shrestha et al., 1999; UNEP, 2002).

Precipitation is also becoming unpredictable and more erratic than ever with more droughts and shorter periods of heavy rainfall (Shrestha et al., 2000). Several regions in the country are already vulnerable to unevenly distributed and erratic weather (Chaudhary & Aryal, 2009). These marked changes in climatic variables are bound to affect the people of Nepal specifically the public health concerns of Nepalese people. Many studies have been conducted concerning this issue of climate change and health burden including water-borne (WB) and vector-borne (VB) diseases in Nepal (Badu, 2013; Bhandari, Gurung, Dhimal, & Bhusal, 2012; Chaudhary & Aryal, 2009; Hansen, Peng, Ryan, Nitschke, Pisaniello, & Tucker, 2008; Joshi, Dhimal, Dhimal, & Bhusal, 2011; Shrestha, Shrestha, & Shrestha, 2016; Shrestha, Shrestha, Shrestha, & Joshi, 2017). WB diseases such as typhoid, diarrheal diseases and dysentery are primarily caused my contaminated drinking water and the level of contamination can be changed due changes in meteorological parameters like temperature and rainfall. Similarly, VB diseases such as malaria, encephalitis, filarisis, dengue and lieshmaniasis can be caused

by infected mosquito bites and is also depended on weather conditions with high temperatures being favorable to disease causing agents.

A cross-sectional household survey conducted in 2016 by Central Bureau of Statistics (CBS), Nepal Government found climate change impacts in Nepal through respondent opinion. The study revealed that majority of the respondents had experienced drought (99%), increase in landslides (78%), increase disease/insects and sporadic rain (98%) in the last 25 years. 84% of the respondent reported decrease in amount of surface water, majority of respondent agreed with change in temperature, delayed and decreased monsoon duration and winter rain, etc. (Central Bureau of Statistics [CBS], 2016). A study conducted in Nepal covering all the three ecological regions and based upon yearly data of 26 years (1982-2007) showed mixed results in terms of occurrence of the number of incidences of malaria and diarrheal diseases with observed rainfall and temperature variability. The total numbers of incidences of malarial diseases in the country significantly declined during the study period. However, incidences of the disease have increased during the last 6-7 years of the study period, particularly in the Hills and Mountains of Nepal, indicating that malarial incidences are spreading to newer locations at higher altitudes of the country that traditionally were considered malaria-free. The study tried to relate between climate changes and occurrences of climate sensitive diseases without obtaining health coefficients (Badu, 2013). The Capacity Strengthening in the Least Developing Countries (CLACC) working paper on climate change and health in Nepal reported that the temperature has risen in Nepal and expected to rise in the coming years partly due to increases in the human population, vehicles, development activities, and change in agricultural patterns. WB and VB diseases have been found to be increasing within the country, along with a strong identified relationship between these diseases and temperature and precipitation (International Institute for Environment and Development [IIED], 2008).

Many studies have been conducted in various parts of the world in order to establish linkages between climate sensitive variables with morbidities and mortalities and calculated health effect coefficients through statistical models (Hajat, Kovats, Atkinson, & Haines, 2002; Yao-Dong et al., 2013; Tong et al., 2014; Kovats, Campbell-Lendrum, & Matthies, 2006; Campbell-Lendrum & Woodruff, 2006; Veneckova & Bambrick, 2013; Bobb, Obermeyer, Wang, & Dominici, 2014; Checkley et al., 2000; Singh et al., 2001; Raju, Kiranmayi, & Rachel, 2014; Hansen et al., 2008; Giang, Dung, Giang, Vinh, & Rocklov, 2014; Tian, Qiu, Sun, & Lin, 2016; Gasperrini et al., 2015).

In the paper, health effect coefficients which can be attributed to climate sensitive variables are estimated and assessed separately for WB diseases like enteric fever and diarrheal diseases and VB diseases like malaria, encephalitis and leishmanaisis through statistical modeling.

MATERIALS AND METHODS

Analysis and statistical models with estimated health effect coefficients are based upon the data of the study entitled 'Study and Assessment of Environmental Burden of Diseases Attributable to Climate Change in Nepal' conducted under Climate Change Research Grant Program (CCRGP), Nepal Academy of Science and Technology (NAST) in 2015/16. Details of area coverage, data and variables, study design, statistical model, and lag structure and lag length used in the study are provided below.

Area coverage

A total of ten districts were covered in the study, one from Mountain (Dolakha), five from Hill (Kathmandu, Lalitpur, Bhaktapur, Kavrepalanchowk and Dhankuta) and four from Terai (Chitwan, Sunsari, Morang and Jhapa) which cover 23.8% of the total population of Nepal according to 2011 Population Census.

Study design and data

Ecological time series design was adopted for the study based upon daily data. Meteorological data was collected for weather variables namely temperature, rainfall, humidity and wind speed for 2009-2014 period from 16 stations located within the districts covered for the study which included 2 from Mountain, 8 from Hill and remaining 6 from Terai and collected from DHM, Kathmandu. In case where more than one station was incorporated in a district then the corresponding meteorological parameters were averaged. Disease burden data assessed by hospital inpatients and deaths were collected on daily basis from hospital records of the leading hospitals of the study area including government, teaching and some private hospitals for the reference period of 5 years from 2066 BS (April 2009 AD) to 2070 BS (May 2014 AD). Other hospitals which were much smaller in capacity in the selected districts were left out since it was not feasible to collect data from each and every hospitals and it is assumed that the effects of excluding these hospitals on estimates would be nominal and can be ignored.

Altogether 22 hospitals were referred from the selected districts which included 2 from Mountain, 13 from Hill and 7 from Terai. Inpatient data were collected for WB diseases (enteric fever, diarrheal diseases, etc.), VB diseases (malaria, dengue, encephalitis, leishmaniasis, etc.), heart diseases (ischemic heart disease, angina pectoris, cardiovascular arrest, cardiac failures, etc.), urinary system diseases (chronic kidney diseases, urinary tract infections, renal failure, etc), all cause mortality and disease specific mortality of the above specified diseases. Inpatient records showed around 50000 hospitalizations of the concerned diseases and around 10000 all cause deaths and 435 WB and VB disease deaths. Hospitalization records were examined along with addresses of inpatients and it was found that very small portions of the inpatients are actually from other districts and thus such cases were neglected. Moreover, in infectious diseases like WB and VB diseases and unlike non-

communicable diseases patients are more likely to visit hospitals which are nearby because of their acute effects and they don't know exactly about their cause of infection. They may simple have fever or diarrhea, for example and will naturally visit nearby hospitals. In the present analysis WB diseases considered are enteric fever (ICD Code: A01), diarrhea including gastroenteritis (ICD Codes: A08, A09) and dysentery including shigellosis and amoeabiasis (ICD Codes: A03, A06, A07). Similarly vector-borne diseases considered are malaria (ICD Codes: B50, B51), encephalitis (ICD Code: G04) and leishmaniasis (ICD Code: B74).

Confounding variables

The confounding variables included are seasonal effects, holiday effect and trend component.

Statistical model

Negative binomial (NB) model also known as Poisson-gamma model with NB2 variance function is found suitable and used for statistical modeling. It is a generalized linear model (GLM) with log link function suitable for over-dispersed count response variables of accounted hospitalizations. Usually for count dependent variable like daily hospitalizations Poison model is used under the assumption of equi-dispersion in the GLM with log link function. However, using Poisson model in the present model building showed high overdispersions in each of the models to be built which would result in high underestimation of errors in regression estimates. Moreover, distributional assumption of the daily hospitalization for all the responses following negative binomial distribution was checked and it was found that all the responses for WB and VB diseases followed negative binomial distribution using statistical distribution assumption test incorporated in XLSTAT software with p values equal to 0.12 for enteric fever hospitalization, 0.42 for diarrhea hospitalization, 0.58 for dysentery hospitalization, 0.78 for malaria hospitalization, 0.99 for encephalitis hospitalization and 0.18 for lieshmaniasis hospitalization (after deleting an outlier). Additionally, NB model was found comparatively more suitable with model adequacy tests being much better for NB model compared to Poisson model. Consequently, NB model is used for present model building.

In the model, since the dependent variable is assumed to be distributed as negative binomial distribution (NBD) it is a mixture of Poisson and gamma distributions. It has log link function with additional multiplicative random effect parameter distributed as gamma distribution to address the unknown heterogeneity. The model is specified as follows.

$$\log\left(\lambda_i\right) = \beta_0 + \beta_1 x_{i1} + ..\beta_k x_{ik} + \varepsilon_i = \beta_0 + \sum_{i=1}^{k} \beta_k x_{ik} + \varepsilon_i$$

where β_is are the unknown parameters, x_{ik} are the values of the predictor variables, λ_i is the mean of the dependent variable, $\beta_0 + \varepsilon_i$ is the random intercept in the model. Also, the model can be expressed as $\lambda_i = e^{\sum_{i=1}^{k} \beta_k x_{ik}} e^{\beta_0 + \varepsilon_i} = \mu_i e^{\beta_0 + \varepsilon_i}$ where, $\mu_i = e^{\sum_{i=1}^{k} \beta_k x_{ik}}$ and $e^{\beta_0 + \varepsilon_i}$ is the random intercept term.

In NB model, the general expression for variance function is $\mu_i + \alpha \mu_i^p$ where α is a scalar parameter and *p* is a specified constant. For $\alpha = 0$, the model reduces to the Poisson model with variance equal to mean and therefore the case of equidispersion. In the NB model with NB2 variance function, the variance function which allows over-dispersion is $\mu_i + \alpha \mu_i^2$ where *p* = 2 allowing quadratic variance function of the mean μ_i is the most common approach and standard formulation in implementing NB model. Moreover, NB2 model has a number of special features not shared by other variance functions such as robustness in distributional misclassification as well. Considering these, the NB model with NB2 variance function is used for modeling. Predictors with *p* values less than 0.3 are retained in the fitted models basically to capture all the relevant predictors under consideration so that important variables are not left out even though statistically insignificant at 95% confidence level. Several confounding variables are also included to account seasonal effects, holiday effect and trend component. Statistical software used for data modeling is SPSS 24.

Lag structure and lag length

Since climate sensitive WB and VB disease hospitalizations in a day could be affected by not only the meteorological and other conditions of the day but also could be due to the conditions of days or weeks before the hospitalization. It is therefore inevitable that lag effects are accounted in exposure-response models. In this regard, several probable lag structures like moving average, geometrical decay and arithmetic decay along with different numbers of lag days (0-2 months) were explored and the one which turned out to be most suitable was finally selected for estimation of health effect coefficients (Shrestha, 2007; Shrestha, 2012).

RESULTS

Six NB models are developed containing different combinations of explanatory variables for different response variables. The first model with enteric fever hospitalization as the response variable contained temperature (GEO 7), relative humidity (MA 15), trend, seasonality (autumn effect) and holiday effect as the explanatory variables. Similarly, the second model with diarrhea hospitalization as the response variable contained temperature (same day effect), relative humidity (same day effect), seasonality (summer, autumn) and holiday effect as the explanatory variables; the third model with

dysentery hospitalization as the response variable contained temperature (GEO7), relative humidity (MA 7), trend and seasonality (autumn, spring) as the explanatory variables; the fourth model with malaria hospitalization as the response variable contained temperature (MA 45), rainfall (same day effect), wind (MA 45), trend, seasonality (summer) and holiday effect as the explanatory variables; the fifth model with encephalitis hospitalization as the response variable contained temperature (MA 45), relative humidity (MA 45), wind (MA 21), trend, seasonality (spring) and holiday effect as the explanatory variables; and lastly, the sixth model with leishmaniasis as the response variable contained temperature (MA 15), trend, seasonality (autumn) and holiday effect as the explanatory variables.

Health effects of four meteorological variables namely temperature, rainfall, relative humidity and wind speed and other variables such as holiday, trend and seasonal effects on WB and VB disease hospitalizations are presented and discussed separately based upon estimates obtained from six fitted NB models, three for WB diseases (enteric fever, diarrhea and dysentery) and three for VB diseases (malaria, encephalitis and leishmaniasis).

Effect of temperature

Temperature is found to be statistically significant in affecting all the response variables of the six built models at 95% level of significance. Moreover, effects are found to be positive in all the models. This implies that temperature is the major variable in affecting WB and VB diseases hospitalizations and tends to increase with increasing surface air temperature. The effect is found to be maximum for malaria hospitalization followed by enteric fever, encephalitis and other hospitalizations with the risk of 12.1% (95% CI: 9.2-15.1%), 8.9% (95% CI:7.7-10.1%), 8.1% (95% CI: 5.8-10.6%) and < 6% increase per 1^0C increase in average temperature, respectively. The least effect was found for leishmaniasis which is 2.1% (95% CI: 0.3-3.9%). Lag effects is found to be relatively higher in case of VB diseases (15-45 days) compared to WB diseases (0-7 days) which is obvious since incubation periods in VB diseases are relatively much higher compared to WB diseases. Moreover, geometrical decay lags are found more statistically significant in WB diseases whereas moving average is found suitable in case of VB diseases (Table 1 & Fig. 1).

Effect of rainfall

Rainfall is found to be statistically significant only in the case of malaria hospitalization at 5% level (p=0.05) with 1.3% (95% CI: 0-2.7%) expected decrease in malaria hospitalization per 1 cm increase in rainfall (Table 1) which implies the risk of malaria hospitalization increases with decrease in rainfall.

Effect of relative humidity

Relative humidity is found to be statistically significant and affecting positively in enteric fever and encephalitis hospitalizations with the risk of 2.12% (95% CI: 1.3-2.8%) and 4.5% (95% CI: 2.0-6.9%) increase in the hospitalizations per 1% increase in relative humidity. In contrast, increase in relative humidity is found to be associated with decrease in diarrhea and dysentery hospitalizations by 1.7% (95% CI: 0.9-2.4%) and 1.3% (95% CI: 0.0-2.6%), respectively per 1% rise in relative humidity (Table 1 & Fig. 2).

Effect of wind speed

The effect of wind is found to be statistically significant only in malaria and encephalitis hospitalizations with mixed effects. Increase in wind speed by 1 m/s is found to have expected decrease in malaria hospitalization by 18.4% (95% CI: 7.1-28.2%) and increase the risk of encephalitis hospitalization by 15.6% (95% CI: -0.8-34.7%) (Table 1).

Holiday effect

Except in the case of dysentery hospitalization, effect of a holiday (Saturday) is found to have association with all the other considered hospitalizations with decrease in hospitalizations in holidays compared to working days with 13.3% (diarrhea) to 83.5% (leishmaniasis) expected decrease in hospitalizations in holidays (Table 2). The results imply that generally working days are more risky than holidays regarding the considered WB and VB disease hospitalizations except in dysentery hospitalization.

Trend effect

Statistical modeling showed that WB disease hospitalization namely enteric fever and dysentery exhibited an expected increasing trend regarding annual hospitalizations with 6.7% (95% CI: 3.1-10.6%) and 6.3% (95% CI: 0.9-11.9%) increase in risk of hospitalizations, respectively whereas VB hospitalizing exhibited a declining trend effect with 21.9% (95% CI: 15.3-28.0%), 12.5% (95% CI: 5.3-19.3%) and 16.9% (95% CI: 11.9-21.7%) annual estimated decline in malaria, encephalitis and leishmaniasis hospitalizations, respectively (Table 2).

Seasonal effect

Varying seasonal effects are detected in different hospitalizations as estimated through different statistical models. According to estimates, seasonal effect due to autumn had a higher effect in enteric fever hospitalization with 30.3% (95% CI: 14.2-48.7%) higher risk of hospitalizations compared to other seasons. Similarly, the seasonal effect of summer showed higher effect with 17.1% (95% CI: -11.8-55.4%) higher risk of malaria hospitalizations; 22.5% (95% CI: -7.6-62.6%) higher risk of

encephalitis hospitalizations due to seasonal effect of spring; and 22.9% (95% CI: 5.8-37.0%) lower risk of leishmaniasis hospitalizations due to seasonal effect of autumn, and so on for remaining hospitalizations (Table 2).

Table 1. NB model estimates of hospitalization coefficients related to climate sensitive variables.

Parameter	B	SE	*P* Value	RR	95% CI for RR		Percent Change			Lag
					Lower	Upper	C	L	U	
Temperature										
Enteric fever	0.085	0.0056	<0.001	1.088	1.076	1.100	8.87	7.68	10.08	GEO 7
Diarrhea	0.029	0.0084	<0.001	1.030	1.013	1.047	2.94	1.31	4.71	LAG 0
Dysentery	0.055	0.008	<0.001	1.057	1.040	1.073	5.65	3.98	7.36	GEO 7
Malaria	0.114	0.0137	<0.001	1.121	1.092	1.152	12.08	9.20	15.14	MA 45
Encephalitis	0.078	0.0115	<0.001	1.081	1.057	1.106	8.11	5.76	10.63	MA 45
Leishmaniasis	0.021	0.0089	0.021	1.021	1.003	1.039	2.12	0.30	3.87	MA 15
Rainfall										
Malaria	-0.013	0.0069	0.050	0.987	0.974	1	-1.29	-2.66	0.00	LAG 0
Relative Humidity										
Enteric fever	0.021	0.0038	<0.001	1.021	1.013	1.028	2.12	1.31	2.84	MA 15
Diarrhea	-0.017	0.0039	<0.001	0.983	0.976	0.991	-1.69	-2.37	-0.90	LAG 0
Dysentery	-0.013	0.0066	0.045	0.987	0.974	1	-1.29	-2.57	0.00	MA 7
Encephalitis	0.044	0.0121	<0.001	1.045	1.020	1.07	4.50	2.02	6.93	MA 45
Wind										
Encephalitis	0.145	0.078	0.063	1.156	0.992	1.347	15.60	-0.80	34.72	MA 21
Malaria	-0.203	0.0657	0.002	0.817	0.718	0.929	-18.37	-28.18	-7.13	

B=coefficient estimate; CI=Confidence interval; SE=Standard error; RR=Relative risk; C=Central; L=Lower; U=Upper; GEO=Geometric; MA=Moving average

Model adequacy tests

Model adequacy tests are performed related to goodness of fit, residual analysis, and multicollinearity. Goodness of fit is checked and assessed through Omnibus test and found to be good with *p* values nearly zero for all the fitted models. Residual analysis showed standardized Pearson residuals scattered randomly and with reasonably constant variances when plotted against predicted values. Screening of standardized residual plots in time sequence showed no visible pattern with fairly constant spread which is an indication of absence of high autocorrelations even though some significant autocorrelations (but not high and <0.3) were present at different lags which was ignored considering large sample size for analysis (1826 days). There is absence of high multicollinearity among predictors in the models with variance inflation factors (VIFs) smaller than 2.5 for 4 models and 1.5 for 2 models.

Table 2. NB model estimates of hospitalization coefficients related to confounding variables.

Parameter	B	SE	*P* Value	RR	95% CI for RR		Percent Change		
					Lower	Upper	C	L	U
Holiday									
Enteric fever	-0.42	0.076	<0.001	0.657	0.566	0.762	-34.30	-43.39	-23.74
Diarrhea	-0.143	0.0711	0.044	0.866	0.754	0.996	-13.32	-24.65	-0.40
Malaria	-0.437	0.1511	0.004	0.646	0.481	0.869	-35.40	-51.95	-13.15
Encephalitis	-0.337	0.1238	0.007	0.714	0.560	0.91	-28.61	-43.95	-8.97
Leishmaniasis	-1.8	0.2143	<0.001	0.165	0.109	0.252	-83.47	-89.14	-74.84
Trend									
Enteric fever	0.065	0.0182	<0.001	1.067	1.030	1.106	6.72	3.05	10.63
Dysentery	0.061	0.0261	0.021	1.062	1.009	1.118	6.29	0.90	11.85
Malaria	-0.247	0.0413	<0.001	0.781	0.720	0.847	-21.89	-27.96	-15.30
Encephalitis	-0.134	0.0407	0.001	0.874	0.807	0.947	-12.54	-19.27	-5.26
Leishmaniasis	-0.185	0.0297	<0.001	0.831	0.784	0.881	-16.89	-21.65	-11.93
Season									
Enteric fever									
Autumn	0.265	0.0673	<0.001	1.303	1.142	1.487	30.34	14.22	48.74
Diarrhea									
Summer	-0.281	0.1088	0.010	0.755	0.610	0.935	-24.50	-38.98	-6.57
Autumn	-0.558	0.1009	<0.001	0.572	0.470	0.697	-42.76	-53.05	-30.30
Dysentery									
Autumn	-0.266	0.0986	0.007	0.767	0.632	0.93	-23.36	-36.81	-6.95
Spring	0.249	0.1156	0.032	1.282	1.022	1.608	28.27	2.22	60.80
Malaria									
Summer	0.158	0.1447	0.276	1.171	0.882	1.555	17.12	-11.84	55.43
Encephalitis									
Spring	0.203	0.144	0.158	1.226	0.924	1.625	22.51	-7.60	62.58
Leishmaniasis									
Autumn	-0.261	0.1027	0.011	0.770	0.630	0.942	-22.97	-37.00	-5.82

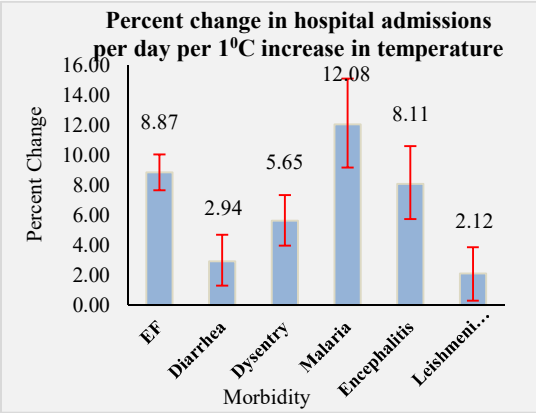

Fig.1. Effect of temperature.

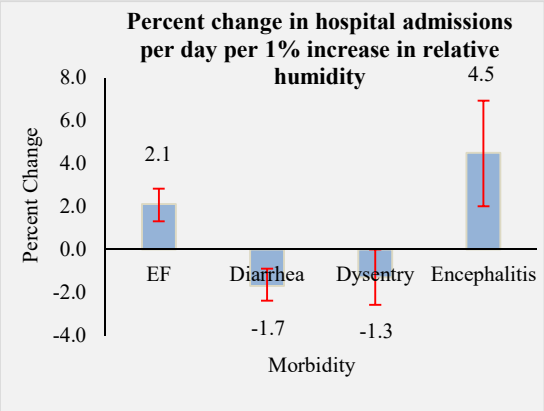

Fig.2. Effect of relative humidity.

DISCUSSION

Varying effects of climate sensitive variables and other variables including trend, seasonal and holiday effects are detected in explaining WB and VB diseases hospitalizations in Nepal. Among the meteorological variables, temperature seemed to be the most prominent predictor and showed consistent effects on the disease hospitalizations with all positive effects detected. Studies in other parts of the world also has found positive association of diarrheal hospitalization with ambient temperature such as in case of a study on Peruvian children conducted between 1993 to 1998 which found that 1^0C increase in average ambient temperature is associated with 8% rise in diarrheal diseases hospitalization (Checkley et al., 2000). Similarly, a study conducted in Pacific Islands found that 1^0C increase in average ambient temperature is associated with approximately 3% rise in reported diarrheal cases in which temperature was lagged by 1 month.

In the present analysis the effect size is found to be highest in case of malaria hospitalizations and lowest in leishmaniasis hospitalization. The remaining climate sensitive variables like rainfall, relative humidity and wind speed did not exhibit consistent effects in WB and VB disease hospitalizations and therefore warrants further studies/researches in this respect. However, moving average lag effects are found more suitable compared to other types of lag effects like geometrical or arithmetic decay lag effects when effects of other meteorological variables are estimated.

Examination of public holidays assessed by Saturdays is found to have significant effects on lowering the accounted hospitalizations compared to working days. This can be due to lowered risk of infection because of reduced exposures and staying in relatively safer environment. Considering annual trend effects on the hospitalizations whose causes are still unknown or unaccounted in the built models,

it is found that the annual trend is on the rise in case of WB diseases whereas decreasing in case of VB diseases. Seasonality is regarded as one of the most influencing factor in weather/climate and environmental health studies. Examination of this in the present analysis showed varied effects of different seasons on the accounted hospitalizations with summer, spring and autumn showing relatively higher malaria, encephalitis (and dysentery), and enteric fever hospitalizations, respectively. On the contrary, lowered hospitalizations of diarrhea, dysentery and leishmaniasis are detected due to seasonal effect of autumn.

CONCLUSION

Increase in average surface air temperature and consequently global warming is known to be the most significant characterization of climate change in the world over. In the context of gradual increase in average temperature of Nepal in the past decades, the findings indicate that public health burden related to WB and VB diseases that can be attributed to rise in temperature or global warming is likely to increase in the coming years. In order to counter the hazards of climate change in a broader perspective, Nepal needs to improve significantly on health facilities, cleanliness, poverty, widespread use of eco-friendly energy and technology as well as other factors that influence public health concerns in years to come through effective implementations of plans and policies particularly related to adaptation and vulnerability concerns. Specifically, some important steps are to minimize water logging to reduce mosquito breeding, widespread supply of safe drinking water to help restricting WB diseases, health education about the prevention of WB and VB diseases, etc.

CONFLICT OF INTEREST

The author declared that there is no conflict of interest.

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