Research

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Association Of Dengue Case Load And Environmental Factors In Four Potentially Disease Risk Areas Of Pakistan

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1. Abstract

Dengue is a crucial public health dilemma. Scarce water supply, population density, inadequate solid waste management, poor socio-economic level and climatic variations are recognized as key factors in *Aedes* breeding and later on in the transmission of Dengue Fever (DF). Dengue incidence (cases) is strongly associated with climatic tiers such as relative humidity, temperature and rainfall. Our findings on values of the bivariate correlation analysis have revealed positive correlation between rainfall and dengue incidences ($r = 0.75^{**}$, $r = 0.913^{**}$, $r = 0.948^{**}$, $r = 0.961^{**}$ $P<0.01$) as rainfall was the main cause of increase in number of cases in all districts. Moreover $r=0.613^*$ $P<0.05$, has depicted a moderate positive association between monthly average humidity and number of incidences, and $r=0.648^*$ $P<0.05$, suggested that there is a moderately positive relationship between monthly average temperature and number of incidences Moreover, high amount of monsoon rainfall 400.93mm in the year 2019 and post-monsoon seasons strongly contributed in the dengue virus outbreak.

2. Keywords:
Dengue Fever incidences1, Correlation coefficient2, Dengue Disease Reporting Portal of Punjab (DRPP).

3. Introduction

Vector-borne infections are considered as health threats for the public. About 30% of newly reported case load of contagious illnesses are considered to be caused by vector-borne infections(Brown *et al.,* 2014). Dengue fever is one of the most common vector-borne diseases in tropical and subtropical areas around the world(Atique *et al*., 2016). Sweating, high body temperature, vomiting, eye discomfort, chills, diarrhea, fatigue, muscle pain, skin rash, headaches, and abdominal pain are a few of the symptoms of dengue fever(Babu *et al.,* 2022). *Ae. albopictus and Ae. aegypti*, are major vectors of this disease, which are well-adapted to urban atmospheres. Around 2.5 billion people in the world are suffering as a result of this infectious disease in Dengue-prevalent areas(Akram *et al.,* 2022). Since 1970, there has been an increase in dengue cases that is now estimated to be around 390 million infections annually, with nearly 0.1 billion people showing clinical signs and symptoms. Recent calculations have shown increase up to three times relative to the previous World Health Organization (WHO) estimations(Bhatt *et al*., 2013). Dengue fever is the most common fever in Asia, with many outbreaks in Pakistan (Rasheed *et al*., 2013), Bangladesh, and India. The increased number of epidemics has serious consequences on public health(Ahmed et al., 2017). Dengue fever (DF) was first detected in Pakistan in the 1980s in Karachi. In 2011, Lahore, the capital city of the province of Punjab, faced its first major outbreak, with over 21,000 confirmed positive dengue cases and 279 deaths(Qureshi *et al*., 2017). Pakistan has faced a minimum of seven recorded epidemics in the last twenty years(Ahmad *et al*., 2014). Over the past 100 years, there has been noticeable global climate change. Future effects of global warming on the rapid spread of diseases transmitted by mosquitoes are currently unknown (Anoopkumar & Aneesh, 2022).

Environmental factors (temperature, precipitation and humidity), apart from globalization, virus mobility, vector population growth, also contribute to the spread of this lethal virus(Choi *et al*., 2016). Climatic changes have a great impact on reproduction of *Aedes* mosquito and ultimately in spread of dengue virus(Li *et al*., 2014). Precipitation and increasing temperatures are considered important supporters of major dengue outbursts in various areas of the world(Duarte *et al*., 2019). Approximately, 5-33 days is the incubation period of *Aedes* at 25 °C, however, it shrinks to a period of about 2-15 days at 34 °C. For disease transmission, the shortage of the incubation period (IP) is very crucial(Chan & Johansson, 2012). Numerous studies have found direct relationship between *Aedes* indices and climatic changes. (Naqvi *et al*., 2019; Qureshi *et al*., 2017; Sajjad *et al*., 2020), however, research on the statistical relationship between confirmed cases and environmental factors in four potentially risk areas of Pakistan has not yet been conducted. The association between environmental factors and confirmed cases of dengue can provide enough information to point out or predict the next disease risk area in future. The current study was designed to assess the association of climatic tiers and incidences (cases) confirmed dengue

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patients and to manifest comparison of positive cases in four metropolitan cities of Pakistan associated with environmental factors. In order to avoid any ambiguity and more accurate results, in this study data of confirmed dengue patients rather than larval or adult populations were used.

4. Methods:

4.1 Study areas:

The study was conducted on confirmed dengue cases of Faisalabad, Lahore, Islamabad, and Rawalpindi.

4.2 Climate:

The average annual rainfall in Faisalabad is approximately 615 mm (24.2 in). Rainfall is at its peak during the monsoon season, which lasts from July to September. Temperatures average 40.5 °C (104.9 °F) in June and 4.1 °C (39.4 °F) in January, whereas, annual average humidity is 68%(Cheema *et al*., 2006).Lahore's annual rainfall averages around 1000 mm. The monsoon season, which lasts from July to September, is the most humid and rainy, the annual average humidity is approximately 72%. Lahore's hottest month is June, and its coolest month is January whereas, annual average temperature ranges from 15°C to 40°C(Alam *et al*., 2012).Rawalpindi gets about 1200 mm of rain per year on average. The monsoon season, which lasts from July to September, is the most humid and rainy, with June being the hottest month of the year with temperatures reaching 38 °C (100.4 °F). August, July and September are the wettest, whereas, January is the coolest month, the average humidity level is about 78-80%(Sajjad *et al*., 2020). Islamabad has a humid subtropical climate with five distinct seasons: spring (March-April), winter (November-February), monsoon rainfall (July-August), summer (May-June), and autumn (September-October). June is the hottest month, with temperatures reaching up to 38 °C (100.4 °F), July is the wettest, and January is the coolest. The annual average humidity in Islamabad is around 78-80%, but temperatures range from 3.9 °C (25.0 °F) in January to 46.1 °C (115.0 °F) in June(Streimikiene *et al*., 2019).

4.3. Duration of study:

The duration of this study was 1 year. During this time, data from the Pakistan Meteorological Department (PMD) website and the published monthly weather report (National Weather Forecasting Center Islamabad) were retrieved monthly from 01-01-2019 to 30-12-2019, which included daily meteorological data on various environmental factors such as temperature, precipitation, and relative humidity. Similarly, dengue cases data was obtained from the Dengue Disease Reporting Portal (DDRP) operated by the Punjab Information Technology Board (PITB), Pakistan.

4.5. Statistical analysis:

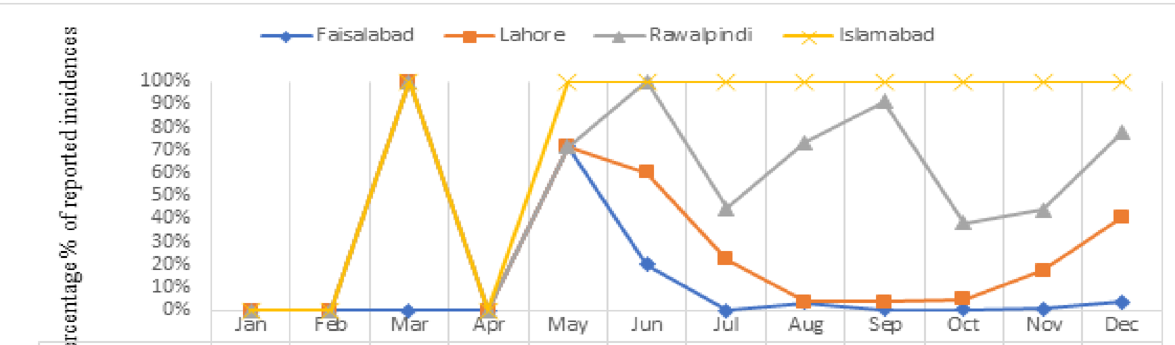
The entire data collected during this period was examined via IBM SPSS Statistics version 24.0 and Excel 2016 were used to analyze statistical parameters like Pearson bivariate correlation and partial correlation(Steel & Torrie, 1980).

5. Results:

The use of a statistical model in this study has revealed strong correlation between climatic conditions and incidences (cases) of dengue fever. This statistical analysis revealed new ways to investigate the relationship between climatic tiers and confirmed disease victims from Islamabad and other major cities in Punjab, including Faisalabad, Lahore, and Rawalpindi. A total of 18676 cases were reported from Punjab during the year 2019, from January 1st to December 31st. Out of the 8676 reported cases, 31 were reported in Faisalabad, 361 in Lahore, 2893 in Rawalpindi, and 4078 in Islamabad. The highest number of incidences (14) were reported in August 2019 from Faisalabad, 188 in October 2019 from Lahore, 1395 cases in the post-monsoon months from Rawalpindi, and 2571 in the post-monsoon months of 2019 from Islamabad. As shown in (Figure 1), Islamabad had the highest number of reported cases in 2019 when compared to other cities such as Rawalpindi, Lahore, and Faisalabad.

Figure Captions:

Figure 1: Number and Percentage comparison of reported cases (FSD, LHR, RWP, ISL) during the year 2019.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Islamabad	0	0	0	0	2	0	5	113	100	2571	377	6
Rawalpindi	0	0	0	0	0	2	2	293	1013	1395	178	10
Lahore	0	0	4	0	0	2	2	2	39	188	114	10
Faisalabad	0	0	0	0	5	1	0	14	2	6	3	1

Month wise number of reported cases of year 2019.

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The highest maximum temperature recorded in Faisalabad during the year 2019 was 40.7 °C in June. The lowest minimum temperature was 4°C in January. The maximum rainfall was 87.78 mm in August, and the highest percentage of humidity and number of cases were also recorded in August (78% and 14, respectively). The highest number of reported cases in Lahore were 188, and the highest average monthly rainfall was 400.93mm in October 2019 and the highest average monthly humidity was 78% in December 2019. In Rawalpindi, the highest number of cases (1,395) and the highest average rainfall (400.93mm) were both recorded in October 2019. In Islamabad, the highest number of cases (2571) were reported in October 2019, as well as the highest average rainfall (494.51mm) (Table no. 1).

Table 1: Monthly reported incidences and average climatic factors (temperature, rainfall, and humidity) of Faisalabad, Lahore, Rawalpindi, and Islamabad.

Variables		**Faisalabad**											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall		14.64	15.6	33.23	37.83	69.03	55.01	29.62	87.73	17.7	44.43	5.41	4.02
Temperature	Max.	19.4	22.4	27.6	33.8	38.9	40.7	37.3	36.3	36	33.6	27.4	21.8
	Min.	4.4	7.4	12.6	18.1	23.3	27.4	27.3	26.9	24.2	17.6	10.4	5.7
	Avg.	11.9	14.9	20.1	25.95	31.1	34.05	32.3	31.6	30.1	25.6	18.9	13.75
Humidity		60	60	55	47	40	42	74	78	71	67	67	65
Reported cases		0	0	0	0	5	1	0	14	2	6	2	1
Variables		**Lahore**											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall		32.63	12.85	83.75	54.53	23.1	27.63	28.54	13.71	110.56	400.93	106.15	3.82
Temperature	Max.	19.8	22	27.1	33.9	38.6	40.4	36.1	35	35	32.9	27.4	21.6
	Min.	5.9	8.9	14	19.6	23.7	27.4	26.9	26.4	24.2	18.2	11.6	6.8
	Avg.	12.85	15.45	20.55	26.75	31.15	33.9	31.5	30.7	29.6	25.55	19.5	14.2
Humidity		70	71	61	48	39	41	68	71	68	62	65	78
Reported cases		0	0	4	0	0	2	2	2	39	188	114	10
Variables		**Rawalpindi**											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall		23	56	16	44	38	37	65.8	100.47	237	209	68	36
Temperature	Max.	17	19.5	24.2	29.9	35.4	39.5	35.8	33.7	33.6	30.9	25	19.3
	Min.	2.7	5.5	10.4	15.3	19.9	24.5	24.8	23.6	21.6	14.5	7.5	3.3
	Avg.	17	19.5	24.2	29.9	35.4	39.5	35.8	33.7	33.6	30.9	25	19.3
Humidity		63	57	47	47	49	52	68	72	75	67	59	49
Reported cases		0	0	0	0	0	2	2	293	1013	1395	178	10
Variables		**Islamabad**											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall		136	113.44	89.8	52	87	31.03	42.51	97.63	252.44	494.51	91.78	16.08
Temperature	Max.	17.7	19.1	23.9	30.1	35.3	38.7	35	33.4	33.5	30.9	25.4	19.7
	Min.	2.6	5.1	9.9	15	19.7	23.7	24.3	23.5	26.6	13.9	7.5	3.4
	Avg.	10.15	12.1	16.9	22.5	25.57	26.8	29.65	30.6	32.89	33.43	27.9	11.55
Humidity		63	57	47	47	49	52	68	72	75	67	59	49
Reported cases		0	0	0	0	2	0	5	113	1000	2571	377	6

5.1. Correlation amongst climatic tiers and number of reported incidences

The value of the bivariate correlation analysis indicates how strongly two variables are related. For Rawalpindi, (r=0.948** P< 0.01)), depicted a strong positive association between monthly average rainfall and number of incidences, (r=0.613* P<0.05), depicted a moderate positive association between monthly average humidity and number of incidences, and (r=0.648* P<0.05), suggested that there is a moderately positive relationship between monthly average temperature and number of incidences (Table no. 2). For Lahore in 2019, (r = 0.913** P<0.01) showed a positive relationship between monthly average rainfall and the number of incidences (Table no. 2). For Islamabad, (r=0.961** P<0.01) showed a strong positive relationship between monthly average rainfall and total number of reported incidences, while (r = 0.683* P<0.05) showed a moderate positive relationship between monthly average humidity and number of incidences (Table no. 2). For Faisalabad, there was a moderately positive relationship between monthly average temperature and incidences (r=0.578* P<0.05) and a positive relationship between monthly average rainfall and incidences (r=0.75** P<0.01) (Table no. 2). In comparison to other factors like temperature and humidity, average rainfall and the number of reported cases showed the highest correlation in all four cities (FSD, LHR, RWP, and ISL) (r=0.75**, r=0.913**, r=0.948**, and r=0.961** P<0.01) respectively. In Rawalpindi and Islamabad (r=0.948** and r=0.961** P<0.01), which had the highest rainfall in comparison to other cities in 2019, more rain resulted in more mosquito breeding and emergence sites, causing an epidemic of this disease in both twin cities (Table no. 2).

Table 2: Temperature, precipitation, and humidity correlation with cases in four major cities (FSD, LHR, RWP, and ISL) for the year 2019.

Variables		FSD	LHR	RWP	ISL
Rainfall	Correlation (r)	0.75**	0.913**	0.948**	0.961**
	% Correlation	56.25	83.35	89.87	92.35
Average temperature	Correlation (r)	0.578*	0.276	0.648*	0.531
	% Correlation	33.4	7.6	41.99	28.1
Humidity	Correlation (r)	0.360	0.204	0.613*	0.683*
	% Correlation	12.96	4.1	37.57	46.64

5.2. Analysis of partial correlation amongst climatic tiers and number of reported incidences

In partial correlation, the strength of an association between two variables is measured while maintaining the effect of one or more variables constant. While keeping the effect of one of the climatic factors, either rainfall, temperature, or humidity, constant for all four cities, the strength of an association between the other two climatic factors was measured using partial correlation.

5.3. Effect of average rainfall, while maintaining temperature as the constant variable, on the overall number of reported cases

Zero-order correlations between incidences and average rainfall had values of r=0.745, r=0.913, r=0.948, and r=0.961; however, when temperature was held constant, the correlation values for FSD, LHR, RWP, and ISL became $r_{12.3}$=0.576, $r_{12.3}$=0.914, $r_{12.3}$=0.913, and $r_{12.3}$=0.959, respectively. The temperature has little effect on the number of incidences and average rainfall in Lahore, Rawalpindi, and Islamabad, as a negligible difference in values was observed when temperatures were kept constant. Temperature, on the other hand, plays an important role in FSD; by maintaining a constant temperature, the positive correlation between rainfall and the number of incidences decreases. The average temperature in Faisalabad increases *Aedes* mosquito survival. *As a result, the number of incidences decreases while the temperature remains constant* (table no. 3).

Table 3: Partial correlation analysis of climatic tiers (temperature, rainfall, humidity) and number of reported incidences.

Constant variables	Partial correlation analysis		Cities			
			FSD	LHR	RWP	ISL
Temperature	Zero order (ZO)	R	0.745	0.913	0.948	0.961
	Rainfall and incidences (RI)	$r_{12.3}$	0.576	0.914	0.913	0.959
	Zero order (ZO)	R	0.360	0.204	0.613	0.683
	Humidity and incidences (HI)	$r_{12.3}$	0.417	0.403	0.357	0.604

Rainfall	Zero order (ZO)	R	0.578	0.276	0.648	0.531
	Temperature and incidences (TI)	$r_{12.3}$	0.040	-0.287	-0.19	0.500
	Zero order (ZO)	R	0.360	0.204	0.613	0.683
	Humidity and incidences (HI)	$r_{12.3}$	0.768	0.255	-0.380	0.722
Humidity	Zero order (ZO)	R	0.578	0.276	0.648	0.531
	Temperature and incidences (TI)	$r_{12.3}$	0.606	0.439	0.186	0.378
	Zero order (ZO)	R	0.745	0.913	0.948	0.961
	Rainfall and incidences (RI)	$r_{12.3}$	0.889	0.916	0.926	0.926

5.4. Effect of average humidity, while maintaining temperature as the constant variable, on the overall number of reported cases

The zero-order correlation between incidences and average humidity was r=0.360, r=0.204, r=0.613, and r=0.683, respectively; however, when temperature was held constant, the correlation became $r_{12.3}$=0.41, $r_{12.3}$=0.403, $r_{12.3}$=0.357, and $r_{12.3}$=0.604 for FSD, LHR, RWP, and ISL respectively. Keeping the temperature constant causes a slight increase in the number of incidences for FSD and LHR, while keeping the temperature constant causes a decrease in the number of incidences for RWP, but the temperature has no effect on the relationship between humidity and the number of reported incidences for ISL. In other words, the combination of suitable temperature and humidity acts as a booster for mosquito development and growth, eventually leading to a higher number of incidences (table no. 3).

5.5. Effect of average temperature, with humidity as a constant variable, on the total number of reported cases

The zero-order correlation between incidences and average temperature was r=0.578, r=0.270, r=0.648, and r=0.531, respectively; however, when humidity was held constant, the correlation became $r_{12.3}$=0.606, $r_{12.3}$=0.43, $r_{12.3}$=0.186, and $r_{12.3}$=0.378 for FSD, LHR, RWP, and ISL. Keeping humidity constant resulted in a slight increase in the positive relationship between average temperature and number of incidences for FSD and LHR, a slight decrease in the association of temperature and incidences for ISL, and a significant decrease in the association of incidences and temperature for RWP, from r=0.648 to $r_{12.3}$=0.186. Thus, for RWP, the combination of suitable temperature and humidity acts as a booster for mosquito development and growth, eventually leading to a higher number of incidences (cases) in 2019 (table no. 3).

5.6. Effect of average rainfall on the total number of reported cases when humidity is held constant

The zero-order correlation between number of incidences and average rainfall was r=0.745, r=0.913, r=0.948, and r=0.961, but when humidity was held constant, the correlation became $r_{12.3}$=0.889, $r_{12.3}$=0.916, $r_{12.3}$=0.926, and $r_{12.3}$=0.926 for FSD, LHR, RWP, and ISL, respectively. The results showed that during the year 2019, humidity alone had no significant effect on the number of incidences and average rainfall, as very few cases were observed during the winter months. In other words, the optimal humidity of 75%, the ideal temperature, and rainfall together act as an amplifier for mosquito growth, development, and transmission, ultimately leading to a higher number of incidents (table no. 3).

5.7. Effect of average temperature on the number of incidences when rainfall is held constant

The zero-order correlation between the number of incidences and the average temperature was r=0.578, r=0.276, r=0.648, and r=0.531, respectively. By controlling for rainfall, the value of correlation became r12.3=0.040, $r_{12.3}$= -0.287, $r_{12.3}$= -0.19, and $r_{12.3}$=0.500 for FSD, LHR, RWP, and ISL, respectively. Rainfall has a remarkable effect on the number of incidences and average temperature for FSD; by maintaining constant rainfall, the positive relationship between average temperature and the number of incidences is greatly reduced. For LHR and RWP, the weakly positive relationship between average temperature and the number of incidences changed to a moderately negative relationship when rainfall remained constant. In other words, the lack of precipitation does not create the ideal environment for mosquitoes to survive and grow. As a result, there is a decline in the number of cases (table no. 3).

5.8. Effect of average humidity on total number of reported incidences by keeping rainfall constant

The zero-order correlation between the number of incidences and the average humidity was r=0.360, r=0.204, r=0.613, and r=0.683, but by controlling for rainfall, the correlation became $r_{12.3}$=0.768, $r_{12.3}$=0.255, $r_{12.3}$= -0.380, and $r_{12.3}$= 0.722 for FSD, LHR, RWP, and ISL, respectively.

Rainfall has a significant impact on the number of incidences and average humidity in Faisalabad, as maintaining constant rainfall increases the positive relationship between average humidity and number of incidences. Keeping rainfall constant had no effect on the association between humidity and total number of reported incidences for LHR and ISL. For RWP, the correlation between humidity and total number of reported cases was r=0.613; by controlling for rainfall, the correlation became $r_{12.3}$= - 0.380. It means that rainfall has a significant impact on the number of incidences and average humidity, as the positive relationship between average humidity and number of incidences decreases when rainfall is constant. As a result, for RWP, the combination of 75% humidity and rainfall acts as an amplifier for mosquito growth, development, and transmission, eventually leading to a higher number of reported incidences (table no. 3).

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6. Discussion

We have used various statistical approaches to find out the relationship between dengue fever incidences and climatic factors. According to the findings of this study, meteorological variables have a significant impact on dengue fever (DF) incidences. This study clearly shows that rainfall has a significant impact on dengue fever incidences in Faisalabad, Lahore, Islamabad, and Rawalpindi; these findings are consistent with other similar studies conducted in Pakistan. (Khalid *et al*., 2021). As the rainfall increases, so does the potential for dengue fever transmission; this finding was consistent with a few previous ones (Islam *et al*., 2018). The monsoon and post-monsoon seasons offer the ideal temperature, precipitation, and humidity for the growth and reproduction of *Aedes* species, which act as an accelerant in the transmission of dengue fever incidences. According to similar findings from other studies (Attaullah *et al*., 2015; Karim *et al*., 2012), rainfall and humidity were significant factors in the spread of dengue fever incidences. *Aedes aegypti* prefers a temperature range of 25 to 35°C (Huxley *et al*., 2022) for development, although they grow most quickly at 27°C (Rowley & Graham, 1968). Rainfall combined with humidity around 75% promotes the growth of dengue mosquitoes as well as dengue outbreaks (Ehelepola *et al*., 2015), the results of this study, however, were in contrast to those of the Jeddah research (Al-Nefaie *et al*., 2022), it is possible that rain caused the breeding areas to be washed away in Jeddah.

Previous research on Lahore, Rawalpindi (Khalid & Ghaffar, 2015a), Faisalabad, and Islamabad (Ahmed & Siddiqui, 2014) found that other two factors (temperature and humidity) other than rainfall also served as key stimulators for the spread of dengue fever (Alshehri & Saeed, 2013; Atique *et al*., 2016; Naqvi *et al*., 2019). In this study, temperature plays no significant role in the increase in the number of reported cases of Lahore and Islamabad. The results of this study were startlingly similar to those of earlier studies (Bisht *et a*l., 2019; Carneiro *et al*., 2017). More incidents were reported in August, September, and even in the post-monsoon month (October), but similar outcomes were already evident in earlier studies (Khalid & Ghaffar, 2015b). The results of this study, however, were at odds with those of previous studies (Campbell *et al*., 2013) that made it abundantly clear that increased rainfall, temperature (Kesetyaningsih *et al*., 2018), and humidity might not always be the cause of an increase in dengue virus transmission. In light of the findings above, dengue cases peak in all four cities of Pakistan during the monsoon and post-monsoon seasons (Aug-Oct). Future outbreaks of the deadly disease in Pakistan could be avoided by taking immediate action to combat the dengue vector and eliminate its breeding grounds during the rainy season, thereby reducing the number of reported cases.

7. Conclusion

Climate factors, especially precipitation and humidity, have a significant impact on dengue cases and the vector. The results showed that the increase in the number of reported cases in all four cities (FSD, LHR, RWP, and ISL) is primarily caused by rainfall, humidity, and temperature. The major dengue virus outbreak in Rawalpindi (2019) was undoubtedly caused by the greater amount of monsoon rainfall that year. Dengue outbreaks are most common in the post-monsoon season each year, giving the Pakistan Dengue Prevention and Control Programme an excellent opportunity to implement vector control and source reduction measures. This gap in the surge of cases provides an excellent chance and sufficient time to mobilize resources for the application of affective actions to reduce the consequences of the outbreak. The creation of a climate-based dengue prediction model is urgently required as it will help to reduce epidemic size, which will stop the spread of the illness and the associated mortality. It is crucial to improve vector surveillance systems in densely populated countries such as Pakistan. To interpret recent climate-health relationships and predict future scenarios, new research should focus on gathering long-term and extremely high-quality weather-based health-related data.

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