GSJ: Volume 11, Issue 10, October 2023
ISSN 2320-9186

Global Scientific JOURNALS
GSJ: Volume 11, Issue 10, October 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

The effect of seasonal variation on the occurrence rates of Dengue Fever transmission in Fiji between 2016-2019

Shafraaz Khan

Dengue fever is a prominent health issue throughout the globe with WHO estimations of 3.9 billion people residing in dengue fever endemic areas, the threat of major outbreaks remains imminent. With Fiji having major outbreaks in the past and increasing evidence of positive association between dengue fever and weather patterns, this study looked at the prevalence of dengue fever in Fiji and the effects of weather variables on its occurrence. Throughout the study period of 2016-2019 a total of 19832 dengue fever cases were found with the highest prevalence of 56.9% of cases being female (95% CI (9128.5 ± 13.3) P-value= 0.001). Most dengue fever cases were found in 2018 with 9178 cases and the least cases were found in 2016 with 508 cases (95% CI 4358 ± 44.5), P-value= 0.01). The age range of 21-30 showed the highest prevalence of cases at 25.4% with the lowest of 8.2% seen in patients above 61 years of age (P-value= 0.01). Using Spearman's rank correlation coefficient minimum temperature (°C) showed the strongest association with dengue fever occurrence at a 1-month (P-value < 0.01) lag period while average rainfall (mm) had the weakest association (P-value=0.01). All weather variables (rainfall mm, minimum and maximum temperature °C) showed a positive association with the occurrence of dengue fever (P-value < 0.05) with rainfall showing no association in 2016. The results of this research suggest a strong positive correlation between dengue fever and weather variables however, further studies are required to prove causation.

Index Terms—**About four key words or phrases in alphabetical order, separated by commas.**

I. Introduction

Dengue Fever is a mosquito-borne aliment which is mainly caused by Aedes aegypti and in lesser quantities Ae. albopictus (Cogan, 2020). Dengue Fever incidence has greatly increased over the past 10 years, putting about half the world's population at risk (Cogan, 2020). According to WHO estimations 3.9 billion people reside in Dengue Fever endemic areas where 96 million are reported to be infected by dengue fever (Cogan, 2020). Dengue fever has as of yet no promising cure (Achee et al., 2015), however consistent progress is being made in terms of development of a vaccine (Da Silveira et al., 2019), (Lyons, 2014). Changes in normal weather patterns have greatly benefitted disease vectors in increasing their range of transmission, this is mainly due to the optimal temperature for infections for most vector species residing in the peaks of higher temperature (Caminade et al., 2019). In this study the prevalence of Dengue fever and the seasonal variations will be focused. Mainly focusing on the occurrence rates of dengue fever in conjunction to the weather pattern in Fiji from January 1st 2016- December 31st 2019. Dengue fever is one of the Pacific's most frequently occurring diseases with a major outbreak recorded in Fiji in 2013 which ran through to 2014 affecting about 15000 people (Getahun, et al., 2014) which led to the highest death toll due to dengue fever in the country. Dengue fever outbreaks are seen to occur in a cyclic 4-5 year-round season (Getahun, et al., 2014), with the last major outbreak in the years 2013-2014 a new dengue fever outbreak may just be beyond the horizon. The previous outbreak in Fiji showed a record number of deaths the public and health officials alike are well versed with the tremendous impact dengue fever can have within the nation and these effects may be linked to seasonal variations. As studies imply there will be more adverse weather conditions in the future (Perkins et al., 2018), dengue fever may grow to be a more prominent national health concern. Dengue Fever has spread to about 100 countries, where Asia shows the highest global burden of 70% (Cogan, 2020). In Fiji the Ministry of Health (MOH) reports a total of 15000 confirmed cases of Dengue Fever in the 2013-2014 outbreak while further classifying the months November to April as high risk for Dengue Fever transmission compared to a lower risk in the remaining months. However, there are limited published data on dengue fever in Fiji and none highlight how seasonal weather patterns may affect the prevalence and the transmission rates of dengue fever. A study on how seasonal variations affects dengue fever transmission will lead to a better understanding of transmission rates. Furthermore, aiding in the development of better policies and public education on dengue fever in Fiji. The range of dengue fever cases continues to increase due to the wide spread prevalence of Aedes species of mosquitoes which is due to the changes in the weather patterns (Khan et al., 2019). Fiji continues to experience adverse weather conditions on a yearly basis thus findings from this study can aid in the development of specific policies to combat disease vectors after certain weather patterns. This study also paves opportunities for future studies, covering the impact of climate change effects on disease and disease vectors over a significant period of time to provide a better understanding of specific policies to combat disease vectors after certain weather patterns. This will also allow for more effective commitment of resources towards prevention of dengue fever at specific times for more effective results.

II. Method

A cross-sectional study style was used for this study. Dengue fever patient data was collected from the Colonial War Memorial hospital (CWM) registers to determine the prevalence of dengue fever in Fiji from 2016-2019. Both age and gender were considered in this study.
Data collected from the Fiji Meteorological Office (FMO) on temperature and rainfall were compared against data of

dengue fever patients collected from CWM hospital in Fiji from 2016-2019 using the Spearman's Rank Correlation Coefficient method.

The study was conducted on Fijian citizens who were laboratory confirmed dengue fever patients during the study period. All records of laboratory confirmed cases of dengue fever from the years 2016-2019 obtained from the CWM records was used in this study. The study contains patients from Labasa (Northern division), Nadi and Lautoka (Western division) and Suva (Central division) all of which were found in CWM dengue fever records. The study does not contain any patients from the Eastern division. The population within the study is referred to as Fiji for the purpose of simplicity and due to most of the major centers within the country being covered. However, the use of Fiji within the study does not imply to every dengue fever case within the country during the study period. Since the patients records from CWM hospital were only accessible due to Covid-19 restriction, it is possible a number of positive cases were overlooked and not included in the data.

A retrospective data collection was done from 2016-2019. All data was collected from the CWM dengue fever records. Data on seasonal weather patterns were collected from the FMO spanning from 2016-2019. A p-value of less than or equal to 0.05 was taken as significant.

Both genders and all age groups were included in this study. The different weather patterns namely the minimum and maximum temperature (°C) and rainfall (mm) were considered in this study.

Furthermore, for analysis in the Spearman's correlation method, positive dengue fever cases were defined as either IgM positive and or dengue antigen (NS1) positive. This was done to ensure accuracy of the results obtained within the study. The Spearman's Rank Correlation Coefficient analysis done in this study correlates the two different data sets (of dengue fever and weather variables) on a month-by-month basis. Considering the longer detectable presence of IgG antibodies within dengue fever patients, there was no way to confirm the exact initial time of infection would fall within the range of the months under study including lag periods (1 and 2 months). The NS1 antigen remains detectable in a patient for about 2-5 days while the IgM antibody remains detectable for around 14 days. The presence of IgG and IgM antibody in a patient indicates a recent infection of the patient (within 2-3 weeks) or a recent reinfection of the same patient (Costa et al., 2012). These time periods ensured that a proper correlation between dengue fever patients and the weather variables could be done using the Spearman's correlation coefficient.

Fig 1.0 Duration of the presence of antibodies in a dengue fever patient. Blacksell, S. D. (2012). Commercial dengue rapid diagnostic tests for point-of-care application: Recent evaluations and future needs? In Journal of Biomedicine and Biotechnology(Vol.2012).

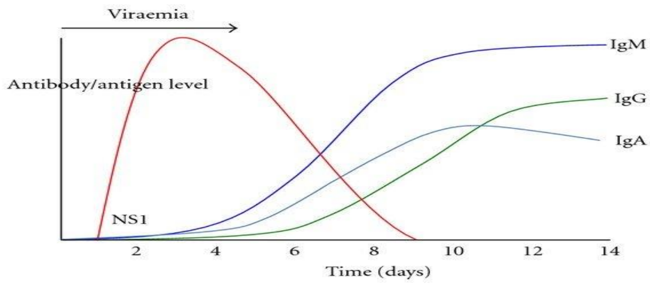

Fig 1.0 Duration of the presence of antibodies in a dengue fever patient. Blacksell, S. D. (2012). Commercial dengue rapid diagnostic tests for point-of-care application: Recent evaluations and future needs? In Journal of Biomedicine and Biotechnology (Vol.2012).

The data of the laboratory confirmed cases of Dengue fever was analyzed. The major geographical locations from which patients are from was noted. This data was then plotted against the different weather patterns observed in these locations, mainly average temperature and rainfall.

The Spearman's rank correlation coefficient method was used to evaluate the data in this study. Spearman's rank correlation coefficient is a non- parametric measure of correlation between two data points of different variables (Chantziaras et al., 2014). Due to its non-parametric approach, it is much more suited to provide significant correlation between non-linear data sets such as weather and dengue fever as shown by a variety of studies (Ogashawara et al., 2019; Yue et al., 2018; Polwiang, 2016; Restrepo et al., 2014). The Spearman's rank correlation coefficient is presented as -1, 0 or 1. A -1 or negative number less than -1 indicates a negative association between variables, 0 indicates no association and 1 or positive numbers less than 1 indicates a strong correlation between variables (Sedgwick, 2014). The closer the acquired number is to -1, 0 or 1 indicates the strength of this association such as 0.8 being a very strong positive association and 0.2 being a weaker positive association. This was then used to determine if the changes in such weather conditions on different geographical locations have any effect of the occurrence rates of dengue fever by measuring the correlation coefficient between dengue fever cases and weather experienced on a month my month basis. A lag period of 0-2 months was introduced into the study to get significant data based on the vector lifecycle and other relevant studies (Colón-González et al., 2013; Ganeshkumar et al., 2018; Liu-Helmersson et al., 2014).

The soft copy of the data was analyzed with excel spreadsheets. All tables, figures and graphs were extracted from this spreadsheet. All confidence intervals and p-values and correlations were calculated from the excel 2016 spread sheet. A p-value of <0.05 is considered significant

III. Results

There was a total of 19832 dengue fever cases in Fiji from 2016-2019. Figure 2.0 shows the total number of positive dengue fever cases in Fiji throughout the different years of study. The highest number of dengue fever cases were recorded in 2018 with 9178 positive cases of dengue fever while the lowest number of cases within the study period was recorded in the year 2016 with a total of 508 cases (95% CI 4358 ± 44.5), P-value= 0.01).

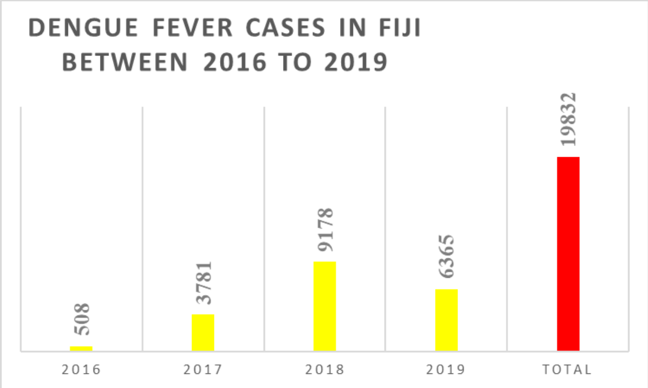

Fig 2.0 The total number of dengue fever cases recorded in Fiji from 2016 to 2019. 95% CI 4358 ± 44.5), P-value= 0.01

In contrast to the number of cases recorded per year, Figure 3.0 shows the total amount of tests done for dengue fever in the corresponding years. The number of dengue fever tests done in the respective years greatly affect the positive cases recorded for the year.

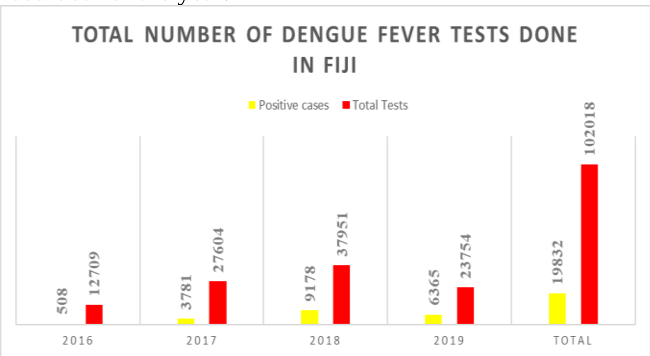

Fig 3.0 Total number of dengue fever tests done in Fiji in conjunction to the positive cases identified.

The highest percentage of 25.39% of all dengue fever patients in Fiji were in the 21 to 30-year-old age range, while the lowest percentage of 8.23% of dengue fever cases were from the age of 61 years and above (p-value= 0.01). Figure 4.0 shows the total number of dengue fever cases in Fiji based on the different age groups and their test center. All centers show the highest percentage from the same age groups except for Lautoka and Nadi centers (LTK and Nadi) which showed the highest percentage of patients at the 31- 40-year-old range (Table 1.0)

Age groups	Fiji	% Totals	Suva	% Totals	LTK and Nadi	% Totals	LAB	% Totals
0-10	1678	9.24%	1195	12.42%	300	8.98%	184	3.98%
11--20	2746	15.12%	1674	17.40%	501	15.00%	573	12.41%
21-30	4612	25.39%	2895	30.10%	730	21.86%	989	21.41%
31-40	2935	16.16%	1586	16.49%	930	27.84%	822	17.80%
41-50	1946	10.71%	920	9.56%	319	9.55%	710	15.37%
51-60	1748	9.62%	739	7.68%	289	8.65%	723	15.65%
61+	1496	8.23%	610	6.34%	271	8.11%	618	13.38%

Table 1.0 Total amount of dengue fever patients in Fiji defined by age, P-value= 0.01

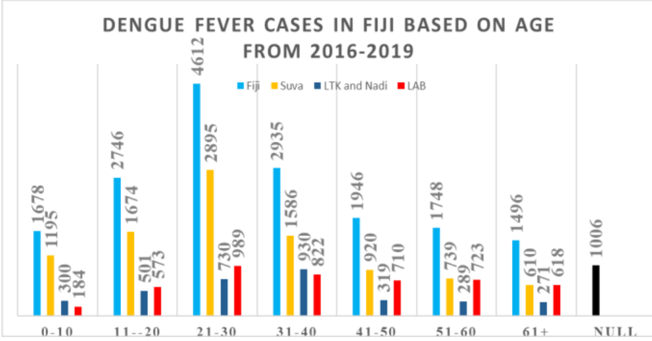

Fig 4.0 Total number of dengue fever patients in Fiji, P-value= 0.01

In the gender demographic, females account for over 50% of all dengue fever cases in the study population. Females account for 54.77% of all cases and are the dominant demographic in terms of dengue fever infection in all centers within the study population (95% CI (9128.5 ± 13.3) P-value= 0.001). Figure 5.0 shows the number of dengue fever from each center based on gender.

Gender	Suva	% Totals	LTK and Nadi	% Totals	LAB	% Totals	Fiji
Male	4587	43.01%	1460	48.44%	2248	48.23%	8295
Female	6079	56.99%	1554	51.56%	2413	51.77%	10047

Table 2.0 Total percentage of male to female dengue fever cases in Fiji. 95% CI (9128.5 ± 13.3) P-value= 0.001

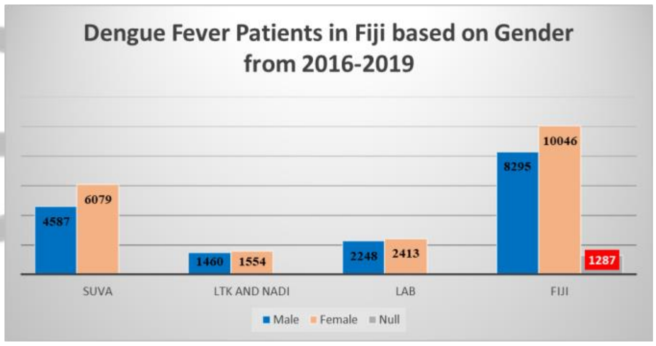

Fig 5.0 Total number of males to female dengue fever cases in Fiji. 95% CI (9128.5 ± 13.3) P-value= 0.001

Table 3.0 shows the Spearman's correlation coefficient for the different weather variables. Correlation coefficient of minimum temperature for the year 2016 could not be calculated due to missing weather data. In 2016 the rainfall weather variable at all lag periods and the maximum temperature weather variable at no lag period had P-values of more than 0.05. Thus, the null hypothesis was accepted whereby there was no association between rainfall and dengue fever cases and no association between maximum temperature and dengue fever at no lag periods.

	Min Temperature	Max Temperature	Rainfall
2016			
No lag Period	Null	No Association	No Association
1-month lag	Null	0.41’	No Association
2-month lag	Null	0.58’	No Association
2017			
No lag Period	0.57’	0.39’	0.56’
1-month lag	0.7’	0.61’	0.73’
2-month lag	0.53’	0.54’	0.49’
2018			
No lag Period	0.64’	0.69’	0.56’
1-month lag	0.82’’	0.86’’	0.73’
2-month lag	0.71’	0.78’’	0.49’’

Table 3.0 Spearman’s rank correlation coefficient between dengue fever and the different weather variables from 2016-2018. P ‘< 0.05, P’’ < 0.001

A positive association was seen at 1 and 2-month lag periods with maximum temperature with max temperature showing a higher association at a 2- month lag period for the year 2016. (Figure 6.0)

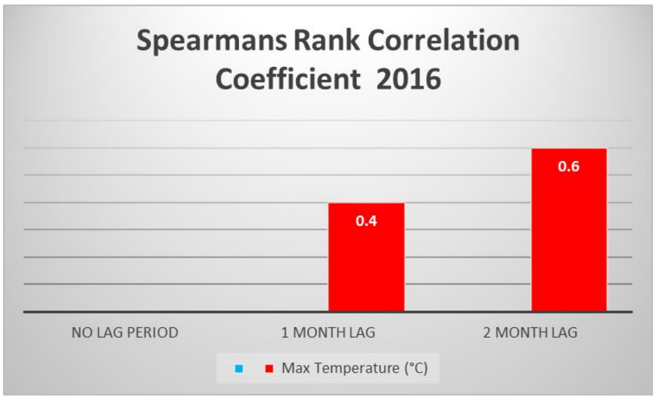

Fig 6.0 Spearman’s correlation for 2016

Spearman’s correlation for 2017 showed strong positive associations throughout all weather variables. The strongest correlation was seen with minimum temperature at a 1-month lag period while the weakest association was seen with rainfall at no lag period

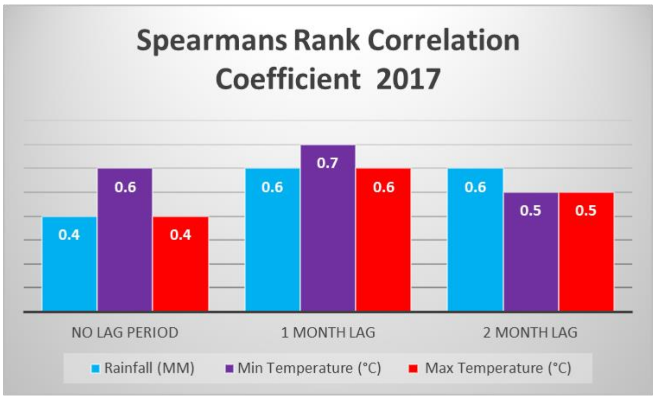

Fig 7.0 Spearman’s correlation for 2017

Spearman’s correlation for 2018 also showed very strong positive association throughout all weather variables. The strongest association was seen with maximum temperature at a 1-month lag period.

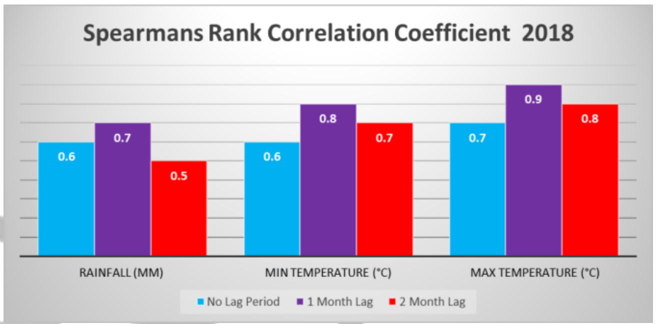

Fig 8.0 Spearman’s correlation for 2018

Overall, a strong positive correlation was seen. In 2016 the null hypothesis was accepted for rainfall at all lag periods and maximum temperature at no lag periods. A lag period of 1 month showed the highest association to dengue fever cases within the study population. Minimum temperature was the strongest weather variable with association to the occurrence rates of dengue fever. Rainfall showed the weakest association to the occurrence rates of dengue fever. None of the weather variables showed a negative effect on the occurrence rates of dengue fever using the Spearman’s rank correlation coefficient

IV. Discussion

Through multiple studies across the world, it is widely considered that there exists a positive correlation between weather and vector borne diseases, the findings from this study does not deviate from this. The findings from this study suggest a strong positive correlation between weather variables and dengue fever. With a total of 19832 positive dengue fever cases in Fiji throughout the study period dengue is a significant health problem within Fiji and may continue to worsen with time

Dengue fever is a prominent medical concern within Fiji. With 19832 cases within the study period, it continues to be a major concern for the Fijian health sector. The lowest number of dengue fever cases were recorded in 2016 however, the number of cases may also be directly connected to the number of tests done in the corresponding years. The year 2016 had recorded the lowest amount of dengue fever tests done in Fiji. With a little over 12000 dengue fever tests done in 2016, this number is relatively small to well over 30000 tests done the following year.

Dengue fever cases continuously rose during the study period with a slight drop in cases in 2019. The findings of this study coincide with the high-risk months established by the Ministry of Health which is from November to April. A majority of the dengue fever casers for the years under study occurred during these high-risk months. The continuous rise may be accredited to the population demographic as well as weather variables. Another often underestimated factor contributing to an increased dengue fever cases are agricultural endeavors. Fiji as a country continues to invest in its agricultural sector in a bid to reduce importation fees and increase the countries income. The agricultural sector holds great promise for Fiji in terms of creating a strong international market and sustainable jobs opportunities for the locals. However, agricultural construction and irrigation processes provides greater breeding opportunities for disease vectors which may lead to an increase in cases. With studies suggesting temperature of water and the surrounding environment affecting mosquito growth rate (Yue et al., 2018), Fiji's agricultural sector may be the hidden breeding grounds for these vectors borne diseases.

Dengue in Fiji shows the highest prevalence of cases in the 21-30 year old range. This is consistent with previous studies done in Fiji (Getahun et al., 2019) as well as other studies conducted outside of Fiji (Signor et al., 2020). Some studies also found a greater prevalence in age group 5-14 years and noted a progressive increase in older brackets (Phanitchat et al., 2019). Many dengue cases are associated with young adults, this is also consistent with the current population demographic in Fiji. Females accounted for over 50% of all cases within the study population and was consistently the larger demographic affected throughout all the centers under this study. Similar studies found a higher prevalence in males to females (Eldigail et al., 2018) when it comes to dengue fever however, difference in these findings may be associated with the present demographic, normal gender roles in different cultures and traditions.

Using Spearman's Rank Correlation Coefficient all weather variables showed strong positive association with dengue fever. No negative association was found within this study. Minimum temperature showed the overall strongest correlation with dengue fever however, maximum temperature showed a higher correlation in 2018. Minimum temperature findings are consistent with multiple studies (Ehelepola et al., 2015, Hii et al., 2012, Chumpu et al., 2019). Maximum temperature is usually associated with a lower correlation with dengue fever but a higher correlation was seen in this study for 2018. Rainfall showed the weakest positive correlation with dengue fever. This is consistent with other studies of the same type (Caminade et al., 2019). Certain studies have also found a negative association with rainfall but this was not consistent with this study's findings. The effect of rainfall has always been questionable with dengue incidence as it can be associated with producing breeding grounds as well as destroying them. Certain studies suggest that a lower intensity and more consistent rainfall may be more positively associated with dengue fever than heavy rainfall (Tokash-Peters et al., 2019).

Furthermore, of the 3 lag periods introduced in the study a lag period of 1 month showed the greatest correlation between dengue fever and weather variables. Lag periods were generally introduced into the study to compensate for possible delays in the mosquito's life cycle in conjunction to the different weather conditions experienced. Studies show the major delay in a mosquitoes life cycle occurs in the hatching of the eggs which can range from days to months depending on environmental conditions (Tokash-Peters et al., 2019). This suggests that in Fiji the weather conditions experienced in the previous month may greatly affect dengue fever cases occurring in the adjacent month

V. Limitation

Correlation studies do not justify conclusions showing causation, it is a significant indicator that changes to one variable within the two datasets compared greatly affects the changes to the second variable. There was also a presence of missing data both on weather conditions and dengue fever cases. This fairly limited the amount of analysis performed on the respective years with missing data. Furthermore, the CWM dengue fever records did not contain data on dengue fever patients from the year 2015 thus the study period had to be reduced. The original years under study which was approved by CHREC were from 2015 to 2019 however, due to missing data this period had to be shortened to 2016-2019. Missing minimum temperature data from the year 2016 caused the exclusion of analysis of the effect of minimum temperature on dengue fever for the above-mentioned year. Moreover, a lack of monthly data availability on temperature and rainfall from the year 2019 also caused an exclusion of the year from the Spearman's rank correlation coefficient analysis. The results of this study do not consider the mortality rate associated with dengue fever or the different dengue fever serotypes

VI. Conclusion

In recent years dengue fever cases have raised in Fiji, after an outbreak in 2014 the cases continued to increase. While there was a consistent raise in dengue fever cases in Fiji a drop in cases was noted in 2019. Dengue fever in Fiji shows the highest incidence in females while showing the highest prominence within the 21–30 years old range. Minimum temperature showed the strongest association with dengue fever in Fiji at lag period of 1 month. Overall, all weather variables showed positive correlation with dengue fever in Fiji. However, this was a correlation study and a strong positive correlation cannot be considered causation. Further research with a longer time span and a greater availability of data is needed to draw stronger correlations between dengue fever and weather variables in Fiji. This study proves a strong correlation exits between weather and dengue fever in Fiji however, more in-depth research is required to draw more concrete evidence for causation

Acknowledgment

First and foremost, I would like to thank all mighty Allah without whom nothing would be possible.

I would like to extend my sincere appreciation to Dr. Aruna Devi for her continued support and valuable criticism throughout the research and writing process.

Furthermore, I would like to extend my gratitude to Sajnel Sharma for his help in acquiring CWM dengue fever records.

I would like to thank CHREC for endorsing the research as well as Fiji Meteorological Office for providing data on weather patterns in Fiji throughout the study period.

References

[1] Achee, N. L., Gould, F., Perkins, T. A., Reiner, R. C., Morrison, A. C., Ritchie, S. A., Gubler, D. J., Teyssou, R., & Scott, T. W. (2015). A Critical Assessment of Vector Control for Dengue Prevention. In PLoS Neglected Tropical Diseases (Vol. 9, Issue 5). Public Library of Science. https://doi.org/10.1371/journal.pntd.0003655

[2] Ahmad, M. H., Ibrahim, M. I., Mohamed, Z., Ismail, N., Abdullah, M. A., Shueb, R. H., & Shafei, M. N. (2018). The sensitivity, specificity and accuracy of warning signs in predicting severe dengue, the severe dengue prevalence and its associated factors. International Journal of Environmental Research and Public Health, 15(9). https://doi.org/10.3390/ijerph15092018

[3] Benedict, M. Q., Levine, R. S., Hawley, W. A., & Lounibos, L. P. (2007). Spread of the tiger: Global risk of invasion by the mosquito Aedes albopictus. Vector-Borne and Zoonotic Diseases, 7(1), 76–85. https://doi.org/10.1089/vbz.2006.0562

[4] Blacksell, S. D. (2012). Commercial dengue rapid diagnostic tests for point-of-care application: Recent evaluations and future needs? In Journal of Biomedicine and Biotechnology (Vol. 2012). https://doi.org/10.1155/2012/151967

[5] Brady, O. J., Golding, N., Pigott, D. M., Kraemer, M. U. G., Messina, J. P., Reiner, R. C., Scott, T. W., Smith, D. L., Gething, P. W., & Hay, S. I. (2015). Global temperature constraints on Aedes aegypti and Ae. albopictus persistence and competence for dengue virus transmission. Parasites and Vectors, 7(1). https://doi.org/10.1186/1756-3305-7-338

[6] Brady, O. J., Charles, H., Godfray, J., Tatem, A. J., Gething, P. W., Cohen, J. M., Mckenzie, F. E., Perkins, T. A., Reiner, R. C., Tusting, L. S., Scott, T. W., Lindsay, S. W., Hay, S. I., & Smith, D. L. (2015). Adult vector control, mosquito ecology and malaria transmission. https://doi.org/10.1093/inthealth/ihv010

[7] Caminade, C., McIntyre, K. M., & Jones, A. E. (2019). Impact of recent and future climate change on vector-borne diseases. Annals of the New York Academy of Sciences, 1436(1), 157-173. doi:10.1111/nyas.13950

[8] Chantziaras, I., Boyen, F., Callens, B., & Dewulf, J. (2014). Correlation between veterinary antimicrobial use and antimicrobial resistance in food-producing animals: A report on seven countries. Journal of Antimicrobial Chemotherapy, 69(3), 827–834. https://doi.org/10.1093/jac/dkt443

[9] Chumpu, R., Khamsemanan, N., & Nattee, C. (2019). The association between dengue incidences and provincial-level weather variables in Thailand from 2001 to 2014. PLOS ONE, 14(12), e0226945. https://doi.org/10.1371/journal.pone.0226945

[10] Cogan. J. E. Dengue and severe dengue. (2020). Retrieved 26 February 2020, from https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue.

[11] Colón-González FJ, Fezzi C, Lake IR, Hunter PR. The effects of weather and climate change on dengue. PLoS neglected tropical diseases. 2013;7(11):e2503.

[12] Costa lima, Jose & Rouquayrol, Maria & Callado, Maria & Florindo Guedes, Maria Izabel & Pessoa, Claudia. (2012). Interpretation of the presence of IgM and IgG antibodies in a rapid test for dengue: Analysis of dengue antibody prevalence in Fortaleza City in the 20th year of the epidemic. Revista da Sociedade Brasileira de Medicina Tropical. 45. 163-7. 10.1590/S0037-86822012000200005.

[13] Da Silveira, L. T. C., Tura, B., & Santos, M. (2019). Systematic review of dengue vaccine efficacy. In BMC Infectious Diseases (Vol. 19, Issue 1, p. 750). BioMed Central Ltd. https://doi.org/10.1186/s12879-019-4369-5

[14] Duong et al (2015) Duong, V., Lambrechts, L., Paul, R. E., Ly, S., Lay, R. S., Long, K. C., … Buchy, P. (2015). Asymptomatic humans transmit dengue virus to mosquitoes. Proceedings of the National Academy of Sciences of the United States of America, 112(47), 14688–14693. https://doi.org/10.1073/pnas.1508114112

[15] Ehelepola, N. D. B., Ariyaratne, K., Buddhadasa, W. M. N. P., Ratnayake, S., & Wickramasinghe, M. (2015). A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003 -2012) and lessons learned. Infectious Diseases of Poverty, 4(1), 42. https://doi.org/10.1186/s40249-015-0075-8

[16] Eldigail, M. H., Adam, G. K., Babiker, R. A., Khalid, F., Adam, I. A., Omer, O. H., Ahmed, M. E., Birair, S. L., Haroun, E. M., Abuaisha, H., Karrar, A. E., Abdalla, H. S., & Aradaib, I. E. (2018). Prevalence of dengue fever virus antibodies and associated risk factors among residents of El-Gadarif state, Sudan. BMC Public Health, 18(1), 1–8. https://doi.org/10.1186/s12889-018-5853-3

[17] Fazidah A Siregar, Tri Makmur and S Saprin. (2018) Forecasting dengue hemorrhagic fever cases using ARIMA model: a case study in Asahan district. Published under licence by IOP Publishing Ltd. https://iopscience.iop.org/article/10.1088/1757-899X/300/1/012032/meta

[18] Fever, D. (2020). Dengue Fever – Ministry of Health & Medical Services. Retrieved 26 February 2020, from http://www.health.gov.fj/dengue-fever

[19] Fouque, F., & Reeder, J. C. (2019). Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: A look at the evidence. Infectious Diseases of Poverty, 8(1), 1–9. https://doi.org/10.1186/s40249-019-0565-1

[20] Ganeshkumar, P., Murhekar, M. V., Poornima, V., Saravanakumar, V., Sukumaran, K., Anandaselvasankar, A., … Mehendale, S. M. (2018). Dengue infection in India: A systematic review and meta-analysis. PLoS Neglected Tropical Diseases, 12(7), 2–3. https://doi.org/10.1371/journal.pntd.0006618

[21] Getahun, A., Batikawai, A., Nand, D., Khan, S., Sahukhan, A., & Faktaufon, D. (2019). Dengue in Fiji: epidemiology of the 2014 DENV-3 outbreak. Western Pacific Surveillance And Response Journal, 10(2), 31-38. doi: 10.5365/wpsar.2018.9.3.001

[22] Golding, N., Wilson, A. L., Moyes, C. L., Cano, J., Pigott, D. M., Velayudhan, R., Brooker, S. J., Smith, D. L., Hay, S. I., & Lindsay, S. W. (2015). Integrating vector control across diseases. BMC Medicine, 13(1), 249. https://doi.org/10.1186/s12916-015-0491-4

[23] Hii, Y. L., Zhu, H., Ng, N., Ng, L. C., & Rocklöv, J. (2012). Forecast of Dengue Incidence Using Temperature and Rainfall. PLoS Neglected Tropical Diseases, 6(11). https://doi.org/10.1371/journal.pntd.0001908

[24] Htun, H. L., Yeo, T. W., Tam, C. C., Pang, J., Leo, Y. S., & Lye, D. C. (2018). Metformin Use and Severe Dengue in Diabetic Adults. Scientific Reports, 8(1), 1–9. https://doi.org/10.1038/s41598-018-21612-6

[25] Jaenisch, T., Tam, D. T. H., Kieu, N. T. T., Ngoc, T., Nam, N. T., Van Kinh, N., Yacoub, S., Chanpheaktra, N., Kumar, V., See, L. L. C., Sathar, J., Sandoval, E. P., Alfaro, G. M. M., Laksono, I. S., Mahendradhata, Y., Sarker, M., Ahmed, F., Caprara, A., Benevides, B. S., … Wills, B. (2016). Clinical evaluation of dengue and identification of risk factors for severe disease: Protocol for a multicentre study in 8 countries. BMC Infectious Diseases, 16(1). https://doi.org/10.1186/s12879-016-1440-3

[26] Kamal, M., Kenawy, M. A., Rady, M. H., Khaled, A. S., & Samy, A. M. (2018). Mapping the global potential distributions of two arboviral vectors Aedes aegypti and Ae. albopictus under changing climate. PLOS ONE, 13(12), e0210122. https://doi.org/10.1371/journal.pone.0210122

[27] Katzelnick, L. C., Gresh, L., Halloran, M. E., Mercado, J. C., Kuan, G., Gordon, A., Balmaseda, A., & Harris, E. (2017). Antibody-dependent enhancement of severe dengue disease in humans. Science, 358(6365), 929–932. https://doi.org/10.1126/science.aan6836

[28] Khan MD, Thi Vu HH, Lai QT, Ahn JW. Aggravation of human diseases and climate change nexus. International journal of environmental research and public health. 2019;16(15):2799. https://www.ncbi.nlm.nih.gov/pubmed/31390751

[29] Kirch, D. G., & Petelle, K. (2018). Addressing the Health Effects of Climate Change: an Approach Based on Evidence and Ethics. Academic Psychiatry, 42(3), 324–326. https://doi.org/10.1007/s40596-018-0907-5

[30] Konongoi, L., Ofula, V., Nyunja, A., Owaka, S., Koka, H., Makio, A., Koskei, E., Eyase, F., Langat, D., Schoepp, R. J., Rossi, C. A., Njeru, I., Coldren, R., & Sang, R. (2016). Detection of dengue virus serotypes 1, 2 and 3 in selected regions of Kenya: 2011-2014. Virology Journal, 13(1), 1–11. https://doi.org/10.1186/s12985-016-0641-0

[31] Lauer, S. A., Sakrejda, K., Ray, E. L., Keegan, L. T., Bi, Q., Suangtho, P., Hinjoy, S., Iamsirithaworn, S., Suthachana, S., Laosiritaworn, Y., Cummings, D. A. T., Lessler, J., & Reich, N. G. (2018). Prospective forecasts of annual dengue hemorrhagic fever incidence in Thailand, 2010–2014. In Proceedings of the National Academy of Sciences of the United States of America (Vol. 115, Issue 10, pp. E2175–E2182). National Academy of Sciences. https://doi.org/10.1073/pnas.1714457115

[32] Liu-Helmersson, J., Stenlund, H., Wilder-Smith, A., & Rocklöv, J. (2014). Vectorial capacity of Aedes aegypti: Effects of temperature and implications for global dengue epidemic potential. PLoS ONE, 9(3), e89783. https://doi.org/10.1371/journal.pone.0089783

[33] Liu, Z., Zhou, T., Lai, Z., Zhang, Z., Jia, Z., Zhou, G., Williams, T., Xu, J., Gu, J., Zhou, X., Lin, L., Yan, G., & Chen, X. G. (2017). Competence of Aedes aegypti, Ae. albopictus, and Culex quinquefasciatus mosquitoes as Zika virus vectors, China. Emerging Infectious Diseases, 23(7), 1085–1091. https://doi.org/10.3201/eid2307.161528

[34] Lwande, O. W., Obanda, V., Lindström, A., Ahlm, C., Evander, M., Näslund, J., & Bucht, G. (2020). Globe-Trotting Aedes aegypti and Aedes albopictus : Risk Factors for Arbovirus Pandemics. Vector-Borne and Zoonotic Diseases, 20(2), 71–81. https://doi.org/10.1089/vbz.2019.2486

[35] Lyons, A. G. (2014). The Human Dengue Challenge Experience at the Walter Reed Army Institute of Research Human Dengue Challenge Model • JID 2014:209 (Suppl 2) • S49. The Journal of Infectious Diseases, 209(S2), 49–55. https://doi.org/10.1093/infdis/jiu174

[36] Mazza JJ. Climate change and agriculture: Future implications. WMJ : official publication of the State Medical Society of Wisconsin. 2017;116(4):191. https://www.ncbi.nlm.nih.gov/pubmed/29323803.

[37] Moller-Jacobs, L. L., Murdock, C. C., & Thomas, M. B. (2014). Capacity of mosquitoes to transmit malaria depends on larval environment. Parasites and Vectors, 7(1), 593. https://doi.org/10.1186/s13071-014-0593-4

[38] Muller, D. A., Depelsenaire, A. C. I., & Young, P. R. (2017). 2) • S89 The Journal of Infectious Diseases The Journal of Infectious Diseases ®. JID, 2017(S2), 89–95. https://doi.org/10.1093/infdis/jiw649

[39] Mustafa, M. S., Rasotgi, V., Jain, S., & Gupta, V. (2015). Discovery of fifth serotype of dengue virus (denv-5): A new public health dilemma in dengue control. In Medical Journal Armed Forces India (Vol. 71, Issue 1, pp. 67–70). Medical Journal Armed Forces India. https://doi.org/10.1016/j.mjafi.2014.09.011

[40] Nair, K. R., Oommen, S., Jagan, O. A., & Pai, V. (2019). Detection of Circulating Dengue Virus Serotypes in a Tertiary Care Centre in Central Kerala, 2016. Int.J.Curr.Microbiol.App.Sci, 8(1), 2669–2678. https://doi.org/10.20546/ijcmas.2019.801.281

[41] Nhi, D. M., Huy, N. T., Ohyama, K., Kimura, D., Lan, N. T. P., Uchida, L., Thuong, N. Van, Nhon, C. T. M., Phuc, L. H., Mai, N. T., Mizukami, S., Bao, L. Q., Doan, N. N., Binh, N. V. T., Quang, L. C., Karbwang, J., Yui, K., Morita, K., Huong, V. T. Q., & Hirayama, K. (2016). A Proteomic Approach Identifies Candidate Early Biomarkers to Predict Severe Dengue in Children. PLoS Neglected Tropical Diseases, 10(2). https://doi.org/10.1371/journal.pntd.0004435

[42] Ogashawara, I., Li, L., & Moreno-Madriñán, M. J. (2019). Spatial-Temporal Assessment of Environmental Factors Related to Dengue Outbreaks in São Paulo, Brazil. GeoHealth, 3(8), 202–217. https://doi.org/10.1029/2019GH000186

[43] O'Reilly, K. M., Hendrickx, E., Kharisma, D. D., Wilastonegoro, N. N., Carrington, L. B., Elyazar, I. R. F., Kucharski, A. J., Lowe, R., Flasche, S., Pigott, D. M., Reiner, R. C., Edmunds, W. J., Hay, S. I., Yakob, L., Shepard, D. S., & Brady, O. J. (2019). Estimating the burden of dengue and the impact of release of wMel Wolbachia-infected mosquitoes in Indonesia: A modelling study. BMC Medicine, 17(1), 172. https://doi.org/10.1186/s12916-019-1396-4

[44] Pérez-Castro, R., Castellanos, J. E., Olano, V. A., Matiz, M. I., Jaramillo, J. F., Vargas, S. L., Sarmiento, D. M., Stenström, T. A., & Overgaard, H. J. (2016). Detection of all four dengue serotypes in Aedes aegypti female mosquitoes collected in a rural area in Colombia. Memorias Do Instituto Oswaldo Cruz, 111(4), 233–240. https://doi.org/10.1590/0074-02760150363

[45] Perkins-Kirkpatrick, S., & Pitman, A. (2018). Extreme events in the context of climate change. Public Health Research & Practice, 28(4) doi:10.17061/phrp2841825

[46] Phanitchat, T., Zhao, B., Haque, U., Pientong, C., Ekalaksananan, T., Aromseree, S., … Overgaard, H. J. (2019). Spatial and temporal patterns of dengue incidence in northeastern Thailand 2006-2016. BMC Infectious Diseases, 19(1), 1–12. https://doi.org/10.1186/s12879-019-4379-3

[47] Polwiang, S. (2016). The correlation of climate factors on dengue transmission in urban area: Bangkok and Singapore cases. PeerJ PrePrints. https://doi.org/10.7287/peerj.preprints.2322v1

[48] Ranjit, S., Ramanathan, G., Ramakrishnan, B., & Kissoon, N. (2018). Targeted interventions in critically ill children with severe dengue. Indian Journal of Critical Care Medicine, 22(3), 154–161. https://doi.org/10.4103/ijccm.IJCCM_413_17

[49] Rankine-Mullings, A., Reid, M. E., Moo Sang, M., Richards-Dawson, M. A., & Knight - Madden, J. M. (2015). A Retrospective Analysis of the Significance of Haemoglobin SS and SC in Disease Outcome in Patients With Sickle Cell Disease and Dengue Fever. EBioMedicine, 2(8), 937–941. https://doi.org/10.1016/j.ebiom.2015.07.002

[50] Restrepo, A. C., Baker, P., & Clements, A. C. A. (2014). National spatial and temporal patterns of notified dengue cases, Colombia 2007-2010. Tropical Medicine & International Health, 19(7), 863–871. https://doi.org/10.1111/tmi.12325

[51] Ryan SJ, Carlson CJ, Mordecai EA, Johnson LR. Global expansion and redistribution of aedes-borne virus transmission risk with climate change. PLoS neglected tropical diseases. 2019;13(3):e0007213. https://www.ncbi.nlm.nih.gov/pubmed/30921321 doi: 10.1371/journal.pntd.0007213

[52] Samy AM, Elaagip AH, Kenawy MA, Ayres CFJ, Peterson AT, Soliman DE. Climate change influences on the global potential distribution of the mosquito culex quinquefasciatus, vector of west nile virus and lymphatic filariasis. PloS one. 2016;11(10):e0163863. https://www.ncbi.nlm.nih.gov/pubmed/27695107. doi: 10.1371/journal.pone.0163863.\

[53] Sedgwick, P. (2014). Spearman's rank correlation coefficient. In BMJ (Online). https://doi.org/10.1136/bmj.g7327

[54] Shrivastava, S., Tiraki, D., Diwan, A., Lalwani, S. K., Modak, M., Mishra, A. C., & Arankalle, V. A. (2018). Co-circulation of all the four dengue virus serotypes and detection of a novel clade of DENV-4 (genotype I) virus in Pune, India during 2016 season. https://doi.org/10.1371/journal.pone.0192672

[55] Signor, L. D. C. C., Edwards, T., Escobar, L. E., Mencos, Y., Matope, A., Castaneda-Guzman, M., Adams, E. R., & Cuevas, L. E. (2020). Epidemiology of dengue fever in guatemala. PLoS Neglected Tropical Diseases, 14(8), 1–12. https://doi.org/10.1371/journal.pntd.0008535

[56] Siregar, F. A., & Makmur, T. (2019). Time Series Analysis of Dengue Hemorrhagic Fever Cases and Climate: A Model for Dengue Prediction. Journal of Physics: Conference Series, 1235(1), 4–11. https://doi.org/10.1088/1742-6596/1235/1/012072

[57] Sun, H., Jit, M., Cook, A. R., Carrasco, L. R., & Dickens, B. L. (2018). Determining environmental and anthropogenic factors which explain the global distribution of aedes aegypti and Ae. Albopictus. BMJ Global Health, 3(4), e000801. https://doi.org/10.1136/bmjgh-2018-000801

[58] Tokash-Peters, A. G., Tokash, I. W., Campos, A. J., & Woodhams, D. C. (2019). Developing Effective Mosquito Control Strategies by Utilizing Vector Mosquito Life Histories and Ecology. Case Studies in the Environment, 3(1), 1.18-12. https://doi.org/10.1525/cse.2018.001743

[59] Ullah, R., Naz, S., Ullah, R., Infection, D., & Dengue, M. (2019). Respiratory System and Dengue Infection, least known culprit. 12(9), 46–47 Pak J Chest Med 2019; 25(02)

[60] United States Environmental Protection Agency (2017). Mosquito Life Cycle [internet]. https://www.epa.gov/mosquitocontrol/mosquito-life-cycle

[61] Vuong, N. L., Le Duyen, H. T., Lam, P. K., Tam, D. T. H., Vinh Chau, N. Van, Van Kinh, N., Chanpheaktra, N., Lum, L. C. S., Pleités, E., Jones, N. K., Simmons, C. P., Rosenberger, K., Jaenisch, T., Halleux, C., Olliaro, P. L., Wills, B., & Yacoub, S. (2020). C-reactive protein as a potential biomarker for disease progression in dengue: A multi-country observational study. BMC Medicine, 18(1), 35. https://doi.org/10.1186/s12916-020-1496-1

[62] Wang, S. F., Wang, W. H., Chang, K., Chen, Y. H., Tseng, S. P., Yen, C. H., Wu, D. C., & Chen, Y. M. A. (2016). Severe dengue fever outbreak in Taiwan. American Journal of Tropical Medicine and Hygiene, 94(1), 193–197. https://doi.org/10.4269/ajtmh.15-0422

[63] Wilder-Smith, A., & Leong, W. Y. (2019). Risk of severe dengue is higher in patients with sickle cell disease: a scoping review. Journal of Travel Medicine, 1–3. https://doi.org/10.1093/jtm/tay136

[64] Yacoub, S., Lam, P. K., Vu, L. H. M., Le, T. L., Ha, N. T., Toan, T. T., Thu Van, N., Quyen, N. T. H., Duyen, H. T. Le, Kinh, N. Van, Fox, A., Mongkolspaya, J., Wolbers, M., Simmons, C. P., Screaton, G. R., Wertheim, H., & Wills, B. (2016). Association of microvascular function and endothelial biomarkers with clinical outcome in dengue: An observational study. Journal of Infectious Diseases, 214(5), 697–706. https://doi.org/10.1093/infdis/jiw220

[65] Yacoub, S., & Wills, B. (2014). Predicting outcome from dengue. In BMC Medicine (Vol. 12, Issue 1, p. 147). BioMed Central Ltd. https://doi.org/10.1186/s12916-014-0147-9
[66] Yee, L. Y., Heryaman, H., & Faridah, L. (2017). The relationship between frequency of fogging focus and incidence of dengue hemorrhagic fever cases in Bandung in year 2010-2015. International Journal Of Community Medicine And Public Health, 4(2), 456. https://doi.org/10.18203/2394-6040.ijcmph20170272
[67] Yue, Y., Sun, J., Liu, X., Ren, D., Liu, Q., Xiao, X., & Lu, L. (2018). Spatial analysis of dengue fever and exploration of its environmental and socio-economic risk factors using ordinary least squares: A case study in five districts of Guangzhou City, China, 2014. International Journal of Infectious Diseases, 75, 39–48. https://doi.org/10.1016/j.ijid.2018.07.023
[68] Yung, C. F., Lee, K. S., Thein, T. L., Tan, L. K., Gan, V. C., Wong, J. G. X., Lye, D. C., Ng, L. C., & Leo, Y. S. (2015). Dengue serotype-specific differences in clinical manifestation, laboratory parameters and risk of severe disease in adults, Singapore. American Journal of Tropical Medicine and Hygiene, 92(5), 999–1005. https://doi.org/10.4269/ajtmh.14-0628

Shafraaz Khan Medical Laboratory Scientist. Technical Higher-Grade officer for Fiji Center of Disease Control Food and Water Lab
Contact- shafmedt@gmail.com shafraaz.khan@health.gov.fj