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The Emergence of the Zika, Chikungunya, and Dengue Viruses in Brazil, the Dominican Republic, and Puerto Rico

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Honors Scholar Thesis

The Emergence of the Zika, Chikungunya, and Dengue Viruses in Brazil, the Dominican Republic, and Puerto Rico

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Abstract

The Zika, Chikungunya, and Dengue viruses are three emerging viral infections of the 21st century. Outbreaks have occurred in twenty countries, including areas of South America, and territories in the Caribbean. These viral diseases are mosquito-borne infections transmitted primarily by *Aedes aegypti* and *Aedes albopictus* mosquitoes. The origins of the diseases, viral morphology, and vector transmission will be described in this review as well as symptoms that humans experience, medical testing procedures, and preventative measures. This study will focus on three locations: Brazil, the Dominican Republic, and Puerto Rico. There are many similarities between the three viruses to emphasize, but also significant differences to highlight.

Introduction

Newly emerging infections are defined as infections that have come into contact with the human body for the first time (Morgan et al., 2016). The disease can be new, or a modified version that contains a drug resistant strain (Fischer et al., 2014). The definition can be further broadened to include the spread of these diseases into new territories (Morgan et al., 2016). The Zika, Chikungunya, and Dengue viruses are three mosquito-borne viral infections that are emerging in Brazil, the Dominican Republic, and Puerto Rico. This paper will discuss the origin, historical perspective, and viral morphology of each virus; the methods of transmission; the number of infected citizens in Brazil, the Dominican Republic, and Puerto Rico; the symptoms observed for each disease; possible treatment options; and preventive methods that these countries can utilize to decrease the spread of these viruses.

Zika virus

The Zika virus is a mosquito-borne flavivirus discovered from the rhesus macaque monkey in the Zika forest of Uganda around April of 1947 (Hayes, 2009). The virus is enveloped and icosahedral, and has a nonsegmented, single-stranded positive-sense RNA genome (Duffy et al., 2009). The virus is closely related to the spondweni virus clade (Duffy et al., 2009; Hayes, 2009).

In Brazil, the Dominican Republic, and Puerto Rico, the spread of the Zika virus is complex. It is primarily transmitted by the *Aedes aegpti* and *Aedes albopictus* mosquitoes (Musso et al., 2014), which are found abundantly throughout these three territories (CDC, 2016). The spread of the Zika virus is seen in the intrapartum

transmission of the viremic mother to her newborn, via laboratory exposure, blood transfusion, and, most recently, sexual transmission (Musso et al., 2015). It has been speculated that the transfer of the Zika virus could occur through organs or tissue transplantation (Morgan et al., 2016). The spread of the Zika virus has also been linked to travelers who have toured infected countries (Zammarchi et al., 2015).

The first documented outbreak of the Zika virus was in 2007 Yap state, the Federated state of Micronesia, where 73% of the population greater than three year old were infected (Duffy et al., 2009; Lanciotti et al., 2008). Since then, there have been outbreaks in Southeast Asia and the Western Pacific (Lanciotti et al., 2008; Musso et al., 2014). On May of 2015, the World Health Organization (WHO) reported the first local transmission of Zika virus in Brazil (Zanluca et al., 2015). The following December of 2015, the Ministry of Health determined that nearly 440,000 to 1,3000,000 Brazilian citizens had contracted the virus (Zanluca et al., 2015). Then, on January 20, 2016, it was reported to the Pan American Health Organization that Barbados, Bolivia, Brazil, Colombia, the Dominican Republic, French Guiana, Guadeloupe, Ecuador, El Salvador, Guatemala, Guyana, Haití, Honduras, Martinica, México, Panamá, Paraguay, Puerto Rico, Saint Martin, Suriname, and Venezuela had locally transmitted cases (Cetron, 2016). In Puerto Rico, one-fourth of the 3.5 million total population are expected to become infected with the Zika virus in 2016, and up to 80% thereafter (McNeil, 2016). Whereas in the Dominican Republic, there has been ten laboratory confirmed virus cases (Recinos, 2016). Of the ten Zika virus infections, eight were determined to be originally from the Dominican Republic (Recinos, 2016). These eight cases came from Jimani-

Independencia, Distrito Nacional, Santa Cruzbarahona, and municipalities of Santo Domingo Norte (Recinos, 2016; WHO, 2016). A possible reason why these areas have been infected with the Zika virus is because they are below 6,500 feet, and the mosquito that carries the Zika virus lives below 6,500 feet (CDC, 2016; Centron, 2016). The remaining two cases of the Zika virus were imported from El Salvador (WHO, 2016). The age of the people infected range from less than five years old to 57 years old (WHO, 2016).

The Zika virus is difficult to target because around 80% of the people who are infected are asymptomatic, while those who are symptomatic show an acute onset of fever, arthralgia, maculopapular rash, and nonpurulent conjunctivitis (Morgan et al., 2016). These symptoms usually last from one to 10 days, with severe cases requiring hospitalization (Zammarchi et al., 2015; Zanluca et al., 2015). In Brazil, the Dominican Republic, and Puerto Rico, it has been noted that the Zika virus RNA has been seen in the tissues of numerous infants with microcephaly (Butler, 2016; Zanluca et al., 2015), which is when the infants brain fails to properly develop; as a result, the infants have poor motor skills, speech, hearing, vision, abnormal facial features, seizures, and are intellectually disabled (Butler, 2016; Zanluca et al., 2015). Also, the virus has been seen in mothers who lost their fetus during pregnancy (Zammarchi et al., 2015). The Brazil Ministry of Health has shown that there has been an increase in the number of cases of microcephaly in 2015 from approximately 0.5 cases per 10,000 live births to 20 cases per 10,000 live births (Butler, 2016, CDC, 2016). Furthermore, the Zika virus is present in patients who suffer from Guillain-Barre syndrome (Oehler, 2014), which is an autoimmune disease

that attacks parts of the peripheral nervous system (Oehler, 2014). Some symptoms of Guillain-Barre syndrome include weakness or the tingling sensation in the legs (Wong, 2016). In Puerto Rico, studies have shown that there has only been one case of Guillain-Barre syndrome linked to the Zika virus (McNeil, 2016).

Treatment options for the Zika virus include rest, fluids, and using analgesics such as paracetamol (Karwonwski et al., 2006; Morgan et al., 2016). While nonsteroidal anti-inflammatory drugs such as aspirin, should be avoided (Hennessey et al., 2016). If a patient uses aspirin without a physician ruling out the Dengue virus instead of the Zika virus, then the aspirin can increase the potential of hemorrhage (Hennessey et al., 2016).

Chikungunya virus

The Chikungunya virus (CHIKV) is a mosquito-borne Togaviridae of the Alphavirus genus, discovered in 1955 in Tanzania, Africa (M. Figueiredo & L. Figueiredo , 2014; Staples et al., 2014). The Alphaviruses are small, spherical, and enveloped viruses (Staples et al., 2009); the genome consists of a single positive sense strand RNA (Nappe et al., 2016). This Alphavirus has a genome that ranges from 11,000 to 12,000 nucleotides. The virus belongs to the Semliki Forest Virus antigenic complex (M. Figueiredo & L. Figueiredo, 2014). There are four known Chikungunya virus genotypes, which are the East-Central-South-African (ECSA), West African, Indian Ocean linage (IOL) and Asian genotype (Nappe et al., 2016; Sam et al., 2012; Vazeille et al., 2007). The ECSA and West African genotypes are mostly enzootic in Africa, meaning that it primarily effects animals at a certain district (Powers & Logue, 2007).

While the other two genotypes are found in Southeast Asia (Powers & Logue, 2007; Sam et al., 2012) and India (Staples et al., 2009; Vazeille et al., 2007)

It is believed that the Chikungunya virus is predominantly transmitted to people through *Ades aegypti* and *Aedes albopictu* mosquito bites (Gibney et al., 2011). Infected people can then later spread the virus to new mosquitoes when the mosquito feeds on them (Fischer et al., 2014). Also, it is possible for the virus to be transmitted from the mother to the newborn at the time of birth (CDC, 2016). It is also believed to spread through blood transfusion, though rarely, and possibly through breastfeeding (CDC, 2016).

In October 2013, the first Asian genotype of Chikungunya was noted in Saint Martin in the Caribbean (Leparc et al., 2014). By 2015, there were over 1 million people infected, with 71 of those cases resulting in death (Faria et al., 2016). In September 2014, the Chikungunya virus was confirmed in two additional locations (Kraemer et al., 2015), the Amapá federal state in northern Brazil (Kraemer et al., 2015) and the Feira de Santana (Nunes et al., 2015). Feira de Santana (FSA) is the second largest city in Brazil with over 615,000 inhabitants (Nunes et al., 2015). By sequencing the genome of the virus, it was shown that the Asian genotype was the one seen north of the country (Nunes et al., 2015), and the ECSA genotype in FSA (Faria et al., 2016; Nunes et al., 2015). This was the first documented time that the ECSA genotype was observed in the Americas.

It is believed through epidemiological analysis that around 94 % of Brazilians are at significant risk of becoming infected with the Chikungunya virus (Nunes et al., 2015). As of 2015, there have been 20,661 suspected people infected across 84 cities in Brazil,

according to the Brazilian Ministry of Health (Faria et al., 2016). FSA has the highest amount of people infected, with 4,088 cases in 2015 (Faria et al., 2016). Of the 20,661 suspected cases, 7,723 have been confirmed by clinical (35%) and laboratory (3%) testing (Faria et al., 2016). Then, in December of 2013, it was determined that the Chikungunya virus spread to 17 new countries, lands in South America and territories in the Caribbean (Nunes et al., 2015), including Anguilla, Antigua, Barbuda, Dominican Republic, French Guiana, Guadeloupe, Guyana, Haiti, British Virgin Islands, the Dominica, Martinique, Puerto Rico, Saint Barthelemy, Saint Kitts and Nevis, Saint Lucia, Saint Martin, Saint Vincent and the Grenadines, and Sint Maarten (Fischer et al., 2014). In Puerto Rico, it has been confirmed by the CDC that Chikungunya has infected more than 27,000 people including 14 fatalities (CDC, 2016). While in the Dominican Republic, 38,656 cases of Chikungunya virus have been documented (Garg et al., 2012). It is expected that the number of infected cases of Chikungunya in Brazil, Puerto Rico, and the Dominican Republic will increase over time (Garg et al., 2012).

When a person becomes infected with the Chikungunya virus, there are three distant stages, which include the acute, subacute, and chronic forms. During the acute stage, patients experience incapacitating joint pain, maculopapular rash on extremities, fever, headache, or myalgia (Garf et al., 2012; Gibney et al., 2011; Nappe et al., 2016). The joint pains can present as symmetric and debilitating, which means the pain is equal on each side of the body, along with weakness (CDC, 2016; Garf et al., 2012; Nappe et al., 2016). Patients experience symptoms relief after 3 to 10 days (CDC, 2016). In the subacute stage, the acute stage symptoms relapse and reappear 2 to 3 months after the

first infection (CDC, 2016; Nappe et al., 2016). Patients often experience exacerbated pain in joints that were initially affected (CDC, 2016). Most patients recover from the acute and subacute stage of Chikungunya virus. However, some patients can experience chronic arthralgia and fatigue for numerous of years (CDC, 2016; Garf et al., 2012).

There is currently no known specific treatment or vaccine for the Chikungunya virus (Leparc et al., 2014). The best way to treat patients is to get rest, fluids and analgesics along with antipyretics (acetaminophen, dipyrone) (Lahariya & Pradhan, 2006). When the patient is in the subacute stage, nonhormonal anti-inflammatories are used (Mittal et al., 2007). When the patient is in the chronic stage, it is best to use corticosteroids like prednisolone and an immunosuppressant like methotrexate (Lahariya & Pradhan, 2006). In most cases, patients' conditions improved within a week (Gibney et al., 2011).

Dengue virus

The Dengue virus is a mosquito-borne viral disease that is a member of the genus Flavivirus, within the family of the Flaviviridae (Bhatt et al., 2013). The Dengue virus is a single stranded positive-sense RNA. The virus is spherical with a diameter of about 50 nanometers (Bhatt et al., 2013; Wang et al., 2000). Other flaviviruses include Yellow Fever, West Nile, and Tick-borne Encephalitis Virus (Brady et al., 2012). In Africa and Southeast Asia, the Dengue virus evolved in nonhuman primates and later jumped from the primates into humans between 500 to 1,000 years ago (Wang et al., 2000). The virus was first discovered in 1943 by Ren Kimura and Susumu Hotta (Bhatt et al., 2013; Wang et al., 2000). These two scientists learned about this virus after they analyzed blood

samples from sick patients in Nagasaki, Japan. Later the virus came to be known as Den-1 (Gubler, 1998). However, there are four serotypes of Dengue viruses which are closely related (65%) of their genome: Den-1, Den-2, Den-3, and Den-4, and result in the same infection (Brady et al., 2012; Halstead, 2008; Wang et al., 2000).

The Dengue viruses spread by infected female *Aedes aegypti* and *Aedes albopictus* mosquitoes (Bhatt et al., 2013). There is a virus mosquito incubation period of 4 to10 days, after which the mosquito is capable of infecting others (Choumet & Despres, 2015). Humans that become infected with the Dengue virus can also spread the virus to mosquitos after five days (CDC, 2010; Halstead, 2008). Therefore, both mosquitoes and humans are contributing to the spread of the Dengue virus (CDC ,2010; Halstead, 2008). The *Aedes aegypti* mosquitos reside in urban habitats and are daytime feeders (Morgan et al., 2016). The female bites in the morning and before dusk. She often bites numerous people during the period that she feeds (Kraemer et al., 2015).

The *Aedes albopictus* mosquito has spread to Europe and North America (Douglas, 2016) due to the international trade of tires as well as lucky bamboo (Raharimalala et al., 2012). The *Aedes albopictus* mosquito is able to live in cold foreign ecosystem due to its ability to hibernate and find shelter in microhabitats (Medlock et al., 2012).

There are 390 million reported cases of Dengue every year (Bhatt et al., 2013), of which 500,000 people are diagnosed with severe Dengue that requires hospitalization; the majority are children and 2.5% die (Bhatt et al., 2013). The World Health Organization reported that there were only nine countries with severe Dengue epidemics in 1970

(WHO, 2016). However, the number of countries now infected has increased to 100 (Bhatt et al., 2013; WHO, 2016). These regions include Africa, the Americas, the Eastern Mediterranean, South-East Asia, and Western Pacific (WHO, 2016). There were 1.2 million cases of the Dengue virus across the Americas, Western Pacific, and Southeast Asia in 2008 (Bhatt et al., 2013). In 2013, the Americas alone produced 2.35 million new Dengue cases of the 3 million total cases in these three territories (Murray et al., 2013; WHO, 2016). In Brazil, the number of Dengue cases rose from 600,000 in 2014 to 1.6 million in 2015 (Phillips, 2016). In the Dominican Republic, there were 8,438 suspected cases of the Dengue viruses in late 2015 (WHO, 2016), of which 97 people died (WHO, 2016). The territories with the most suspected cases are the National District, La Vega, Hermanas Mirabal, Santo Domingo, Monte Plata, Santiago, Azua, Espaillat and San Cristobal (Bhatt, 2013; Gubler, 2002), and the reason is because these lands are below 6,500 feet, and the mosquito that carries the virus lives below 6,500 feet (Centron, 2016). In Puerto Rico, there were 26,766 reported Dengue cases, with 47 % confirmed by laboratory testing (Sharp et al 2013).

When a person becomes infected with the Dengue virus, there are numerous symptoms which manifest themselves after 4 to 10 incubation days (Chan & Johansson, 2012; Gubler, 1998), such as severe flu-like illness for infants, children, and adults for 2 to 7 days (Chan & Johansson, 2012), a fever of 40°C or 104°F (Chan & Johansson, 2012), muscle and joint pains, severe headache, pain behind the eyes, vomiting, rash, and swollen glands (Carson-DeWitt, 2006). Mild fever caused by the Dengue virus rarely causes death (Choument & Despres, 2015; Carson-DeWitte, 2006; Gubler, 1998), but

severe fever can cause death due to fluid accumulation, plasma leakage, respiratory distress, organ impairment, and severe bleeding (Phuong et al., 2004; Gubler, 2002). These symptoms manifest themselves around 3 to 7 days when the body temperature falls below 38°C with either persistent vomiting, bleeding gums, tiredness, abdominal pain, or rapid breathing (Phuong et al., 2004; Chan & Johansson, 2012).

Currently, there are no vaccines for the Dengue viruses (Gubler, 2002; Sharp et al., 2013). Patients who are suffering from severe Dengue should be given fluids and rest to maintain the body fluid volume (Souza et al., 2013). After a patient becomes infected with one of the Dengue viruses, they have gained immunity from the other serotypes for three months (Wahala & DeSilva, 2011). After three months, the patient can now be susceptible to severe Dengue illnesses, compared to those who are not infected (Souza et al., 2013; Wahala & DeSilva, 2011)

Discussion

There are currently no vaccines that have been developed for the Zika, Chikungunya, and Dengue viruses (Karwowski et al., 2016). Nonetheless, there are preventive measures that Brazil, the Dominican Republic, and Puerto Rico can utilize to decrease the spread of these viruses. The most important step is to avoid *Aedes aegpti* and *Aedes albopictus* mosquito bites, which are the carriers of the diseases (Sharp et al., 2014). There are five ways to avoid them (Hayes, 2009; Sharp et al., 2014; WHO 2016), such as: use air conditioners instead of leaving the windows- open (Hennessey et al., 2016; Sharp et al., 2014); use window and door screens (Hennessey et al., 2016; Petersen et al., 2016;Sharp et al., 2014); wear long sleeves shirts and pants (Hayes et al., 2016;

Sharp et al., 2014); use permethrin-treated clothing, use insect repellent like N,N-diethyl-m-toluamide (DEET) when outdoors (Hennessey et al., 2016; Petersen et al., 2016). DEET has been registered with the Environmental Protection Agency (EPA) to be safe to use for children older than two years of age, pregnant women, and women who are breastfeeding their offspring (Hennessey et al., 2016).

Presented below is how Brazil, the Dominican Republic, and Puerto Rico have attempted to decrease the spread of these three viruses. So far, the Brazilian government has launched a mega-operation to reduce the proliferation of the *Aedes aegpti* and *Aedes albopictus* mosquito (Douglas, 2016). The Brazilian government believes that 80% of the breeding grounds for the *Aedes aegypti* mosquito that carries the Zika, Chikungunya, and Dengue virus is on private properties (Douglas, 2016). That is why the current president of Brazil, Dilma Roussef, announced on February 13, 2016, that 300,000 health workers will accompany 220,000 soldiers to visit private homes to eradicate these mosquitoes breeding grounds (Douglas, 2016;Natalia, 2016). So far, health workers have visited over 20.7 million Brazilian homes (Douglas, 2016; Natalia, 2016; Romero,2016), which is about 30% of the country's total private residences (Douglas, 2016; Douglas, 2016).

The Dominican Republic's government plans to decrease the spread of the Zika, Chikungunya, and Dengue viruses by setting up vector control measures; increasing surveillance activities; educating the general public about these viruses; and establishing preventive measures for citizens to protect themselves from mosquito bites, like placing window screens in public schools (WHO, 2016).

The current governor of Puerto Rico, Alejandro Garcia Padilla, recently demanded that the islands 37 municipalities attack hot spots to eradicate *Aedes aegpti* and *Aedes albopictus* mosquitoes, including auto junkyards, piles of old tires, unsealed septic tanks, cemeteries, and abandoned houses (Douglas, 2016; McNeil, 2016). Thus far, more than one million tires have been removed (McNeil, 2016).

Puerto Rico has changed their public dress code allowing females to wear pants instead of skirts (McNeil, 2016). In addition, school teachers and staff members have been equipped with mosquito repellent to give to their students (McNeil, 2016). Around the community, pesticides are being used at 109 cemeteries, dumps, junkyards, and properties that are within 150 yards of a house; this is the distance traveled by mosquitoes (McNeil, 2016). However, environmental factors such as rain are making the use of pesticides difficult (McNeil, 2016), and there are numerous abandoned homes which cumulatively can add up to 500,000 septic tanks, which each may produce more than 1,500 new mosquitoes per day (Douglas, 2016).

Mother and child nutritional clinics around the islands of Puerto Rico have been giving 20 minutes lectures about the Zika virus (Douglas, 2016). To date, more than 5,000 women have attended these Zika conferences (Douglas, 2016). The CDC has devoted $25 million to help Puerto Rico fight against the Zika virus from President Obama's 1.8 billion Zika package, and it plans to ask Congress for $225 million dollars in the near future (CDC, 2016; Douglas, 2016). The CDC in Puerto Rico has permanent laboratories where they are conducting more than 100,000 blood tests annually to reduce the spread of the Zika virus (CDC, 2016; Douglas, 2016).

Personal Experiences

In order for me to better understand the effects of the Zika, Chikungunya, and Dengue viruses on Brazil, the Dominican Republic, and Puerto Rico, I found opportunities to interview individuals who have been diagnosed with these viruses. I have learned new, overlooked symptoms for the three given viruses and social difficulties that these territories have towards overcoming this virus epidemic.

Zika virus

A tourist by the named Pablo Rodriguez was touring Puerto Rico with his wife from Brazil. They shared the following story with me when I was recently visiting Puerto Rico:

> "On December 4, 2015, I woke up one morning at a hotel in Brazil, and I had the biggest headache in my life along with a skin rash. So I waited a couple of days, for the headaches to clear, but it just got worse. Also, I remember I was constipated, and my eyes were sensitive to bright lights, so I started to wear sunglasses. Then, my wife told me that I was distant to her, and I remember feeling that I did not want any one to touch me including her. So my wife brought me to the doctor, and he told me I had the Zika virus. I was shocked. At the time, I never heard of the Zika virus, and I didn't know what the heck it was. This virus has made me feel sick, and less of a human. My wife and I are trying to have a child, but now that this virus can be sexually transmitted, I have abandoned those plans. It has been one years after I got the virus, I still feel like a cloud is over my

> head, my wife thinks I am depressed, which is why we are touring Puerto Rico on vacation" (Rodriguez, P (2016, March 18). Personal interview).

Pablo's comments trouble me. He believes that the Zika virus was responsible for his headaches, skin rash, constipation, sensitivity to light, lack of sex drive, and depression. So far, headaches and skin rash are common symptoms cited in most recent Zika literature reviews, (CDC, 2016; Butler, 2016; Morgan et al., 2016; Zanluca et al., 2015; Zammarchi et al., 2015) but not constipation, light sensitivity, lack of sex drive, or depression. I believe that organizations like WHO and the CDC should look more into Pablo's story. His symptoms were overlooked, and could be a valuable tool to help medical providers spot patients that are suffering from the Zika virus.

Chikungunya virus

While in Puerto Rico, I met Carolina and Maria, who are professors at a local university. They are both natives who became infected with the Chikungunya virus around 2005, Carolina shared the following story with me:

> "My bones hurt so much, I used to be a dancer, but now that I got the Chikungunya, I just feel hollow inside, almost like a cup. I never have felt so fragile in my life, and these intense pains spreads throughout my joints every month, which makes forgetting about the Chikungunya virus impossible. My doctor has given me opioids because my pain is so severe that it makes me constipated, yet the drug doesn't do anything for my pain. The drug does more bad than good" (Carolina, R (2016, March 19). personal interview).

This is noteworthy because despite that Carolina has shown symptoms of chronic arthralgia for nearly 11 years, the drug available today to treat joint pain associated with the Chikungunya virus is not effective. There needs to be future development for better drugs for Chikungunya patients suffering from chronic arthralgia. Also, when I asked Carolina and Maria what tools they had to prevent themselves from becoming infected, Maria shared the following comments:

> "I learned about the Chikungunya virus from my dad, but what can we really do to prevent this virus? The government tells us to use insect repellent, and cover up as much as possible, but that is just not practical. For example, the insect repellent that I use to cover my body works against mosquitoes, but the repellent is harming me in the process. I remember getting tremors, therefore it's a two-way knife. Also, its 100°F outside; there is no way I can wear long sleeves shirts and pants without having a heat stroke. That is why I don't use insect repellent nor cover up. My community and I believe there is nothing we can do, and that it will just be a matter of time before all of us become infected" (Maria, T (2016, March 19). Personal interview).

Maria's comments shocked me because she realistically taught me how difficult it is to fight Chikungunya. I empathize with these women and urge scientists to develop practical, preventive measures for these viruses in tropical climates.

Dengue virus

At the University of Connecticut Storrs campus, I met Dr. Eric Schultz, who is a Professor in the Department of Ecology and Evolutionary Biology. He shared the following story with me about his Dengue viral infection:

> "I acquired the Dengue virus in August of 1981 when I was working on a project in Saint Croix with my colleagues, which is one of the United States of America's Virgin Islands. During that time, I don't recall that I was warned about the Dengue virus, nor were my colleagues. It wasn't until we returned to the United States (Georgia), that we suffered from the symptoms. It was a dramatic experience for me; it was not like a typical fever. My temperature was high, I remember that I slept, and woke up feeling refreshed, and thinking to myself that I could go back to work, but I only got as far as the kitchen. I was partially disabled for a week. The Dengue virus is also called Break Bone Disease because most people have severe limb pain, but I don't recall the pain, only the fever, and the exhaustion. I am worried to get the Dengue virus again because next time it can be hemorrhagic. I think what the world needs to do to decrease the spread of the Dengue virus is to have an inexpensive means to monitor mosquito levels. Also, insecticides are often people the go to solution, but we need to make sure that we use insecticides with great care because there are irreversible consequences of using a wide spread of pesticides. For example, the insecticides can kill the insects' predator, which is a bad effect, and the other is the insect can gain resistance to the insecticides. Therefore, an insecticide should be used in hot

> spots, but not widespread. Recently, people are talking about genetically altering male mosquitoes to be sterile, and I believe that this has a lot of promise. They tried some experiments in Florida, but people freak out about the idea since people are suspicious of the new technology and the consequences that can come. I believe people should have an open mind, since one day we have to do something" (Schultz, E (2016, April 13). Personal interview).

Dr. Schultz's story was interesting to me because it showed me what Brazil, The Dominican Republic, and Puerto Rico can do to decrease the spread of these emerging viruses. He mentioned one way is to find inexpensive means to monitor mosquito levels. This is significant because Dr. Schultz has addressed how to prevent instead how to treat future emerging viral diseases from manifesting. Another key point that Dr. Schultz mentioned was monitoring how insecticides are widely used, since there are irreversible environmental consequences. These effects can disrupt the ecosystem by killing the predator or enabling the insect to gain resistance to the insecticide. Lastly, Dr. Schultz touched on the topic of using genetically altered organisms to treat emerging viral diseases like Zika, Chikungunya, and Dengue viruses.

Preventative measures based on viral infections that have been controlled

In the interest of researching efficient methods to decrease the spread of the Zika, Chikungunya, and Dengue viruses, the methods used to control Malaria, West Nile virus and Yellow Fever were evaluated. These viral infections have been controlled with the use of insecticide-treated mosquito nets (ITNs) (Lengeler, 2004), insect repellents with Picaridin and DEET (Kajfasz, 2009), along with indoor residual spraying (CDC, 2006;

Pluess et al., 2010). ITNS that contains Pyrethroids at a low toxicity offer 70% more protection from mosquitos than no nets, and so far has saved more than 250,000 infants in Sub-Saharan Africa (Howitt et al., 2012; Pluess et al., 2010). Furthermore, indoor residual spraying sprays insecticides like DDT, Pyrethroids, Deltamethrin, and Cyfluthrin on walls inside the home, which kills resting mosquitos (Pluess et al., 2010; WHO, 2006). The preventive methods that have been used in these three viruses could be utilized to decrease the spread of the Zika, Chikungunya, and Dengue virus.

Summary

The Zika, Chikungunya, and Dengue viruses are three mosquito-borne viral infections that are emerging in Brazil, Dominican Republic, and Puerto Rico. These three viruses are all carried by the *Aedes aegypti* and *Aedes albopictus* mosquitoes. Currently, there is no vaccine for these viruses, but there is a lot of promising work that is being carried out to reduce the spread of these viruses throughout these territories. In the near future, I hope to see WHO and CDC investigate constipation, light sensitivity, lack of sex drive, and depression as possible symptoms for the Zika virus, and new pharmaceutical drugs to target Chikungunya patients suffering from chronic arthralgia.

Furthermore, to decrease the spread of the Dengue virus, I hope to see these territories have an inexpensive method to monitor mosquito levels, to control future viral infections like they have have for Malaria, West Nile Virus, and Yellow Fever. I wish to see future research look at the long term harmful environmental effects of the overuse of N, N-diethyl-m-toluamide (DEET) on the *Aedes aegypti* and *Aedes albopictus* mosquitoes predators. Also, I would like to see ways to prevent these mosquitos from

gaining resistance. Moreover, there needs to be regulations in place to control the use of insecticides in Brazil, the Dominican Republic, and Puerto Rico to preserve the world's ecosystem. Furthermore, government officials need to begin to think about using genetically altered organisms to treat emerging viral diseases. Citizens need to have an open mind, for they may never know the consequences or benefits of using sterile mosquitoes if they do not try. Lastly, I would like to see effective practical methods that Brazil, the Dominican Republic, and Puerto Rico can implement to decrease the spread of the three emerging viral diseases.

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