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SYSTEMATIC REVIEW ON DENGUE PREVENTION WITH SPECIAL REFERENCE TO HOSPITAL-BASED AND PUBLIC HEALTH INTERVENTIONS

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ABSTRACT

Dengue fever remains one of the most significant mosquito-borne viral diseases, posing a major public health challenge, particularly in tropical and subtropical regions. The effectiveness of hospital-based and public health interventions for dengue prevention by synthesizing evidence from published research, policy documents, and international health guidelines. The hospital-based strategies, including early diagnosis, standardized clinical management, infection prevention and control practices, patient education, surveillance, and healthcare worker training. It also examines public health interventions such as integrated vector management, environmental sanitation, community participation, health education, larval source reduction, insecticide-based control measures and surveillance systems. The isolated interventions produce limited outcomes, whereas integrated, multi-sectoral approaches combining clinical preparedness with community-based vector control and continuous surveillance significantly reduce dengue transmission and disease burden. Furthermore, public awareness campaigns, intersectoral collaboration, and strengthened health systems enhance the sustainability and effectiveness of dengue prevention programmes. The coordinated approach integrating hospital-based care with comprehensive public health interventions is essential for reducing dengue incidence, improving patient outcomes, and strengthening resilience against future dengue outbreaks, particularly in endemic and resource-constrained settings. In this article,

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systematic review on dengue prevention with special reference to hospital-based and public health interventions were discussed.

Keywords: Dengue, Prevention, Hospital, Public, Health, Interventions.

INTRODUCTION

Dengue fever is an infectious disease caused by a group of viruses that are transmitted through the bite of infected mosquitoes and is considered as one of the most important re-emerging tropical diseases of the 21st century. Contracted from any of the four serotypes of the dengue virus (DENV-1 to DENV-4), it is transmitted by infected Aedes aegypti and Aedes albopictus mosquitoes (World Health Organization (WHO), 2023). Dengue has become a more significant burden globally and WHO estimates that there are 390 million instances of dengue a year of which 96 million are clinical (Bhatt et al., 2013). The disease is present in over one hundred countries in the tropical and subtropical areas of Asia, both Americas, Africa, and Middle East (Guzman and Harris, 2015).

Several interrelated factors have contributed in the last two decades to the increase in the global incidence of dengue. Lack of provisions of effective infrastructure, high mobility of human population and changing climatic conditions, and inconsistent vector control measures have instigated the spread of Aedes mosquitoes and the virus it transmits into areas it was hitherto unheard of, such as arid and semi-arid regions (Brady et al., 2012; Ooi & Gubler, 2009). For instance, the frequency of the dengue outbreak appears in parts of Europe and the southern part of the United States of America, which are characterized by irregular cases of indigenous transmission notwithstanding their temperate climate (ECDC, 2020).

Dengue fever has gradually emerged as a major health concern for KSA, especially in its urban areas including Riyadh and Jeddah in the last decade due to several factors such as population growth, waste management and draining facilities and changing climate conditions which are favorable for mosquito breeding (Alhaeli et al., 2016; Al-Tawfiq & Memish, 2019). While Riyadh is in a semi-arid region, the city hosts a diverse range of microenvironments which favour Aedes mosquitoes breeding including irrigated landscapes, construction sites, standing water formations and poorly managed storm water drainages (Khan et al., 2020). Therefore, dengue fever cases in the city have simmered into repeated epidemics that both seasonal and costly year-round concern to health organizations.

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The Saudi Ministry of Health (MOH) has initiated many control programs to prevent the dengue virus such as fogging, larviciding, sanitation, and health promotion by increasing awareness among the community members. Measures that have been targeted according to the hospital include disease surveillance, early diagnosis, and better case management interventions among others (Halstead, 2019). However, research for this disease to find interventions to prevent and control the incidence of dengue fever is still high and other methods to hold the effectiveness of these strategies are still inconclusive evidence.

Some previous research indicates that conventional chemical-based methods such as pyrethroids and organophosphates could possibly be less effective attributable to the present insecticide resistance in Aedes mosquitoes (Smith et al., 2020). Furthermore, various community-based vector control campaigns that aim at modifying people's behaviours and practicing insecticide-treated nets, repellents, indoor and environmental residual spraying and other activities that need people to take active role, experience low compliances, knowledge and follow-ups (Alobuia et al., 2020; Erlanger et al., 2008). Health care facility readiness is also diverse, and whilst some facilities may have proper ways of monitoring, screening, and reporting dengue cases there are those that are unable to detect early warning systems of an outbreak (O'Neill et al., 2018). The objective of the study is to explore the systematic review on dengue prevention with special reference to hospital-based and public health interventions.

OVERVIEW OF RELEVANT LITERATURE

Global Prevalence and Burden of Dengue

Dengue fever is one of the major transmitted diseases that affect man in tropical and subtropical countries and is caused by Aedes Aegypti mosquitoes. Dengue has evolved from being an episodic disease in the second half of the 20th century to become a predicted epidemic disease today across the world with some of the continents being hyperendemic. Currently, it is estimated that more than 50% of the world's population is at risk of getting infected, with about 105 countries being affected by dengue incidence annually (Murray et al., 2013). The disease has now become a major social and economic as well as a health concern, especially in the low- and middle-income countries that experience high rates of population growth and urbanization (Stanaway et al., 2016).

Dengue virus (DENV) has been known to be responsible for several classifications of illness

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including apparently uncomplicated febrile illness to severe diseases including DHF and DSS. The disease is most prevalent particularly in Southeast Asia, Latin America, and some parts of Africa. For instance, in 2019, over 2 million cases were reported in a year an identification of one of the severing forms in Brazil (Teixeira et al., 2020). Likewise, constant new cases have been reported in India with an increasing trend keeping in view urbanized areas contagious due to improper disposing of water and storage facilities (Vaidya et al., 2021).

Notably, the geographical distribution of dengue is increasing southern states of China, some countries in Europe and that of America that formerly had regional transmission have also emerged as areas affected by local transmission due to climate change, globalization and enhanced human travels (Messina et al., 2019). These factors include rise in temperatures and changes in rainfall patterns leading to increase in the vector breeding sites for Aedes mosquitoes meaning that there are more months of the year potential for transmission of the virus (Liu-Helmersson et al., 2016).

Preliminary economic costs are also troubling; travellers have to spend a great deal of money to be tested and treated for the disease. It also overloads the healthcare system, and families have to spend large sums of money to manage illnesses in endemic countries. It is estimated that global annual direct and indirect costs of dengue fever exceed $8.9 billion USD, here the cost shifting impact was mostly borne by households through loss of income and expenditure on health facilities (Zeng et al., 2018). However, to date, there are still no specific antiviral agents accessible in the market and the deployment of vaccines was restricted, especially to three serotypes, so dengue prevention strategies still depend on vector control and extensive health promotion and education which are costly and difficult to sustain.

It is crucial to comprehend the worldwide trends and distribution of dengue fever to compare and contrast the situation in Riyadh with other places where the problem has become critical due to the changes in environment, particularly urbanization and climatic conditions that favor development of the disease. This makes a need for general non-partisan local approaches since the disease is now prevalent in almost every country.

Characteristics of Aedes Mosquitoes

Dengue virus can only be transmitted through the help of two species namely, Aedes aegypti and Aedes albopictus. Among these, Aedes aegypti is the most prominent vector because of its

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strict preference for human hosts, high susceptibility to a wide range of pathogens, and choice of breeding sites consisting of artificial containers that are often located near human habitations (Powell & Tabachnick, 2013). These vectors have truly thrived especially in urban areas thus increasing the prevalence and sustained nature of dengue virus all over the continents.

Despite the evident physiological and morphological variations in Aedes aegypti, this mosquito species is particularly well-suited for urban environments. Eggs are deposited on small placid clean water especially in containers, tires, flowerpots, gutters and in roof tops as pointed by Fay and Perry, (1965). This vector is predominantly peridomiciliary (rests indoors) and therefore is likely to bite humans, a characteristic referred to as endophagic. These attributes make it difficult to apply vector control measures such as bed nets and other protective measures in the evenings since the mosquito tends to bite in the early morning and late afternoon.

The lifespan of the mosquito comprises four stages, namely; egg, larvae, pupa, and adult stages. According to Christophers (1960), under ideal circumstances, it is possible to undergo this cycle within a period ranging from 7 to 10 days only. These eggs are very resistant and can survive under desiccation for several months and hence the species is able to survive in the dry season and then breed again in the rainy season (Rezende et al., 2008). This biological adaptability that Aedes mosquitoes possess has empowered them to not only exist in the regions of humidity but also regions of aridity, something that makes this vector robust.

Aedes albopictus, the Asian tiger mosquito which was only prevalent in Southeast Asia is now transported all over the world through movement of used tires. Although it is less anthropophilic compared to Aedes aegypti, it transmits dengue, chikungunya, and Zika virus efficiently (Bonizzoni et al., 2013). It is also more tolerant of cooler climates and rural environments, increasing the areas of the world where dengue virus might spread (Kraemer et al., 2015).

Poor urban development measures and the constant improvement and growth of these urban areas as seen from Riyadh provide the Aedes mosquitoes with numerous opportunities for breeding. Areas such as construction sites, water tanks, irrigation channels, and poor systems of waste management become favorable breeding grounds. These are compounded by tendencies of informal human settlements and inadequate housing structures that influence breeding grounds of vectors (Brady et al., 2015). Also, this has shown that climate fluctuations and unpredicted rain patterns directly cause the formation of temporary water puddles, which

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Impact Factor: 3.66

mosquitoes use especially during wet and dry season interphase.

However, many challenges continue to be faced in the management of the mosquito population as articulated in this paper. Fogging and larviciding measures of the mosquitoes have their drawbacks and disadvantages since some breeds cannot be easily reached or availed. Furthermore, many insecticide resistance effects have been attributed to the emergence of resistance to pyrethroids, which remains a threat to the chemical insecticide control strategy in the long run (Moyes et al., 2017).

Thus, the knowledge of the biology, breeding and behavior of Aedes mosquitoes is essential to implement efficient vector control measures. In the case of Riyadh, for example, where environmental conditions are tending to become more suitable for mosquitoes, then public health strategies need to reflect this to meet entomological realities in combating dengue fever.

Common Dengue Control Strategies Worldwide

The management of dengue fever is still a significant issue for communities across the world because of the lack of a protective vaccine that can be used globally, and because the virus can only be transmitted through the Aedes mosquitoes. Most countries of the world have invested mainly in what is called, if not disease control, then at least in vector control, community education, and clinical case management. All of these areas of control, biological substances, environmental control, publicity, and medical treatment are developed in a complex structure.
The usage of chemical vector control has been embraced for many years by South Asian and other dengue-endemic nations. It works by employing insecticides like organophosphates (malathion and temephos) and pyrethroids (deltamethrin and permethrin) to besist insect invasion. These are by means of fogging, indoor residual spraying, and larvicidal treatments. Although, the use of these chemicals is very effective in the control of the mosquito vectors, their continuous and uncontrolled application hampers the effectiveness of the reconstructed human vaccines since they have paved way for resistance among the Aedes aegypti and Aedes albopictus mosquitoes in different parts of the world (Dusfour, et al., 2019). Resistance development has been reported in more than 60% of mosquitoes from Southeast Asia and Latin America, which means that there are demands for rotation of chemical classes and integrated vector resistance management (Marcombe et al., 2014).
Scientists have recently paid more priority to the methods of biological control than the chemical methods. These include the larvicides that include the Bacillus thuringiensis

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Impact Factor: 3.66

israelensis, a bacterium that kills mosquito larvae without posing harm to the surrounding environment (Lacey, 2007). Another experimental innovation is the spread of Wolbachia susceptible Ae. Aedes mosquitoes, whereby the affectivity of the mosquito in transmitting the dengue virus decreases. There is evidence that large scale field trials in Australia, Indonesia and Vietnam showed a reduction of dengue infections in areas where Wolbachia inhabited Aedes populations (Utarini et al., 2021). For instance, the sterile insect technique (SIT) of releasing sterilized male mosquitoes to mate with wild females and reducing their ability to reproduce, an approach has initially worked in Brazil and China as per Zheng et al. in 2019.

Environmental management has been one of the most effective ways to prevent dengue. To achieve this includes the zeal to eliminate or minimize mosquito breeding grounds including water sources such as; disused containers, tires, debris, and faulty drainages. With economic hubs with high population densities and informal settlements, it becomes challenging to implement these practices in a consistent manner (Heintze, Velasco Garrido, & Kroeger, 2007). These interventions are based on collaboration between the sectors of public health, municipal administrations and other groups of affected communities.

Community participation and health promotion is a comprehensive approach that ensures sustained control. Such ones as school-based education, utilization of media, community cleaning activities, and providing mosquito repellent and treated bed nets. These programs rely heavily on the level of knowledge, attitude and practice of the people regarding dengue prevention (Espino et al., 2012). For instance, in Philippines and Malaysian communities' proper structure in community mobilization tactics has been associated with corresponding reductions in breeding indices and dengue (Vanlerberghe et al., 2009). However, like any campaign, these programs often lack funding, face specific cultural challenges and lack proper support systems when followed up.

While vector control programs are paramount in the prevention of disease transmission in environments, hospital-based initiatives are crucial in the next step of combating the disease that comes with control of the vector. That is why it is recommended that when an individual contracts dengue, he or she should seek medical attention as soon as possible to avoid severe cases, hospitalization and death. Most of the countries in the world today have come up with clinical management protocols for dengue cases which include; replacement of fluids, monitoring of complications or warning signs, and categorization of the severity of the disease (Lee et al., 2017). The application of rapid diagnostic tests in diagnosing malaria has enhanced early diagnosis particularly in low-resource settings despite presenting some challenges in its

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Impact Factor: 3.66

sensitivity and specificity (Blackell et al., 2012).

In addition, integrated disease surveillance systems are recognized as effective tools that help in early identification of disease outbreaks. For instance, Thailand and Singapore implement hourly information from hospitals about the vectors and release control measures as well as public announcement (Gubler, 2011). However, common use of such systems requires adequate reporting, data sharing in between the different institutions and qualified staff.

In sum, where there is a large span of programmes implemented to control diseases, the efficacy of those programmes depends on the ecological setting, people's behavior, political capacity, and health systems in place. The best interventions are those that are chemical, biological, environmental, clinical, and social depending on the epidemiology patterns of the region.

Dengue Situation in Saudi Arabia and Riyadh

The incidence of dengue fever in the Kingdom of Saudi Arabia, especially in the city of Riyadh and Jeddah, has taken a new dimension due to many factors including urbanization, environment and demography. In the past, dengue fever affected only the coastal areas, including Jeddah and Makkah because of suitable conditions for breeding of Aedes mosquitoes, including humidity and rainfalls. Nevertheless, over the last few years, the disease has spread to the central areas, and Riyadh recently has recorded higher disease rates even though the climate in this region is deserted (Ashgar et al., 2020).

These changes are, however, partly attributed to climatic changes that have in recent years seen a lot of transformations. Despite the low mean annual rainfall, especially in Riyadh, occasional irrigation, water storage, storm or other conditions that apply to create water logging habitats for mosquitoes for a certain period. These artificial breeding places common in construction sites, roof tanks, and containers in gardens play a role in the breeding of Aedes mosquitoes (Ahmed et al., 2019). Air conditioning systems covered tanks also make the climate of complexes cool and humid that are suitable for Aedes aegypti.

The urban structure of Riyadh exacerbates this problem. The influx of people and population growth makes it easy for vectors to thrive because of poor waste management practices in the city. Informal settlements for instance may use portable water sourced from neighbors' water supply, stored in utensils, buckets and any other open containers for storage and once contaminated with feces from the surrounding environment act as a breeding ground if not

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Impact Factor: 3.66

cleaned or covered (Mohammed et al., 2021). Industrial construction in the various parts of Riyadh also contributes to the situation where debris and open bins are left over to accumulate rainwater.

The Saudi Arabian government has become aware of the increasing cases of dengue and had embarked on putting several control measures in place. The Ministry of Health (MOH) together with the municipal authorities has developed vector surveillance, insecticide fogging and to some extent a sensitization crusade. The MOH has also harmonized care and treatment clinical management guidelines and considerate dengue wards in the tertiary health facilities to contain the outbreak (Alsharif et al., 2022). In addition, all new programs of Integrated Vector Management (IVM) have been conducted in the urban areas with a focus on chemical spraying, routine larval source management and community mobilization.

However, interventions have emerged as ineffective with fluctuating results. Before discussing this, one needs to understand that one of the significant difficulties is to identify and track the cases of dengue. The symptoms of Covid-19 overlap with those of the flu and many other febrile illnesses, meaning that diagnosis is sometimes not made promptly particularly among primary health care facilities, and there is limited availability of point of care testing. Also, there is low level of compliance with the measures put in place for controlling the vectors. Research conducted in households within the Riyadh region shows poor awareness regarding the breeding sites of mosquitoes and the disease consequence's magnitude denoting that residents apply few preventive measures in their homes (Alahmadi & El Keshky, 2021).

Further, the excessive use of chemo-techniques such as fogging in combating the mosquitoes may result in development of resistance among the local population of mosquitoes. Little research has been done on the resistance status of Aedes in KSA; however, early data from Jeddah and Makkah indicate a decreasing susceptibility towards pyrethroids (Habib et al., 2020). Failure to include a mechanism for monitoring resistance, the use of these chemicals may gradually diminish the effectiveness of vector control.

The implementation of integrated disease early control centers also lead to coordination problems between the health sector and the other sectors which are related with Riyadh dengue prevention such as environment services and education and municipal departments. Inadequate, discontinuous pieces of information and minimal instances of information exchange in real-time are related to slow deployment efforts. Recent scholarly work by Saudi researchers has

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CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

established that the country needs an inter-sectoral approach to dengue control, which involves real-time disease surveillance, ideal vector control, public health campaigns, and inter-institutional cooperation (Basheer et al., 2021).

All in all, it is crucial to note that despite the activities Saudi Arabia has taken in order to eradicate this disease, specifically in large urban areas like Riyadh, several shortcomings exist. Due to factors such as the urban environment, together with behavioural, institutional and environmental factors it is necessary to reconsider current strategies and employ more comprehensive and arguably evidence-based concepts in line with the community needs.

KEY THEORIES OR CONCEPTS

Integrated Vector Management (IVM)

Integrated Vector Management (IVM) is therefore a rational, evidence-based, cost-conscious approach to resource utilization geared towards vector control. Its principle is based on the combination of chemical, biological, environmental, and social approaches within a mutually connected framework that is sensitive to the geographical area, unlike the former 3-5-7 tactic (Beier et al., 2008). IVM was formally endorsed by the WHO in the early 2000s as the better strategy for replacing the chemically reliant vertical approach, which had been facing serious challenges including resistance, lack of sustainability and low community participation (Yadouléton et al., 2010).

The principal features of IVM include the application of multiple physical vectors; cross-organizational work; coordination with health care delivery systems; reliance on scientific data when making decisions; and participation of communities and interested parties (Achee et al., 2015). These components discussed here are therefore relevant to malaria but equally important in the case of dengue where the vectors, Aedes aegypti and Aedes albopictus live in predominantly man-made breeding places in the urban areas.

Second, Urban centred strategies have to be based on local ecological and socio-economic analyses and have to be adapted to the context. Dengue transmission in general is constrained by factors; high population density, poor disposal of waste, irregular water supply and fragmented systems of governance (Meder et al., 2003). In such contexts therefore, stand- alone forms of chemistry, for example fogging or even indoor spraying may be inconsequential or transient at best. IVM focuses on the reduction of larval source breeding sites such as container disposal and proper water management to complement structural and social interventions and other innovations like better drainage systems (Horstick et al., 2010).

Moreover, IVM promotes a multi-sectoral approach whereby the sectors of health, housing, water, education as well as local government come together and coordinate their responses. Such a model is essential for enhancing the possibilities of sustainable expansion of dengue control measures since multiple sectors are involved, especially for a city like Riyadh where many departments influence the sources of vectors' breeding places (Erlanger et al., 2008).

However, to summarize, the following points are in favor of IVM that makes it appropriate for the countries at different stages of development and infrastructure quality of the health sector: Thus, for example, turning to Latin America, IVM has been applied through decentralisation, enhancing the planning at the municipal level and working with the direct participants in the decision-making process for some time (Valle et al., 2013). IVM therefore pertains to Riyadh because of its capacity to coordinate the disintegrated vector control, constantly monitor within the community and involve the community in its plans.

Health Belief Model (HBM)

The Health Belief Model (HBM) is a common theoretical approach of understanding and predicting health behaviors especially when it comes to disease prevention. The health belief model was formulated by social psychologists Hochbaum, Rosenstock, and Kegels in the 1950s and posits that a person is likely to engage in preventive action if they feel a personal threat, if the consequences of the disease are viewed as severe, benefits of taking preventive action are seen and if they perceive few barriers to the action (Rosenstock, 1974).

HBM has been used often in vector-borne diseases studies to examine the role of perceived control factors in the prevention activities like use of repellents, elimination of sources of standing water, and covering of water containers with lids. Several studies have also identified that perception of risk in dengue has a direct impact on communal compliance with recommendations (Koenraadt et al., 2006). For example, those people who do not regard dengue or other similar diseases as very dangerous or common will not pay attention to the messages or protect themselves even if such messages circulate intensively.

Furthermore, components of HBM like" cues to action" including media campaigns, community alerts or firsthand experience of a family member falling sick due to dengue has been reported to bring about behavioral change. In another study conducted in Vietnam, people who have been affected by dengue in the past are more likely to engage in cleanup campaigns and report places where the vector breeds (Van Benthem et al., 2002). This lends credence to

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the notion that people are more receptive to messages that are targeted at their individual personas and appeal to their emotions.

HBM also proves useful in conceptualising barriers to behavioural change based on perceived knowledge, perceived cultural beliefs, and perceived perceptions of the inconvenience thereby postulating a new HBM. Low-income families in several studies conducted in Asia and the Caribbean perceived that covering water containers or cleaning drains took time was not important because they relied on the government's fogging activities to safeguard them (Pérez-Guerra et al., 2009).

However, it is crucial to recognize that HBM-centered interventions have been proven to succeed in changing behavior, in particular when combined with several other forms of community mobilization efforts. Brazil and Thailand health campaigns that were formulated using the HBM styles showed an increase in the use of household larvicides, improved water storage and enhanced participation in dengue surveillance (Khun & Manderson, 2007).

The HBM approach could provide significant implications if applied to Riyadh to identify community engagement disparities. It can be used to ensure health authorities establish suitable awareness raising interventions aimed at correcting misconceptions and reminding individuals and communities about the nature of dengue and the risks associated with its outbreak in semi-arid urban centres and calling for collective efforts to prevent it.

Public Health Systems Framework

The Public Health Systems Framework provides a holistic approach to understanding the structure of health systems, its service delivery, and governance to address issues such as dengue fever. It fosters a systems approach, which negates the reinforcement that disease control hinges on sporadic measures but rather a combination of workforce capacity, information systems, financing, regulation and community participation.

In its essence, this framework interprets the health system as a set of complex interactions of institutions as well as actors who create, fund, and deliver services. They include the Ministry of Health, hospitals, municipal services, laboratories, vector control units as well as the general public in the context of dengue control. Quantitative coordination of these actors defines the capacity of the system in terms of surveillance, outbreak response, case management, and community engagement (Shakarishvili et al., 2010).

One of the four indispensable components of this framework is surveillance, as the systems

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Impact Factor: 3.66

employed must inform epidemiological and entomological data in a timely manner. This helps in early detection of disease outbreaks, mapping of endemic areas, and management of available resources. However, cross-level implementation of surveillance systems remains a challenge in most countries including Saudi Arabia, inadequate data quality and data sharing between agencies (Madhav et al., 2017). Lack of surveillance affects the early warning systems and thus slows down the vector control measures.

Another critical factor is service delivery, especially the efficiency of healthcare facilities in diagnosing and treating dengue. Lack of training, inadequate resources, and variation of clinical protocols lead to under-diagnosis, overwhelmed health systems, and delayed treatment which all contribute to disease burden and transmission (Barrett & Brown, 2008). Good practice in capacity building is also recommendable by providing training to health facilities and professionals, education and distribution of protocols.

The other important aspect of the public health system is governance and leadership. Eradication of disease control involves a multisectoral approach of housing, water, education, environment, and enhancement of political will to fund sustainable structures like sanitation and drainage systems (Agyepong et al., 2017). Singapore and Cuba offer good practices of a centralised approach and a connection between health and urban planning to prevent a continuous spread of dengue.

Community engagement is the fourth and final foundation to this framework. And of course, it is self-evident that no public health system can work if it lacks faith and endorsement from the public. Promoting community participation through dissemination of information, involvement in planning processes and raising awareness reduces vulnerability especially in urban dengue-affected areas (Gilson, 2003).

For Riyadh, the Public Health Systems Framework can help the policymakers to identify the areas of deficiency in dengue control not just from an entomological standpoint but from multiple aspects of the system including collaboration between agencies, surveillance, and preparedness for health. It entails the formulation and implementation of comprehensive measures arising from medical, social, and environmental realms of dengue control.

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EMPIRICAL STUDIES

Effectiveness of Chemical and Biological Vector Control:

Several research works have been done on the efficacy of chemical and biological control of the dengue vector. They focus majorly on the vector, Aedes aegypti whose control is imperative since there is no cure for dengue or effective vaccine. In the last two decades, the use of insecticides and larvicides has remained an option for many countries. However, there are factors like resistance mechanism, ecological impact, and sustainability factors that have contributed to the search for biologically based insecticides.

It is a fact that chemical fogging and residual spraying control programmes were effective for reducing adult mosquito densities and interrupting the transmission chain during outbreaks. For instance, Thavara et al. (2004) in their study conducted in Thailand showed that deltamethrin-based insecticide fogging led to near elimination of mosquitoes and reduced the reported number of dengue cases particularly during the periods of transmission. Likewise, in urban areas of Colombia, the organophosphate larviciding with temephos has reduced the larval indices and case counts remarkably (Ocampo et al., 2006). However, most of these successes were considerably short term and did not translate to long-term positive changes.

Another issue that has cropped up recently is product resistance, especially through insects developing a resistance to insecticide. Survey carried out on Aedes aegypti in Vietnam showed that all the three compounds namely permethrin, cypermethrin, and malathion, popular in dengue-endemic countries were fully resistant and way ahead by Aedes aegypti (Kawada et al., 2014). Similar observations were made in Sri Lanka where bioassay conducted following WHO recommendation, revealed resistance to pyrethroids and reduced effectiveness of fogging (Fernando et al., 2017). This insecticide resistance can be blamed for the excessive and improper use of insecticides in vector control, and also to the use of insecticides for agricultural purpose which also has added pressure.

However, due to the continued emergence of resistance, resulting in a decline in the efficacy of chemical methods, several countries have resorted to biological control methods. One of the best-known microbial pesticides is Bacillus thuringiensis israelensis – Bti – which contains proteins toxic to these larvae. Such research was conducted in Malaysia where it was determined that if Bti was administered monthly in the urban breeding sites larval density was reduced by 70% within one year period (Lee et al., 2010). Notably, Bti is residual, unlike other chemicals, and does not have any impact on other species, making it an environmentally

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friendly option.

Another field with potential has been identified as endosymbiotic bacteria such as Wolbachia that when ingested by a mosquito, inhibits the mosquito's capability to transmit dengue virus. For instance, experiments conducted in the province of Yogyakarta, Indonesia showed that there was low vector competence of Wolbachia infected Ae. aegypti and resulted in a 77% reduction in dengue outbreak in the areas that received the treatment (Indriani et al., 2020). Comparable decreases were also observed in Cairns, Australia, in blinded randomized controlled trails reporting the effectiveness of this approach and its feasibility at community level (Ryan et al., 2019). However, most of these approaches need a consistent and continuous disbursement in order to apply the changes and along with this, a comprehensive public sensitisation effort.

Another area of biological advancement consists of genetically modified mosquitoes, including the Oxitec OX513A that develops only sterile offspring. In Brazil it was found that more than 90% reduction in population of local Aedes aegypti in a controlled field release study for several months (Carvalho et al., 2015). However, these genetically modified programs have faced much criticism in several countries, and controversies are still present in terms of the effect on ecological systems and the failings of regulations.

Together, these findings point to a paradigm change toward more synergistic multi-disciplinary treatments combining chemical and biological ones especially given the rising instances of resistance. It is equally important to ensure that the use of these tools is targeted to respect context-specific issues on vector ecology, resistance, and communities. These approaches will ensure effective long-term control through surveillance-driven deployment of insecticide, rotational use of insecticide, and use of environmentally friendly solutions.

Community-Based Interventions:

Besides the chemical and biological control other community-based strategies have been used for the integration into dengue prevention programs. These measures entail altering individual behaviors and empowering communities to drive behavior towards the elimination of breeding grounds and appropriate use of personal protective measures as well as upscaling knowledge on the issue and available check points. A review of several empirical research studies addressing such interventions reveal that a considerable number of them indicate the significance of the interventions for the sustained decrease of dengue incidence when implemented and sustained properly.

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Impact Factor: 3.66

In world experience, a Nicaraguan RCT identified that source reduction applying community activation in health education and in active surveillance of Aedes breeding places and probabilistic control together reduced the Breteau indices and incidence of dengue (Sanchez et al., 2005). It was more sustainable than the fogging method adopted by the community through recruiting the services of the health workers, school, and other juvenile committees in the neighborhood. Finally, knowledge and perceived community behavioral changes regarding eclectic variables including covering water containers after use and disposal of litter were documented to have changed positively after the intervention.

Another cluster randomized trial was the Camino Verde trial conducted in Nicaragua and Mexico that underpinned education in the households regarding the evidence-based approaches towards the elimination of mosquito breeding sites. The outcome showed that there was up to 29% reduction of dengue incidence and the vector indices in the areas under intervention than to those that were not under intervention according to Andersson and his fellow researchers. This event also exposed the effectiveness of engaging the people in learning processes, development of fellow trust and the use of local trainers in maintaining the changes.

Such successes notwithstanding, there are drawbacks to how these steps have been implemented in the following ways. For instance, a cross-sectional study result on people in urban area of Sri Lanka, revealed a prevalence of knowledge in the community regarding dengue disease but low practice in the implementation of practice showed that this was due to the belief that vector control was the responsibility of the government (Tissera et al., 2013). Experienced in several other matters, this “externalization of responsibility” is one of the major factors that can hinder long-term outlook.

In addition, one of the factors that affect community-based interventions is socio-cultural factors. A document suggested that in rural Thailand, cultural perceptions about the roles and responsibilities of men and women, poverty, and other conventional norms influenced the household’s involvement in dengue prevention. Thus, it was common to see women being assigned the roles of washing utensils and caring for the sick, but they were not allowed to participate in decision making or attend any meeting that discussed vector control (Lenhart et al., 2014). This paper looks into such dynamics as important in focusing on any interventions of fairness to its intended targets.

Fiscal support is therefore another long-term factor because it relies on institutions. Research

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CODEN (CAS, USA): JRLAB4
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studies from Brazil point out that where community campaigns are taking place, they deteriorate if they are not frequently supported by municipalities, training programs, funding, as well as linkages with funding and religious institutions within the setting (Caprara et al., 2009). Where these linkages are lacking, increases are momentary, and the larval indices rise again, even after a slight improvement.

Among these solutions, technology-enhanced interventions can be noted as relatively recent innovations. Technology Intervention: Social networking platforms, applications on smartphones, testing for response to messaging of topics, mobile phone alert traditions, such as Singapore and Philippines, which use these forms of communication to create awareness and report cases of breeding of mosquitoes. A study done in Colombo, Sri Lanka says that the use of mobile apps for the reporting of standing water helped to fasten the response of the municipal authorities and brought more satisfaction among the communities (Wijayanti et al., 2020).

Therefore, it can be inferred that for any control measure to be effective, there is need to adopt community-based strategy since source reduction needs to be implemented at individual household level in urban settings. Their success, however, hinges on trust, ownership, continuity, and integration with broader public health systems. The study therefore recommends that cities such as Riyadh should employ a participatory model that is anchored on the principles of belonging and culture in order to improve dengue prevention.

Hospital-Based Interventions:

Hospitals and healthcare facilities play a central role in dengue, especially in detecting it at an early stage, controlling most of its manifestations, as well as reducing mortality and generating epidemiological data for further utilization in tackling this illness. They are commonly divided into three main groups: Surveillance systems, early clinical diagnosis, and case management strategies. Each of these plays an ultimate role in preventing the spread of dengue especially within the endemic and epidemic-prone cities.

Hospitals that have adopted surveillance systems play a critical role with regard to the identification of dengue cases and response. Beatty et al. (2010) have stated that effectiveness of national dengue control depends on current data quality and the speed in hospitals. Real-time syndromic surveillance systems are implemented in hospitals in certain countries like

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Online ISSN: 3048-667X
CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

Singapore and Thailand, decisions to increase the level of case detection and the initiation of vector control can be done immediately (Wilder-Smith et al., 2010). These systems provide data on febrile illnesses, patients' demography, and lab confirmation with comprehensive health databases for modeling and geographical approach for isolating hot areas.

However, it is important to note that hospital-based surveillance may be limited by many factors including poor staffing, inadequate personnel, and poor recording and reporting to the surveillance systems at the public health agency. In low and middle-income countries, some features of reporting delay, significant lack of laboratory confirmation as well as under-diagnosis limit desk research utility of surveillance data (Runge-Ranzinger et al., 2014). Furthermore, low numbers of diagnostics for dengue in primordial healthcare facilities lead to its misdiagnosis as other malaria, chikungunya or complicating typhoid (Chakravarti & Arora, 2012). These limitations do not only have negative effects on disease preparation but also conceal the actual incidence of dengue within overall health statistics.

Hypertension is one of the most critical vital signs that often entail early diagnosis as part of the hospital's intervention. Early identification of dengue signs and the presence of severe warning signs helps the patients receive adequate attention and lowers the death rates in individuals with the illness. NS1 antigen assays for RDTs and ELISA with IgM/IgG also have gained popularity because of their speed than the other diagnostic tests. In Laos, Blacksell et al. (2011) demonstrated that NS1 tests can detect dengue in the first day of fever with sensitivity of more than 70% particularly, in first time infections. But diagnostic specificity in depressed patients also depends on the serotype and the day of illness as well as the other pathogens present in different iterations (for instance, Hunsperger et al., 2016). This underlines the importance of employing the dual approach to diagnosis – a clinical suspicion supplemented by laboratory findings, due to variability of epidemiological settings.

Implementation of the clinical practice guidelines of care management would help in the admission to hospitals and influence its support care devices based on seriousness of the ailment. Presently, there is no cure for dengue, but prompt identification of the warning signs and the giving of intravenous fluids would help immensely in avoiding shock or hemorrhagic episodes. In a recent survey conducted in a large hospital in Vietnam, Nguyen et al. (2013) showed that WHO recommended case management practices greatly contributed to decrease the mortality rate of dengue including severe cases. Improving health workforce competencies,

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Online ISSN: 3048-667X
CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

especially in aspects of assessments, triage, fluid resuscitation, and monitoring of the hematocrit and platelets were other emergent needs pointed in the study.

The governments of several countries have developed standard treatment protocols and dengue specific wards to hospitals with an aim of enhancing the flow of treatment. Integrated care pathways with algorithms and flowcharts in dengue cases in Malaysia caused a cut short of hospitalization by one-third and reduced the number of patients admitted to the Intensive Care Unit (ICU) by one-fifth (Yusoff et al., 2012). Nevertheless, the effectiveness of such models depends on the systematic factors; hospital funding, staff strength and patient enlightenment.

A study naïvely suggests that although tertiary hospitals in Saudi Arabia are pound-for-pound better equipped, they still lack appropriate diagnosis equipment for screening dengue as well as the updated clinical management protocols to adopt the same. Almalki et al., (2022) write that there is a necessity for largely strengthening laboratories and better cooperation between the medical care facilities as well as the municipal level dengue surveillance. Also, because there are travelers and immigrants from countries affected by dengue fever, there is a possibility of importation that may mentor further transmission—highlighting the part of the hospital on both clinical and epidemiological fronts.

Therefore, based on these empirical findings, hospital-based interventions that are adequately supported and allied with national healthcare systems are effective means of controlling the occurrence of dengue fever. Early diagnosis coupled with standardized, testing treatment are important for dengue fever management and good reporting systems are critical in addressing this disease in urban areas.

Regional and Riyadh-Specific Studies:

Although dengue fever has been mainly endemic to tropical regions, its recent appearance in the Middle East, especially in urban Saudi Arabia has drawn both scholars and policy makers into research. Several research on Middle East countries documented the emerging nature of the disease and its progressive movement inland in the last two decades with factors such as increased urbanization, cross-border travel and changing climates further boosting the propagation of dengue (Al-Zahrani et al., 2021). Therefore, Riyadh as one of the populous cities of Saudi Arabia can serve as a location of vector-borne disease research due to factors such as population density, construction sites and especially urbanization and changing

Online ISSN: 3048-667X
CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

environment.

A temporal investigation on the distribution of dengue cases in Riyadh was conducted by Al-Nasser et al., 2020 where he established that dengue cases increase exponentially in many cases during the post-rainy season; the months of April, May and June inclusive. The authors described focal breeding grounds in communities with poor water drainage, construction zones and low-income peri-urban areas. This was supported by entomological surveys, which confirmed the presence of Aedes aegypti larvae in rooftop water tanks, tyres and any container that has been found to be unused in the residential areas.

According to clinical manifestations, a cross-sectional study done in KSA, King Saud Medical City for 5 years showed among 27 dengue patients 62% has classic trait of dengue fever, myalgia and rash and 14% develops severe form of dengue; DHF (Al-Mazrou et al., 2019). For instance, there were delays in diagnosis and wrong prescription of antibiotics among the patients, implying there was no policy being followed. The study suggested that febrile patients should undergo dengue screening during the high-risk season and to enhance diagnostic facilities at the primary health care sector.

Research on dengue outside KSA was also useful in identifying the disease in other regional Middle Eastern settings. Khamis et al. (2019) for the first identified local outbreak of dengue in Muscat through inadequate surveyed vector control, absence of public health awareness, poor waste management in middle east-central Asia. The experience exposed some Gulf cities which were hitherto believed to be at low risk adhering to arid weather. Along the same line, outbreaks in Al-Hudaydah link to the breakdown of municipal services due to conflict, which shows the direct correlation between the infrastructure in a community and the risks of dengue (Bawazir et al., 2018).

Sero prevalence surveys in Jeddah and Makkah in the recent past have also revealed a significant seropositivity to dengue in the inhabitants suggesting active transmission and cycles (Al-Ghamdi et al., 2017). These outcomes are important in the argument because they state that dengue is not only an imported disease in Saudi Arabia, but its vectors are habituated in several cities, including Riyadh. This dispels a notion in the literature that places arid climate as less favorable for dengue transmission hence changing the approach to the vector risk assessment in the desert urban areas.

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CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

Similarly, a study done by Balkhy et al. (2021) conducted a spatial epidemiological study of dengue in the Riyadh region and found out that using GIS mapping he was able to identify the hotspots of the disease. It showed that distance to water, population density, stagnant water sources and low socioeconomic status are correlated at different degrees of the outbreak's cluster. With regard to vector breeding and control, it recommended the adoption of geospatial tools to achieve effective surveillance before allocating resources to high-risk areas.

THEORETICAL FRAMEWORK

Therefore, choosing a suitable theory facilitates the organization, analysis, and application of data in empirical research. To evaluate the efficacy of prevention measures of dengue fever in Riyadh, it is important to look at the IVM and the Public Health Systems Framework to analyze the community and environmental level intervention in addition to the health system response in terms of integrated layers of interventions. These frameworks can be seen as adding operational versatility, systematic thickness, as well as a cross-sectoral coverage to one another.

Rationale for Using Integrated Vector Management (IVM)

Integrated Vector Management (IVM) is a dynamic and evidence-based strategy that was designed to overcome the shortcomings of single tool vector control. Proposed by the WHO as a response to increasing resistance and ecological unsustainability in anopheles' control, IVM is grounded in multi-stakeholders, localization, and community engagement (van den Berg et al., 2012). The reason why IVM was used in this study is due to modularity and portability and has been successfully used in various geographical, climatic and political settings.

In an urban setting of more significant concern as Riyadh, with concerns of urban growth rate, water storage methods and solid waste disposal, and the general economic differences, it is clear that a one-size-fits-all approach does not work for vector control. IVM addresses these complexities since it allows incorporating chemical, biological, environment, or social remedies. For example, it makes it possible to spray larvicide, conduct public health education, modify the environment, and implement community-based surveillance at the same time and in line with the vector and system ecology along with human and administrative capacities in the given context (Chanda et al., 2013). This feature of organizing makes it particularly useful for cities of the type of Riyadh, where there are problems to be solved, which are connected with the functioning of different jurisdictions (municipal, sanitary-and-epidemiological, environmental).

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Online ISSN: 3048-667X
CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

IVM also includes continuous monitoring and feedback systems to the implementation of interventions, showing ways that can be used by local governments to change interventions due to changes in vector's behavior or resistance, or community response. The programmes that employed IVM strategies in Kenya and Philippines produced prove that dengue cases declined sustainably through cooperation with the local government and the use of strategic control instruments that target vectors contingent on entomological intelligence (Utzinger et al., 2014). In these contexts, IVM was not only used as a vector control tool but was also a policy map of the agencies' collaborative framework, which is quite necessary in Riyadh today due to fragmentation of practices.

In addition, IVM is consistent with the goals of health equity by boosting the health literacy of the populace based on community engagement. In Riyadh, increasing acknowledgement of the social behavior and slum dwellers as agents. Also, due to the participation of a large number of households encouraging this element is the best strategy of combating social diseases as it increases mass participation and helps to overcome the lack of trust in the health system. Thus, in addition to technical adaptability, IVM consists of social and institutional sustainability that recommends the approach for vector control assessment in semi-arid urban regions.

Justification for the Public Health Systems Framework

Despite the potentiality of IVM to treat the ecological- community aspect of dengue control, there is the need to incorporate a systemic appraisal of health facilities and processes, decision-making systems, and institutions. This is where the Public Health Systems Framework proves to be more useful. This approach provides an uncommon view that embraces an examination of a number of large-scale issues such as; the resources, systems and policies as well as the players in relation to infection disease progression and control measures (de Savigny & Adam, 2009).

More specifically it can be utilized to analyze how such interventions that are undertaken in the health systems in Riyadh specifically within the context of the hospital interact with the general health governance systems. Although health systems are organizations that deliver clinical services, they are equally a set of organizations, a financial structure, policies, and people. For dengue vector control, there must be integration of these components. For instance, inadequate primary care facilities to diagnose diseases, inadequate data surveillance between the hospitals and municipal administration, and between the ministries and their budgets lead to system gaps (Shakarishvili et al., 2011).

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Online ISSN: 3048-667X
CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

The framework also facilitates the assessment of Health Information Systems, which are vital in the monitoring of the outbreak of dengue. In many contexts, and especially in the GCC, the hospital data are not routinely reported to the vector control units or integrated into public health surveillance dashboards. The Public Health Systems Framework also calls for the consideration of working together and data governance and feedback that are required for real time analysis of epidemics (Mounier-Jack et al., 2014).

Another useful component is governance and leadership. Since multiple departments synchronize some of Riyadh’s dengue control interventions (e.g., Ministry of Health, Riyadh Municipality, Environmental Services), the framework helps to assess accountability and integration issues. Sheikh et al. (2015) revealed that weak governance leads to poor communication, ambiguous roles, or lack of coordination hampers even technically good interventions.

Moreover, the framework has enablers for considering service delivery equity. Migrant laborers and the low-income population, which is the majority of the population in Riyadh, may face difficulties in accessing diagnosis or adequate treatment. The Public Health Systems Framework incorporates social determinants of health into its structure, thereby permitting a comprehensive evaluation of which population groups to gain from dengue interventions and which remain excluded, making it an excellent tool when it comes to policy formation.

Integration of Both Frameworks

The combined IVM and the Public Health Systems Frameworks provide a coherent approach that connects the concepts of entomological control strategies and health care delivery. This is so since the prevention of dengue is a combination of environmental engineering, healthcare, behavioral psychology, and institutional factors. If intervention effectiveness is viewed from only the vector ecology model or the healthcare delivery model, it would give a skewed perspective. Consequently, a dual-framework approach is embedded in a way that I can assess its ground-level operations but also policy-level foundations.

This comprehensive approach allows researchers and policy makers to map causal relationships between entomological indicators (larval indexes, vector densities) and clinical indicators (hospitalization rates, case fatality) adjusting for variables such as health worker training or community mobilization or budgetary implications. For example, if vector control processes in Riyadh, turned out to reveal diminished efficiencies then by the establishment of this combined

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CODEN (CAS, USA): JRLAB4
Impact Factor: 3.66

framework investigators are able to subdivide the cause of inefficiency into either chemical resistance by vector, poor adherence by the community, inept collaboration in between various agencies or even late reporting by hospitals.

Also, this synthesis relates to adaptive learning, the capability of a system to change the learning approach depending on the result obtained. IVM is in consonance with the specific factor of the Public Health Systems Framework that stresses institution's responsiveness and appropriate use of the available resources (Sundararaman et al., 2012). This dual lens fosters continuous improvement and policy coherence.

CONCLUSION

In conclusion, it can be stated that not only is the use of IVM and the Public Health Systems Framework not simply a matter of preferred methodological approach in assessing the multifaceted factors of dengue and its control, but a definite necessity when addressing such multi-level approaches to the issue. It provides the ecological resolution sufficient to encompass a wide scale of threats and opportunities in vector borne illness prevention but it also encompasses the broad system's view.

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