Gender- and Age-Stratified Aedes Mosquito Rising and Dengue Burden During COVID-19 Pandemic in Saudi Arabia

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Research Article

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Abstract

Background

COVID-19 pandemic led to unprecedented healthcare gaps and challenges linked to COVID-19 pandemic induced constraint on domestic mosquito vector and vector control programs leading to increase in vector-borne diseases public health burden. The study evaluate gender and age linked the increasing Aedes mosquito vector and Dengue virus fitness during COVID-19 pandemic response, in order to provide evidence-based policy decision and priority on integrated vector-borne diseases management with COVID-19 response interventions in Jeddah municipalities, Saudi Arabia.

Methods

A cross-sectional, retro/prospective and analytic increase mosquito risk factors and cases prevalence study was conducted to guide ongoing field mosquito surveillance and integrated vector control interventions during and post COVID-19 response and recovery interventions in Jeddah municipalities, Saudi Arabia.

Results

There were marked but not statistically significant fluctuations in the number of monthly confirmed dengue cases during both periods. The highest number of monthly confirmed cases before the pandemic was reported in June 2019 (205 cases) and January 2019 (247 points). Similarly, the first peak during the pandemic was recorded in June 2020 (274 cases), whereas the highest number was documented in April 2021 (311 cases). Monthly gender-based trend of dengue cases before and during the COVID-19 pandemic showed that males were the most affected over the study period as compared to the females. During Covid-19, the trend is increasing with peak over 150 cases in June 2020 and April/May 2021 during COVID-19. Age-stratified variations of dengue cases reveals that more cases were during the age range of 15–45 and few above 45 years old with peak precovid recorded in June and December 2019 with over 150 cases recorded. We documented a rise in dengue cases amongst local Saudi with a surge from April to the peak over 100 dengue cases in July 2020, but lesser that non Saudi cases with a surge during the same period and peak over 170 dengue cases in 2020.

Conclusions

To the best of our knowledge, this is the first study documented on the impact of gender and age linked the increasing Aedes mosquito vector and Dengue virus fitness during COVID-19 pandemic response interventions in Saudi Arabia. There is an urgent need to harnessing evidence-decisions on integrated
vector-borne diseases surveillance and integrated vector management policies, with COVID-19 response interventions including vaccination coverage and effectiveness in Jeddah municipalities, Saudi Arabia

**Background**

Coronavirus pandemic crisis has affected over 120 million people globally and the death toll has reached around 2.65 million, with the unprecedented global and public health effects [1]. Since the 12 February 2020, Saudi Arabia has had 382,752 cases and 6,573 deaths, with 372,926 recovered according to the Ministry of Health (MOH, Saudi, 2021)[2] COVID-19 pandemic is placing immense pressure on health systems and programs. As COVID-19 vaccination efforts continue in cities and states across the country, as effective engagement and communication with the public is crucial to address COVID-19 response and recovery [1]. It has taken time, attention, and personnel away from all other unrelated health priorities and understaffed health sector respond to COVID-19 pandemic induced constraint on domestic mosquito vector and vector control programs leading to increase in vector-borne diseases public health burden [3].

COVID-19 linked halting surveillance and control activities could be linked to increasing vector-borne disease threats. The increasing spread of mosquito-borne virus and causing epidemics represent a serious threat to public health burden and threats such as dengue, chikungunya and Zika outbreaks threats [2].

Jeddah is an important harbor and occupied more than 73% (3161 cases in total) laboratory-confirmed dengue cases in 2015 in Saudi Arabia, according to the Saudi Ministry of Health [3]. Dengue endemic area in Saudi is mainly in western areas, including Jeddah, Makkah (Mecca), and Madinah, as well as Jizan region in the southwestern part of the country [3, 4, 5]. DENV-1 and DENV-2 were the most circulating serotypes during the first DENV outbreaks in Saudi in 1994, following that DENV-3 was detected in 1996 and dominant the dengue epidemic of 1997 [9, 10]. Moreover, the overall prevalence of DENV infection in asymptomatic residents in Jeddah was 47.8% (927/1939), measured by anti-dengue IgG antibodies [6].

Millions of Muslims from DENV endemic countries will go through Jeddah to Makkah for performing Hajj and Umrah pilgrimage. Pilgrims increase the risk of introduction of DENV and other pathogens from endemic areas into Jeddah [5, 6]. With the increasing presence and high density of *Aedes aegypti* which is the most abundant species in local area, constant utilization of vector control methods have led to high resistance to pyrethroids mainly deltamethrin in Jeddah and Makkah [7, 8].

However, to the best of our knowledge, little is documented on the impact of COVID measures and response interventions on rising mosquito and vector-borne pathogen surveillance and integrated vector management programs in Saudi Arabia. Case management relies on DENV serological detection and molecular assays (PCR) on clinically suspected cases in endemic areas. Mosquito samples have not been applied in study on the geographical distribution, species, and mosquito-borne viruses in vectors [5, 7, 9].
The study aims to map field caught mosquito diversity, geographic distribution and fitness of vector-borne diseases threats; understanding the risk factors /determinants of increasing circulating mosquito competence during COVID-19 pandemic precautionary and emergency response measures and interventions in Jeddah municipalities.

The study aims to assess the COVID-19 pandemic linked rising *Aedes* mosquito abundance and Dengue virus fitness or threat, in order to provide evidence-based policy decision and targeted integrated vector-borne diseases management during public health crisis response in Saudi Arabia.

**Methods**

**Study Design**

A cross-sectional, retro/prospective and analytic increase mosquito risk factors and cases prevalence study was conducted to guide ongoing field mosquito surveillance and integrated vector control interventions during and post COVID-19 response and recovery interventions in Jeddah municipalities, Saudi Arabia.

**Study Area**

The study was conducted in Jeddah municipalities based on information the daily ongoing mosquito surveillance program and clinical cases reporting in Jeddah. It is worth noting that Jeddah is an important harbor and occupied more than 73% (3161 cases in total) laboratory-confirmed dengue cases in 2015 in Saudi Arabia. DENV-1 and DENV-2 were the most circulating serotypes during the first DENV outbreaks in Saudi in 1994, following that DENV-3 was detected in 1996 and dominant the dengue epidemic of 1997[10]. Moreover, the overall prevalence of DENV infection in asymptomatic residents in Jeddah was 47.8% (927/1939), measured by anti-dengue IgG antibodies. Also, Millions of Hajj and Umrah Muslims pilgrims and visitors from DENV endemic countries come to the Kingdom through Jeddah to Makkah and other cities [11]. Pilgrims and tourist visitors as well as Saudi-Yemen cross border instability increase the risk of introduction of DENV and other pathogens from endemic areas into Jazan and Saudi Arabia.

**Study subjects**

Mosquito samples was collected from field trap from routine mosquito surveillance was conducted and sorted from stored from various vulnerable municipality from March 2020 to date in Jeddah, Saudi Arabia, for speciation, host identification and viral detection in order to prepare and prevent potential dengue. Mosquito traps was done dropped overnight and collected the next day when setting new trap, so collection was done based on 24h cycle routinely from Monday to Sunday and dropped in the lab for sorting around 9.00 AM daily and sorted by species, date and location of collection, with a maximum number 20 individuals per pool in confirmed cases of dengue from the regional laboratories in Jeddah and Surveillance data from vector borne diseases and Jeddah municipality.
Sample Size

The study covered a period of March 2019 to March 2021. (mention the input criteria for sample size estimation.) Infection rates was calculated by bias-corrected maximum likelihood estimation (MLE) value and minimum infection rate (MIR) using the Excel add-in PooledInfRate version 4 statistical software package [27]. The rates are expressed as the number of infected mosquitoes per 1000 individuals. The infection rates of flavivirus in mosquitoes, estimated by bias-corrected MLE and MIR values, was assessed at 95% confidence interval.

Sampling Technique

Randomized mosquito samples were used in order to obtain a representative sample for your target population. All dengue confirmed cases/samples from January 2017 to March 2021 included in this study.

Data Collection methods

Dengue data was collected from MOH system and vector borne diseases administration which include demographic and clinical information of reported cases of dengue patient from both governmental and private hospitals. Data included age, sex, nationality, location (Districts), symptoms and signs, laboratory results (PCR, NS1, IgG /IgM), Surveillance dengue data and any other data to support the rising in Aedes mosquito abundance/cases or hospitalization.

Data Management

Data were analyzed using SPSS statistical software version, 20.0. Also, it was utilized to identify and map Aedes mosquito linked dengue cases, diseases prevalence rates and COVID-fatality pre and during COVID-Pandemics in Jeddah, Saudi Arabia. Also, to determine the risk factors and determinants of rising mosquito competence and diseases burden or threats in studied municipalities areas (households, buildings under construction). Also, we evaluated the epidemiological situation of dengue fever cases in Jeddah in the age of COVID 19 crisis pandemic in order to provide preventive measures and response interventions during and post COVID pandemic effects.

Results

1. Trends in dengue cases variations before and during COVID-19 pandemics Jan 2019- April 2021

The overall trend of confirmed dengue cases in Jeddah before and during the COVID-19 pandemic showed the significant variation during the two periods of the current study. There were marked but not statistically significant fluctuations in the number of monthly confirmed dengue cases during both periods. The highest number of monthly confirmed cases before the pandemic was reported in June 2019 (205 cases) and January 2019 (247 points). Similarly, the first peak during the pandemic was recorded in
June 2020 (274 cases), whereas the highest number was documented in April 2021 (311 cases). The lowest number of cases reported before and during the pandemic in October 2019 (27 cases) and April 2020 (18 cases) (Fig. 1).

2. Gender-based impact of COVID-19 on dengue rise

Our findings showed that monthly gender-based trend of dengue cases before and during the COVID-19 pandemic showed that males were the most affected over the study period as compared to the females. The reason could be males are responsible for sourcing for food in malls and long outdoor stay. Also, it can be seen that the peak was observed for males before the pandemic in June 2019 (187 cases) and January 2020 (210 cases), whereas it was June 2020 (237 cases) and April 2021 (273 cases) during the pandemic. Additionally, the dengue confirmed cases trends (peaks period) of females were similar to male, although the monthly cases were always fewer (Fig. 2).

3. Age-based stratified dengue cases before and during COVID-19 pandemic

Our findings showed that Age-stratified variations of dengue cases reveals that more cases were during the age range of 15–45 and few above 45 years old with peak precovid recorded in June and December 2019 with over 150 cases recorded. During Covid-19, the trend is increasing with peak over 150 cases in June 2020 and April/May 2021 (Fig. 3).

4. Citizenship-based distribution of dengue fever before and during the COVID-19 pandemic

Our findings on citizenship-based dengue distribution reveal that non Saudi and mainly workers were more prone to dengue prior COVID with two peaks in June 19 and Dec 22, 2019. Similarly during COVID-19, we documented a rise in dengue cases amongst local Saudi with a surge from April to the peak over 100 dengue cases in July 2020, but lesser that non Saudi cases with a surge during the same period and peak over 170 dengue cases in 2020. Likewise as COVID-19 pandemic persists in Saudi Arabia, the new surge was documented from Dec 2020 till May 2021 with over 100 and 100 and 200 dengue cases amongst and non-Saudi respectively. No reported death was documented either pre and during COVID-19 pandemic in Jeddah, Saudi Arabia.

Discussions

There is an urgent need to harnessing evidence-decisions and targeted interventions are crucial on integrated vector-borne diseases control and elimination, and COVID-19 response/recovery interventions in Jeddah, Saudi Arabia. Our findings showed that pre and during COVID-19 pandemic effects had significant variation during the two periods. We documented a marked but not statistically significant fluctuations in dengue cases number on monthly variations. COVID-19 lockdown and restrictions on
routine dengue control measures has been documented, since local Jeddah health and related ministries authorities focused more on curtailing the pandemic effects and saving more lives in Jeddah and Saudi Arabia. Jeddah being the cosmopolitan city witnessed an increasing cases of dengue, since access to control measures were limited and restricted or even refused by some houses owners or inhabitants due to unknown toxic effect of repellents and spays. Gaps in evidence-based access and use to community participation to mosquito associated vector diseases prevention and control approaches, coupled with environment sanitation and time waste management can promote breeding sites and dengue persistence and potential outbreak threat in Western regions of Saudi Arabia.

Understanding of mutual cooperation by communities and local inhabitants is vital in vector control activities in neighbourhood areas, limiting *Aedes* breeding sites and discarding containers and tyres those could be potential water reservoirs and larva breeding environment preventive measures implementation and community participation and resilience against dengue.

Although Saudi and expatriates showed high level of knowledge and awareness of Dengue, the risk of exposure was higher due to COVID-19 restrictions in households and surroundings risky environment than before the pandemic, low or lack of regular hygiene and sanitary environment and limited or low vector control activities [10].

In 2018 and 2019, vector control activities showed to have stable dengue endemicity, 2019 results showed that waves of COVID-19 related lockdown measures and restrictions in 2020 presented an opportunity to better understand local human contact rates, timing and intensity vis a vis field surveillance and control activities impact on dengue virus transmission. Compared to previous travel and pilgrims associated dengue importations, where travelers including pilgrims which were often blamed for spreading dengue serotypes in Jeddah and Makkah regions. Plausibly, each lockdown could affect virus transmission with both increase and decrease in risk populations, disrupt routine surveillance and compromised vector control efforts as well as dual treatment seeking in hospital and clinics/health centers.

Previous studies have reported that lockdowns had protective effects in some endemic prone municipalities, yet our findings could not attest for this claims due to sustained and rise dengue cases in Jeddah based on Ministry of Health monthly reports [2, 5]. Hence, resurgence of dengue and other arboviral infections during COVID pandemic indicates that these diseases still represent an important menace that require strengthening health systems.

Evidence-based vector control interventions coupled with community engagement, awareness and participation activities remain crucial to curb and eliminate dengue. Moreover integrated vector-borne diseases activities into emergency response and recovery programs can offer more promising alternative in crisis in Western regions of Saudi Arabia and elsewhere. We noted that the disruption of routine vector control activities such as space and buildings under-construction sprays, larval breeding sites mosquito and transmission interruption activities, environmental sanitation and better waste management impact could provide valuable insights in Mosquito vector prevention, control and elimination interventions. In
addition, previous literature evidence showed mixed impact of lockdown and restrictions on dengue transmission and vector control efforts and monitoring of performance in most endemic settings, and some countries experience low level of transmission in early 2020 onset of pandemic, but long-term positive effects were not measured.

Despite the continuous efforts of Jeddah and Saudi government on Dengue control programs, improving evidence synthesis and use for different strategies is urgently needed to measure and monitor the effectiveness of current vector control and sustainability of these interventions mainly population-based participation in fastening concurrent dengue and COVID-19 containment [2].

Extreme weather, climate change effects and seasonal variations have showed to affect *Aedes* mosquito abundance and prevalence and should be considered in interpreting dengue and COVID-19 related activities and impact. Previous reports documented r disruption of interventions and workforce allocation to COVID-19 response and reporting and more funding allocation to COVID-19 response and recovery programs, this reducing mosquito vector and surveillance to environmental management staff affected the effectiveness of integrated vector control and performance of designed dengue linked covid-19 interventions [12, 13].

Monthly gender-based trend of dengue cases before and during the COVID-19 pandemic showed that males were the most affected over the study period as compared to the females. The reason could be males are responsible for going out for work, sourcing for family food in malls and long outdoor stay. Also, it can be seen that the peak was observed for males before the pandemic in June 2019 (187 cases) and January 2020 (210 cases), whereas it was June 2020 (237 cases) and April 2021 (273 cases) during the pandemic. Additionally, the dengue confirmed cases trends (peaks period) of females were similar to male, although the monthly cases were always fewer (Fig. 2). The reasons could be due to prevailing female biased sociocultural factors and gender specific dengue home testing capacity, unreliable vector surveillance and other related preventative behavior to both diseases.

Age-stratified variations of dengue cases reveals that more cases were during the age range of 15–45 and few above 45 years old with peak pre-COVID-19 recorded in June and December 2019 with over 150 cases recorded. During COVID-19, the trend is increasing with peak over 150 cases in June 2020 and April/May 2021. It should also be noted that under-reporting of COVID-19 due to lack or limited household diagnosis and case management. Moreover, asymptomatic COVID-19 cases and clinical manifestations similarities of Dengue and COVID-19 could impact dengue surveillance activities, thus further case time series study is needed at various COVID-19 waves to dual emergency response activities and ongoing vector control practices [2, 14, 15]. It is still unclear of *Aedes* vector seroprevalence and dengue virus transmission dynamics within home or household and neighborhoods or hospital settings during pandemic with lockdown measures; as lockdown provided also a unique opportunity to understand local dengue dynamics and impact of vector control programs within COVID-19 pandemic crisis in different settings in Jeddah.
During the COVID-19 lockdown measures including airport and land entry points closures, our results reported a rise in dengue cases amongst local Saudi with a surge from April to the peak over 100 dengue cases in July 2020, but lesser that non Saudi cases with peak over 170 dengue cases a surge during the same period in 2020. These results indicates that there are endogenous factors and challenges those could be responsible for the increasing vector seroconversion and virulence. Probably, this can be related to changing habits indoors, house confinement allowing more exposure to outdoors or indoors mosquito, non-Saudi workers expending more time in houses under construction and remote residential houses with high likelihood of *Aedes* mosquito [16, 17]. Furthermore, erratic control and surveillance activities during COVID-19 including periodic mosquito vector sprays and targeted control due to lockdown/restrictions measures and inaccessibility to houses could also have a contributing role in dengue sustained efforts and jeopardized ongoing dengue response and COVID-19 recovery efforts [18].

It is important to note that strengthening key performance indicators for evidence decision making and actions is crucial in supporting proven effective and locally adaptable integrated mosquito vector control and dengue control activities. In addition, recent community responsive assessment showed the role of MOH and municipality Jeddah authorities team when they visit the patient houses of the dengue-reported cases to educate them about dengue and spray the house if the mosquitoes found [19]. These results showed the percentage of people response was so low due to sanitation and environment monitoring, advice and COVID-19. Yet, municipality team, MOH and private partners should be more prepared and build future crisis resilience strategies against fear of COVID-19 infection and readily carried community and household engagement and tracking/monitoring, and there was little information and data COVID-19 restrictions adherence, and COVID-vaccination coverage and compliance [3, 20].

**Conclusion**

To the best of our knowledge, this is the first study documented on the impact of gender and age linked the increasing *Aedes* mosquito vector and Dengue virus fitness during COVID-19 pandemic response interventions in Saudi Arabia. Our results documented on the impact of COVID-19 lockdown measures and response interventions against rising mosquito and vector-borne pathogen in Jeddah, Saudi Arabia. Harnessing evidence-decisions on integrated vector-borne disease and COVID-19 pandemics response interventions in Jeddah municipalities remain major public health threats and burden in Saudi Arabia. There is an urgent need to harnessing evidence-decisions on enhanced integrated and sustained vector-borne diseases surveillance and response, mosquito vector population-based studies to understand their behavior changes and increasing severity to proven integrated vector management and lessons learnt COVID-19 response and recovery interventions implementation in Western regions of Saudi Arabia.

**Declarations**

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**Availability of data and materials**

Data are readily presented and further insights could be provided upon request.

**Author contributions**

AMN conceived and designed the study. AMN collated data and provide additional inputs on the manuscript, AMN facilitated the obtaining the patient files, data and coordinated with private and governmental health sectors and drafted the manuscript. AMN corrected and approved the final version of the manuscript.

**Ethical Approval and Consent to participate**

The ethical clearance was obtained from Jeddah Institute Review Board, IRB no. 1482, KCAST, KSA; H-02-J-002.

**Consent for publication**

Not applicable

**Competing interests**

The author have no competing interest.

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Figures
Figure 1

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Figure 2

Gender-based impact of covid on dengue rise in Jeddah, Saudi Arabia
Figure 3

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Figure 4
Citizenship-based distribution of dengue fever over the period before and during COVID-19 pandemic