Saudi Arabian Administrative Areas and Neighborhoods in COVID-19 Infections: An Application of 3 X 3 Model

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Short report

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Abstract

Saudi Arabia has been seriously affected by COVID-19 across various administrative areas. Not only the prominent cities but also upcoming future cities and small townships were affected. This research aims at an analysis of COVID-19 data published by the Ministry of Health of Saudi Arabia to understand effects of broader administrative areas and neighborhoods and its interaction on spread of the epidemic. This research applies a generalized linear model (3 X 3) of administrative areas (major, middle sized and others) and neighborhoods (large, medium sized, and others) on COVID-19 infected cases classifying on a monthly basis from March to November, 2020. A total of 213 neighborhoods of various categories have been affected in the country with various frequencies and changes, based on local demographics. More than the broader administrative areas smaller neighborhoods receive significance and thus the interaction of variables in producing the number of cases: giving lessons for policies, programs and plans of development.

Introduction

COVID-19 spread rapidly in the Kingdom of Saudi Arabia where a population of 34.3 million live in an area of 2.2 square kilometers. The initial rapid rise, peak, and erratic behavior of the epidemic with geographic variations depend heavily on super-spreaders and heterogeneous population characteristics (Eilersen and Sneppen, 2021). Highly populated industrial cities, the epic centres demand epidemic compartmental models to policy interventions distinguishing early implementation, later interventions, and mild interventions to pave way for post-pandemic urban growth strategies to boosting urban potential (Tian et al., 2021; Guaralda, et al., 2020). Such urban units are commonly found everywhere including Saudi Arabia, where spatial architecture, urban inequalities, and local governance patterns differ, which add up to the precarious conditions challenging protection measures (Ziccardi, 2020). Besides, regional comparisons on COVID-19 including mortality are determined by health services delivery, community-level healthcare, testing approaches, and characteristics of surveillance systems enabling opportunities and dynamics of balancing regional development (Signorelli et al., 2020; Guaralda, et al., 2020).

Despite the precautionary and preventive measures adopted in Saudi Arabia, the epidemic spread faster than anticipated, thus crafted political and economic strategies with proactive precautionary measures, thereby flatten the epidemic curve by increasing recovery and thus achieving comparatively low case fatality (Ministry of Health. 2020; El Sayed, 2020; Jdaitawi et al., 2020; Al-Otaibi, 2020). Besides, the Kingdom continues decisive bold measures to safeguard population at a great socioeconomic cost geared with swift community action, hospital preparedness, and mitigation measures (Yezli and Khan, 2020; Obeid et al., 2020; Barry et al., 2020¹). As a result, the metropolises and future cities are seriously affected despite availability of essential health services (Jdaitawi et al., 2020). Thus, the rapid urbanization, particularly around capital cities undergo rethinking beyond conventional, neoliberal growth strategies to reduce risks of urban growth within national, regional, and local planning, design, and development strategies (Guaralda, et al., 2020).
Cities with high concentration of population and economic activities are the seriously affected locations, hotspots of COVID-19 infections. Thus, dynamics of the pandemic in urban areas are important in establishing the impact of COVID-19, as stated by Sharifi and Khavarian-Garmsir, (2020). Moreover, Saudi Arabia is a large country in terms of geographic area having vivid climatic and ecological conditions, climatic sensitivity, socioeconomic conditions, seasonal patterns, and population factors play havoc in transmission rate, disease burden, and control policies, as stated by Metelmann et al., (2021); Jdaitawi et al., (2020); Alyami et al., (2020); Alqahtani et al., (2020). Limitations of vast geographic area in such emergencies include exacerbating poor access to health-care professionals; delays between disease development, progression, and diagnosis; and poor information on disease spread due to the absence of trustworthy sources and reliable guidance (Barry et al., 2020; Almaghlouth et al., 2020). In short, cities in Saudi Arabia vary, from one area to another, in terms of population dynamics, geographical conditions, environmental situation, and availability of resources including health infrastructure like hospitals, medical facilities, etc., and thus the risk factors, immune system, response to treatment, and danger of mortality: this makes areas divisible into safe, susceptible, and vulnerable (Baz and Alhakami, 2021).

On this backdrop, this research aims at testing a model consisting of three types of administrative areas and three types of neighborhoods leading to differentiate COVID-19 new cases reported on a daily basis to (i) effects of each dimension (ii) interaction effects.

**Methodology**

This research made use of daily reports of COVID-19 infection published by Ministry of Health, Saudi Arabia on social media platform, from 21 March to 28 November, compiled on Excel worksheet and thereafter analyzed on SPSS 26. There are 213 neighborhoods with at least one person infected as on 28 November 2020, of which 94 are from major administrative areas (Riyadh, Makkah Al-Mokarramah, Al-Madina Al-Monawarah, and Eastern Region); 55 from middle sized regions (Al-Qassim, Aseer, Northern Borders, and Najran); and 48 from, other administrative areas (Tabouk Hail, Jazan, Al-Baha, Al-Jouf): there are 16 unclassified neighborhoods. Of all the neighborhoods, 5 are large cities (Riyadh, Jeddah, Makkah, Madina and Dammam); 21 are medium sized cities (Taif, Yanbu, Buraiydhah, Al Ahsa, Al-Jubail, Al-Mubarass, Dhahran, Hoful. Khobar, Qatif, Raz Tanura, Abha, Khammis Mushayt, Mahayel, Tabouk, Hail, Arar, Jazan, Najran, Baha, and Sakaka) and 187 are other types, usually smaller and remote (refer Table 1 for the number of affected neighborhoods in each category of region and of the neighborhoods month-wise): thus forming a 3 X 3 analysis model.
Table 1

| Neighborhoods | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. |
|---------------|------|------|-----|------|------|------|------|------|------|
|               | 31   | 30   | 31  | 30   | 31   | 31   | 30   | 31   | 28   |
| Major         |      |      |     |      |      |      |      |      |      |
| administrative areas |
| Large         | 5    | 5    | 5   | 5    | 5    | 5    | 5    | 5    | 5    |
| Medium sized  | 9    | 9    | 10  | 10   | 10   | 10   | 10   | 10   | 10   |
| Others        | 5    | 35   | 68  | 77   | 78   | 79   | 79   | 79   | 79   |
| Total         | 19   | 49   | 83  | 92   | 93   | 94   | 94   | 94   | 94   |
| Middle sized administrative areas |
| Large         | 0    | 0    | 0   | 0    | 0    | 0    | 0    | 0    | 0    |
| Medium sized  | 5    | 6    | 6   | 6    | 6    | 6    | 6    | 6    | 6    |
| Others        | 3    | 15   | 35  | 47   | 49   | 49   | 49   | 49   | 49   |
| Total         | 8    | 21   | 41  | 53   | 55   | 55   | 55   | 55   | 55   |
| Other          |      |      |     |      |      |      |      |      |      |
| administrative areas |
| Large         | 0    | 0    | 0   | 0    | 0    | 0    | 0    | 0    | 0    |
| Medium sized  | 3    | 5    | 5   | 5    | 5    | 5    | 5    | 5    | 5    |
| Others        | 1    | 19   | 35  | 39   | 42   | 43   | 43   | 43   | 43   |
| Total         | 4    | 24   | 40  | 44   | 47   | 48   | 48   | 48   | 48   |
| Total         |      |      |     |      |      |      |      |      |      |
| Large         | 5    | 5    | 5   | 5    | 5    | 5    | 5    | 5    | 5    |
| Medium sized  | 17   | 20   | 21  | 21   | 21   | 21   | 21   | 21   | 21   |
| Others        | 9    | 69   | 138 | 163  | 169  | 171  | 171  | 171  | 171  |
| Total         | 31   | 94   | 164 | 189  | 195  | 197  | 197  | 197  | 197  |
b. Number of infected persons included in the analysis by administrative areas classified

| Major Area            | Middle sized Area          | Persons | Name         | Persons | Others Area         | Persons |
|-----------------------|-----------------------------|---------|--------------|---------|----------------------|---------|
| Name                  | Persons                     | Name    | Persons      | Name    | Persons              |         |
| Riyadh                | 73,765                      | Al Qassim | 13,631      | Tabouk  | 4,803                |         |
| Makkah Al Mokarramah  | 85,115                      | Aseer    | 27,394      | Hail    | 6,646                |         |
| Al Madina Al Monawarah| 28,789                      | Northern Borders | 2,582 | Jazan  | 11,836               |         |
| Eastern Region        | 85,589                      | Najran   | 6,392       | Al Baha | 4,322                |         |
| Total                 | 273,258                     | Total    | 49,999      | Al Jouf | 1,307                |         |
| Grand Total           |                              | Total    | 28,914      |         |                      | 352,171 |

Although, the total number of infected persons, as on November 28 is 356,911, this research accounts for only 352,171 after adjusting for calculation issues, data missing, administrative areas total without neighborhoods, cases reported before March 21, and unclassified neighborhoods. A break up of the total number is given below.

**Results And Discussions**

Considering the theme of this research, data analyzed by means of 3 X 3 ANOVA (univariate general linear model), one-way ANOVA, and mean number of infected persons at various neighborhoods classified by the above mentioned criteria of administrative areas and neighborhoods. There is a significant F value in case of neighborhoods, on all months, but not in case of administrative areas (Table 2). As this analysis considered 197 neighborhoods (divided into large cities, medium sized cities, and others including small towns and villages) located at various parts of 13 administrative areas (divided into major, middle sized and other smaller), it could be understood that more than the broader administrative boundaries the locational characteristics matter in case of COVID-19 epidemic. Although, the major administrative areas accounted for the majority of infected cases reported in the country, as a characteristic it plays a role lesser than the more homogenous neighborhoods which is proxy of grass-root level demographics including geography, livelihoods, and proportion of expatriate population, where super-spreaders operate on heterogeneous population, as stated by Eilersen and Sneppen, (2021).
Table 2
Two Way ANOVA results (3X3 Model) calculated with univariate general linear model

| Month   | F (Significance) | R² (Adjusted R²) |
|---------|------------------|------------------|
|         | Corrected Model  | Intercept        | Admin. area | Neighborhoods | Admin. area X location |
| March   | 6.1 (0.00)  | 11.0 (0.00)  | 0.1 (0.99) | 15.5 (0.00) | 0.1 (0.97) | 0.60 (0.50) |
| April   | 91.3 (0.00) | 304.1 (0.00) | 0.7 (0.50) | 237.7 (0.00) | 0.8 (0.45) | 0.86 (0.85) |
| May     | 154.6 (0.00) | 539.1 (0.00) | 2.6 (0.07) | 395.2 (0.00) | 2.5 (0.08) | 0.85 (0.85) |
| June    | 111.8 (0.00) | 427.8 (0.00) | 4.0 (0.02) | 272.6 (0.00) | 3.6 (0.03) | 0.78 (0.77) |
| July    | 125.5 (0.00) | 535.6 (0.00) | 5.4 (0.01) | 298.5 (0.00) | 4.8 (0.01) | 0.79 (0.78) |
| August  | 131.3 (0.00) | 588.1 (0.00) | 4.5 (0.01) | 315.6 (0.00) | 4.1 (0.02) | 0.79 (0.79) |
| September | 140.1 (0.00) | 633.2 (0.00) | 4.8 (0.01) | 336.0 (0.00) | 4.4 (0.01) | 0.80 (0.80) |
| October | 147.3 (0.00) | 669.4 (0.00) | 5.0 (0.01) | 353.2 (0.00) | 4.6 (0.01) | 0.81 (0.81) |
| November | 148.4 (0.00) | 676.4 (0.00) | 4.8 (0.01) | 356.7 (0.00) | 4.4 (0.01) | 0.81 (0.81) |

Moreover, these variables (3X3) are found to have significant interaction in producing the number of COVID-19 positive cases: similar to the epidemic compartment model tested by Tian et al., (2021). High concentration of population and economic activities in an urban area makes it a hotspot of COVID-19 as revealed by its spread at various locations in the world (Sharifi and Khavarian-Garnsir, 2020). Locations represent climatic conditions, socioeconomic and disease control capacity that determines rate of transmission and health burden (Metelmann et al., 2021). Overall, it implicitly explains that the neighborhood plays a significant role in determining the increase or decrease in number of cases detected on a monthly basis. Statistics are striking that the five major cities having 77.6 percent of
infected persons carry only 30.1 percentage of population whereas the middle sized cities and townships having 14.2 per cent of infected persons carry 16.7 percentage of population and other neighborhoods having 8.2 percent of infected persons carry 53.2 percent of the population.

The F value of neighborhood was found to be the highest in May (395.2). Higher F values are reported in November, October, September and August too, which are considered to be months of intense spread of COVID-19. On the other hand, the F value for administrative area remained low between 0.1 and 5.0 throughout the period: insignificant till May. This pattern was found to be reflected in the interaction also. That means, the two variables operate together to produce differentials on COVID-19 infections. There are reasonable $R^2$ values, above 0.60 and adjusted $R^2$ above 0.50 making the tests logical.

There are five large cities namely Riyadh, Jeddah, Makkah, Madina, and Dammam, all of them are part of major administrative areas of Riyadh, Makkah Al-Mokarramah, Al-Madina Al-Monawarah, and Eastern Region. These large cities accounted for a large share of the cases but it declined rapidly over the period (Fig. 1). These metropolises with high community and business activities have higher mitigation potential as part of emergency preparedness associated with health delivery; community outreach; diagnostic and surveillance systems etc., as stated by Signorelli, et al., (2020). During the early months of infection, that is, March and April these major cities had higher proportions above 80 percent but which decreased to 48 percent by the month of November. It is to be examined for the effect of intervention strategy adopted, early or late, that impact effectiveness, besides, the characteristics such as spatial architecture and governance pattern (Tian et al., 2021; Ziccardi, 2020). Saudi Arabia has taken a lead in implementing precautionary preventive measures anticipating the danger of epidemic throughout the country (Ministry of health, 2020). Despite, emergencies and disease spread to all parts with varying intensities. Thus, explaining opportunities and dynamics in regional towns are essential, as stated by Guaralda et al., (2020). The future city program initiated in the country is a move on this direction.

On the other hand, there are 21 cities in the country such as Taif (Makkah Al-Mokarramah); Yanbu (Al-Madina Al-Monawarah); Buraïydah (Al-Qassim); AlAhsa, AlJubail, AlMubarass, Dhahran, Hoful. Khobar, Qatif, and Raz Tanura (Eastern Region); Abha, Khammis Mushayt, and Mahayel (Aseer); Tabouk (Tabouk); Hail (Al Hail); Arar (Northern Borders); Jazan (Jazan); Najran (Najran); Baha (Al Baha); and Sakaka (Al-Jouf); whose share has increased. These upcoming neighborhoods (medium sized cities and towns), had multiplied their COVID-19 cases from 18.0 percent in March to 31.3 percent in November. Here, the impact of major urban components such as environmental quality; socioeconomic impacts; management and governance; and transportation and urban design on COVID-19 spread receives importance (Sharifi and Khavarian-Garmsir, 2020). On the contrary, other 171 smaller neighborhoods also experienced a rapid increase from 2.1 percent in March to 21.0 percent in November. In short, while the larger cities located at major regions had a month wise decline in reported cases, a faster increase in the upcoming and slower increase in smaller neighborhoods experienced. Probably, this trend is reflected in the interaction results.
Separate effects of administrative area and neighborhood were investigated by means of One-Way ANOVA performed on month-wise COVID-19 cases with administrative areas as well as neighborhoods. The former one is not found to be significant at 0.05 level from May onwards whereas the later variable has significance at 0.00 level throughout the period since March (Table 3). These results are indicative of the above that more than the broader regions, the smaller geographic units play prominent roles in creating the spread of COVID-19. During the initial stages of infection (March and April), administrative areas did not play significant roles, but slowly their roles became clearer and by September, it started playing the prominence. This explains geographic variations in spread of infection along the population heterogeneity.

| Month   | Administrative area | Neighborhood |
|---------|---------------------|--------------|
|         | F       | Sig      | F      | Sig      |
| March   | 1.3     | 0.287    | 21.1   | 0.000    |
| April   | 2.7     | 0.073    | 279.0  | 0.000    |
| May     | 3.2     | 0.044    | 455.5  | 0.000    |
| June    | 3.8     | 0.024    | 323.5  | 0.000    |
| July    | 4.3     | 0.016    | 357.5  | 0.000    |
| August  | 4.0     | 0.020    | 378.8  | 0.000    |
| September | 4.1   | 0.018   | 402.9  | 0.000    |
| October | 4.1     | 0.017    | 422.7  | 0.000    |
| November| 4.1     | 0.017    | 326.9  | 0.000    |

For a better clarity, an analysis of mean number of infected cases was done by taking the model of 3X3 design (Table 4), giving mean for each category of neighborhood (large cities, medium sized cities and townships, and others) in each type of administrative area (major, middle sized, and others). Each neighborhood, as a whole has 1,657 infected persons, as on 28 November, which varied from 33700 in large cities, 5,259 in medium sized cities and townships to 396 in others. In case of large cities, average number of infected persons increased from a low of 176 in March bringing a faster increase at populated industrial cities, the epic centers, as compared to that of mediums sized cities and others. This might be driven by super-spreaders as stated by Eilersen and Sneppen (2021); Tian et al., (2021). This calls for seeking options of human settlements to distribute population including migrants to various parts of the country (Guaralda, et al., 2020).
Table 4
Mean number of infected persons in each category of neighborhood by administrative area classified, month-wise

|               | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. |
|---------------|------|------|-----|------|------|------|------|------|------|
|               | 31   | 30   | 31  | 30   | 31   | 31   | 30   | 31   | 28   |
| **Major administrative areas** |      |      |     |      |      |      |      |      |      |
| Large cities  | 176  | 3564 | 12827 | 24168 | 28943 | 30591 | 31913 | 32859 | 33700 |
| Medium sized cities | 15 | 263 | 1214 | 3676 | 5781 | 6248 | 6661 | 6914 | 7044 |
| Others        | 1    | 9    | 44  | 157  | 297  | 367  | 396  | 417  | 434  |
| **Total**     | 54   | 418  | 955 | 1844 | 2426 | 2600 | 2739 | 2834 | 2907 |
| **Middle sized administrative areas** |      |      |     |      |      |      |      |      |      |
| Medium sized cities | 7 | 49 | 216 | 399 | 3116 | 669 | 3925 | 4131 | 4263 |
| Others        | 5    | 14   | 28  | 108  | 303  | 425  | 456  | 480  | 498  |
| **Total**     | 6    | 24   | 55  | 254  | 610  | 778  | 834  | 878  | 909  |
| **Other administrative areas** |      |      |     |      |      |      |      |      |      |
| Medium sized cities | 8 | 71 | 245 | 698 | 1641 | 2385 | 2629 | 2763 | 2885 |
| Others        | 1    | 18   | 36  | 62   | 131  | 218  | 239  | 250  | 258  |
| **Total**     | 6    | 28   | 59  | 118  | 253  | 390  | 426  | 446  | 463  |
| **Total**     |      |      |     |      |      |      |      |      |      |
| Large cities  | 176  | 3564 | 12827 | 24168 | 28943 | 30591 | 31913 | 32859 | 33700 |
| Medium sized cities | 12 | 151 | 698 | 2316 | 4034 | 4592 | 4919 | 5130 | 5259 |
| Others        | 3    | 13   | 38  | 116  | 247  | 335  | 362  | 381  | 395  |
| **Total**     | 36   | 224  | 496 | 944  | 1309 | 1471 | 1552 | 1612 | 1657 |

In case of major administrative areas, the mean number of infected persons, by November, is 2907 with 7044 in medium sized cities and 434 in others: that of large cities remain the same as all 5 of them falls into major administrative areas. The medium sized cities and others of this group of administrative areas had higher number of infected persons than the total. The middle sized administrative areas had only medium sized cities and other neighborhoods, together having 909 mean infected persons (4,263, in medium sized cities and 498 in other neighborhoods). Here, in this category, the medium sized cities and
townships undergone rapid increase in the reported cases as compared to the other neighborhoods. In other type of administrative areas, which are relatively smaller, there are fewer mean number of cases, as on November, 463, varying from 2,885 in medium sized cities to 258 in other neighborhoods. Here too, the medium sized cities, reportedly, shows higher rate of increase. Thus, a demand for mitigation strategies at venues where people meet in large numbers of strangers is mandatory, as stated by Eilersen and Sneppen (2021). Besides, different strategies and restrictions adopted shall comply with population density component coupled with employment.

Thus, there arises a need for rethinking beyond conventional growth strategies of cities in line with growth models and urbanization in the emergency preparedness and epidemic spread accounting for planning, design, and development strategies (Guaralda et al., 2020). One way, COVID – 19 enlightened the development community with the planners and policy makers on transformative actions towards creating resilient and sustainable cities (Sharifi and Khavarian-Garmsir, 2020.). It is also important for the authorities to be vigilant and evidence informed as a preparation for immediate disease prevention measures and policies (Metelmann, et al., 2021).

Conclusions And Recommendations

The popular concept giving ‘importance to grass-root level action plans and interventions give output’ proves right in this context of COVID-19 epidemic in Saudi Arabia. The larger administrative areas that divide the country into 13 for the purpose of administration and public policies have lesser effect healthcare interventions focusing on COVID-19 epidemic control. The number of infected cases changed in a haphazard manner, with the factors uncontrolled. But, with the increasing number of infected cases started following a pattern inside administrative areas; thereby gaining significance. On the contrary, the smaller neighborhoods have a more important role in changes in the number of infected cases per day. Moreover, the interaction effect of these two variables received significance since July, 2020. Thus, there is an interactive rout for the neighborhoods COVID-19 infections via administrative area dynamics. Thus, the developmental plans, programs, and policies accounting the grass root level demographic dynamics proves to be of value especially in the context of epidemics and other emergencies.

Declarations

Ethics approval and consent to participate

As this manuscript is based upon published data, ethics approval and consent to participate are not applicable

Consent for publication

As this manuscript is based upon published data, consent for publication is not applicable. However, the authors express their consent to publish this manuscript in your esteemed journal
Availability of data and materials

This research used a compilation of daily status reports published by Ministry of Health, Saudi Arabia (www.moh.gov.sa). The compiled data, in Excel worksheet, may be made available on request.

Competing interests

There are no competing interests or conflict of interests

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Authors’ contributions

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AAS – Concept development, data compilation, analysis, writing, finalization.

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Figures
Figure 1

Proportion of cases by month in various categories of neighborhoods