International Journal of Infectious Diseases 98 (2020) 153–160

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Spatiotemporal dynamics of the COVID-19 pandemic in the State of Kuwait

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ARTICLE INFO

Article history:
Received 4 June 2020
Received in revised form 21 June 2020
Accepted 23 June 2020

Keywords:
Spatiotemporal cluster
COVID-19
Surveillance
Time-dependent reproductive number
Migrant worker

ABSTRACT

Objectives: Prompt understanding of the temporal and spatial patterns of the COVID-19 pandemic on a national level is a critical step for the timely allocation of surveillance resources. Therefore, this study explored the temporal and spatiotemporal dynamics of the COVID-19 pandemic in Kuwait using daily confirmed case data collected between the 23 February and 07 May 2020.
Methods: The pandemic progression was quantified using the time-dependent reproductive number ($R_{(t)}$). The spatiotemporal scan statistic model was used to identify local clustering events. Variability in transmission dynamics was accounted for within and between two socioeconomic classes: citizens-residents and migrant workers.
Results: The pandemic size in Kuwait continues to grow ($R_{(t)}$s ≥ 2), indicating significant ongoing spread. Significant spreading and clustering events were detected among migrant workers, due to their densely populated areas and poor living conditions. However, the government's aggressive intervention measures have substantially lowered pandemic growth in migrant worker areas. However, at a later stage of the study period, active spreading and clustering events among both socioeconomic classes were found.
Conclusions: This study provided deeper insights into the epidemiology of COVID-19 in Kuwait and provided an important platform for rapid guidance of decisions related to intervention activities.

Introduction

The world has experienced an unprecedented pandemic caused by the novel coronavirus (SARS-CoV-2), which causes COVID-19. The World Health Organization (WHO) declared it a public health emergency (WHO Emergency Committee, 2020). Within a short period of time, COVID-19 rapidly spread to more than 190 countries, causing severe morbidities and mortalities (John Hopkins Coronavirus Resource Center (JHCRC, 2020). This rapid spread has placed unparalleled implications on global healthcare systems and economies (McKee and Stuckler, 2020). To date, there are no effective vaccinations or pharmaceutical therapies that can halt the spread of this emerging viral pandemic. Currently, strict intervention measures implemented worldwide of rapid detection, control and prevention are the only effective strategies for minimising the spread of COVID-19 (Lai et al., 2020). However, the necessity of such drastic actions has had a huge societal and economic impact, making these policies unsustainable as a long-term strategy.

The first cases of COVID-19 in the State of Kuwait were diagnosed in travellers, who were placed under immediate institutional quarantine on 23 February 2020. Since then >12,000 cases and >100 deaths have been reported up to 15 May 2020 (John Hopkins Coronavirus Resource Center (JHCRC, 2020). Like other countries in the Arabian Gulf, a large proportion of Kuwait's population is made up of low-wage manual labourers (69.2%), who tend to come from poorer countries and have a low level of education. The average salary for a migrant worker in Kuwait has been estimated to be $250–300 per month compared with $7,820.04 per month for the average Kuwaiti household (Central Statistical Bureau of Kuwait (CSBoK, 2018). This socioeconomic disparity is reflected in the housing

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https://doi.org/10.1016/j.ijid.2020.06.078

arrangements for manual labourers, where most reside in unsanitary crowded group homes to share rent expenses. A survey by Nadoum et al. reported that 14% of its migrant labourer respondents in Kuwait had more than 14 roommates in a two-bedroom, two-bathroom apartment (Nadoum, 2014). This has resulted in unique COVID-19 transmission dynamics within distinct communities in Kuwait, making public health intervention measures more difficult to track and effectively implement. Several strategies have already been tried by the government, including: targeted area lockdowns, suspending all non-essential services, school and border closures, as well as partial and full curfews. Despite this, the current daily numbers of detected cases among migrant workers are approximately 10 times the number of cases detected among Kuwaiti citizens and non-Kuwaiti residents of equivalent socioeconomic status (Portal KE-G, 2020).

Part of the challenge of controlling the continuous rapid spread of COVID-19 is its complex spatial and temporal epidemiology due to rapid changes in human population dynamics and its demographic and environmental drivers. This likely accounts for the notable differences in pandemic magnitude and transmission dynamics across the world. As each country has unique demographics, healthcare infrastructure, and cultural and political factors that shape the behaviour of the circulating viruses, analytical tools that do not account for these heterogeneities can be ineffectual. Consequently, the use of temporal and spatial analytical tools for rapid risk-based surveillance activities during emerging pandemics can offer valuable near-real-time insights into the severity of pandemic spread and effectiveness of intervention measures within and between communities in a population. Rapid risk-based surveillance is also critical for efficient deployment of resources and early identification of high-risk groups for disease transmission, such as those with a low-socioeconomic status (Khalatbari-Soltani et al., 2020).

This study explored the temporal and spatial dynamics of COVID-19 in Kuwait, combining two analytical methods. Specifically, it quantified temporal and spatiotemporal patterns of pandemic spread at a country-level and within communities. The objectives were to examine daily pandemic progression and identify spatiotemporal patterns of clustering events, and to use these metrics to assess the effectiveness of intervention measures. To address some of their current utilities and limitations, it also evaluated the selected analytical methods in the context of COVID-19 surveillance in Kuwait.

Methods

Data source

See Supplementary Text 1 and Supplementary Figure 1 for a brief description of the study setting. Data were obtained from the Ministry of Health's official passive and active surveillance records. Passive surveillance records included self-reported cases across multiple government hospitals, while active surveillance data were collected through targeted testing of arriving travellers and heavily infected areas. The final data comprised 5988 confirmed cases detected by real-time PCR tests between 23 February–07 May 2020 (Supplementary Table 1). Data included the date of detection, nationality, sex, age, and geographical location of the confirmed cases (i.e. latitude and longitude of current home address). Twelve resident nationalities were identified as being equivalent to the socioeconomic status of the average Kuwaiti citizen, while the remaining 31 nationalities were identified as migrant workers (Supplementary Table 1). ArcGIS version 10.5 (https://www.arcgis.com) was used to generate all the maps presented in this study. A kernel density function was used to spatially smooth the geographical locations of the reported cases with a spatial resolution of 5 m^2.

Estimation of the time-dependent reproductive number

Pandemic progression of COVID-19 was quantified using the effective time-dependent reproductive numbers ($R_{(t)}$) model between 23 February–07 May in Kuwait. It compared transmission dynamics between citizens and residents on one side and migrant workers on the other. The ($R_{(t)}$) model is based on a likelihood procedure that was used for the SARS epidemic in 2002, as described elsewhere (Wallinga and Teunis, 2004). Briefly, the method estimated $R_{(t)}$s for each point of time since the beginning of the pandemic by averaging all possible disease transmission networks that were compatible with the observed cases. $R_{(t)}$s was computed for each day, starting from the onset day of the pandemic using the R package 'R_0' (Obadia et al., 2012). It then calculated the daily $R_{(t)}$s for the pandemic as the sum of the probabilities that a given observed case was the source of infection for the subsequent case based on the elapsed time of the study period. Daily significant spreading events were interpreted when the 95% CI of the $R_{(t)}$ for a given day did not include $R_{(t)} = 1$. Additionally, the selected model was used to predict daily observed cases for Kuwait citizens, residents and migrant workers.

Retrospective and prospective spatiotemporal cluster analysis

The multivariable permutation scan statistic (MPSS) model (Kulldorff, 1997, 2001, Kulldorff et al., 2005, 2007) implemented in SatScan™ was used to detect retrospective and prospective spatiotemporal clustering events. The retrospective analysis was performed to identify all past and current (i.e. active) significant clustering events throughout the study period (Kulldorff, 1997). In contrast, prospective analysis of the scan statistics was used to identify clustering events that were still active (i.e. emerging clusters) until the last day of the study period (Kulldorff, 2001). The scan statistic method detected local clustering events using multiple hypothetical cylinders as scanning windows, in which the base and the height of each cylinder represented the spatial and temporal dimensions of the potential cluster, respectively. Each cylinder was centred at the geographical location (i.e. longitude and latitude) where a case had been detected. The permutation model of scan statistic test used case data only within each candidate cylinder (c) and computed the ratio of the observed number of cases (O_c) to the expected number of cases (E_c) under the null hypothesis that observed cases are randomly distributed in space and time. E_c was calculated as the sum of all observed cases multiplied by the size of the scanning window and divided by the size of the whole study area (Kulldorff, 1997). The observed-to-expected ratio (O_c/E_c) was used to estimate the likelihood that a candidate cylinder represented an actual significant clustering event of COVID-19 cases (Kulldorff et al., 2005). The multivariable extension of the scan statistic (i.e. MPSS) was used to simultaneously estimate O_c/E_cs and detect clustering of COVID-19 in multiple partitioned datasets (Kulldorff et al., 2007). Since the proportion of O_cs in migrant workers was substantially higher than citizens and residents combined, data were divided into two independent sets to calculate adjusted numbers of E_cs for each location and timeframe combination. The MPSS could show adjusted spatiotemporal clusters and distinguish whether the significant clustering event was caused by migrant workers alone, citizens and residents alone, or both (i.e. a confounded cluster). The candidate cluster with the highest likelihood ratio test estimate was ranked as the primary most likely significant cluster, while the remaining non-overlapping clusters were ranked as secondary clusters. All secondary clusters were reported with a p-value < 0.05 level.

Results

Parameter settings

To calculate the $R_{(t)}$s, a serial interval with a log-normal distribution and a mean of 4.7 and a standard deviation of 2.9 days (Nishiura et al., 2020) was used as a parameter estimate to calculate the generation time from the observed pandemic curve. Also, 10,000 simulations were used to obtain the 95% confidence interval (CI) for each daily $R_{(t)}$s. For both retrospective and prospective MPSS models, the base and the height of the scanning windows were set to vary up to a maximum size equivalent to the inclusion of 50% of the reported COVID-19 cases (Kulldorff, 2018). The models were also set to scan for areas with a high infection rate, using a scanning window with a maximum spatial extension of 2 km^2 (average neighbourhood size), and minimum temporal duration of 3 days (average time between case observation and confirmation dates). The time aggregation was set to 1 day, due to the rapid spread of the pandemic and the short duration of study, in other words: the models worked with a temporal resolution of 1 day. The study used 999 Monte Carlo simulations to obtain the distribution of the likelihood ratio test and its corresponding p-value for each candidate cluster under the null hypothesis, described above.

COVID-19 pandemic spread

In Kuwait, approximately 78.8% of the COVID-19 cases were detected in migrant workers, mostly of Indian nationality (40.1% of migrant workers; Supplementary Table 1). Imported primary cases comprised approximately 11% of the total number of cases. Overall, the mean age of detected cases was 45 years, while the proportion of males was approximately 76% (Supplementary Table 1). The observed pandemic curve of COVID-19 demonstrated sporadic occurrences of cases until 30 March, followed by a marked increase in the number of cases from 01 April until the end of the study period (Figure 1).

Figure 2 illustrates the temporal patterns of the inferred $R_{(t)}$s, observed and predicted daily cases throughout the study period in Kuwait, citizens and residents combined, and migrant workers. In the case of Kuwait, the first identified significant spreading events ($R_{(t)}$s >1) were between 26 March and 04 April, followed by a substantial decline until 14 April. Another small increase in the spreading events was seen between 15 April and the end of the study period (Figure 2A). No significant spreading events were seen in citizens and resident communities until 17 April. However, a notable rise in the daily secondary cases caused by a primary case ($R_{(t)}$s ≤2.3) was seen between 18–25 April (Figure 2C), which was similar in terms of the temporal patterns to the national level $R_{(t)}$ curve (Figure 2A). These results indicate that significant spreading events among migrant workers occurred between 26 March and 05 April, which were marked by a distinctly high number of daily secondary cases ($R_{(t)}$s ranging 2.5–3.5; Figure 2E). A sharp decline in the number of daily significant spreading events was seen after 05 April. However, a small rise in the number of spreading events after 17 April followed another decline (Figure 2E). No significant spreading events were seen at the end of the study period (Figure 2A, C and E). However, temporal patterns of daily and predicted cases were generally similar on a national, citizen, resident, and migrant worker level (Figure 2B, D and F), and indicated that the exponential growth phase of the pandemic was established after 18 April (Figure 2B, D and F).

COVID-19 spatiotemporal clustering events

Overall, the highest spatial point prevalence of COVID-19 cases was observed in Farwaniya (30%), followed by Asima (26%) and Hawalli (18%) governorates (Figure 3A). The retrospective MPSS model showed that 25 significant spatiotemporal clustering events (p < 0.05) occurred throughout the study period. The temporal duration of the retrospective clusters ranged between 5–35 days, while the spatial extension ranged between 0.02–1.93 km^2 (Table 1). Of the 25 significant clusters, 13 were identified in dormitories and housing areas mostly occupied by migrant workers located in Asima, Farwaniya and Ahmadi governorates (Figure 3B). Moreover, 16 significant retrospective clusters only affected migrant worker cases, while the remaining nine clusters affected both citizens-residents and migrant workers combined (Table 1). No significant clustering events were caused by citizens-residents alone. Additionally, notable differences were seen in the O_c/E_c estimates for citizens-residents and migrant workers within the adjusted multivariable clusters (Table 1).

The prospective MPSS model revealed 13 significant (p < 0.05) emerging spatiotemporal clusters with temporal durations

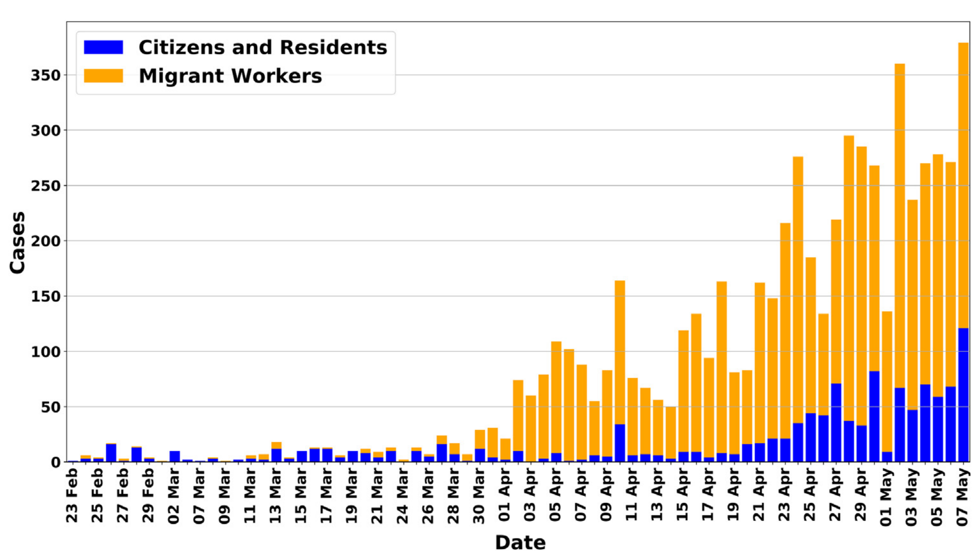

Figure 1. Temporal distribution of daily COVID-19 confirmed cases between 23 February and 07 May 2020 in the State of Kuwait.

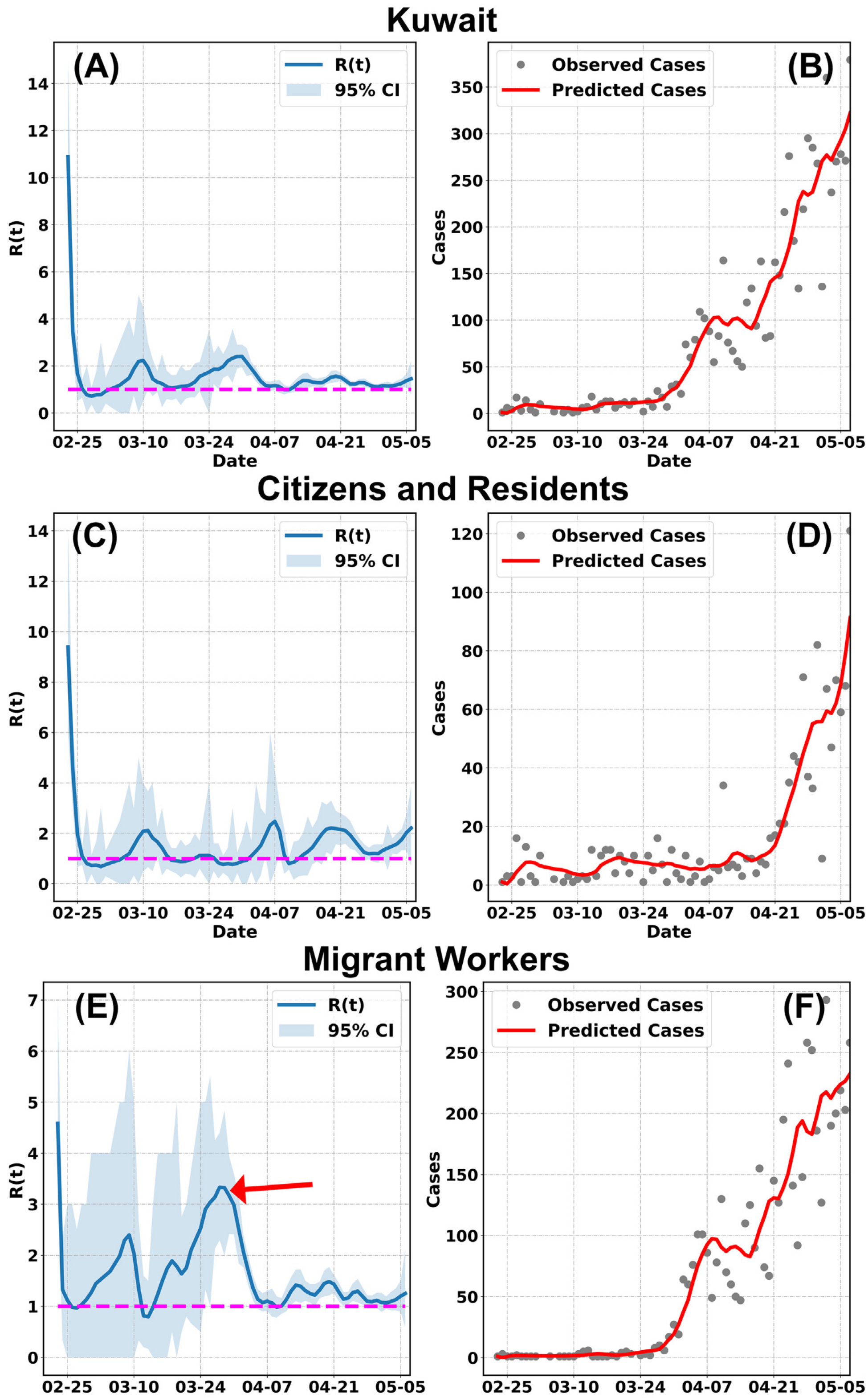

Figure 2. Time-dependent reproductive numbers ($R_{(t)}$) and model-predicted incidences of COVID-19 cases in the State of Kuwait between 23 February and 07 May 2020. (A, C, and E) Blue lines indicate the calculated $R_{(t)}$s; light blue shaded areas indicate their 95% confidence intervals (CI); and the magenta lines indicate $R_{(t)}$s = 1. (B, D, and F) Gray lines indicate the daily observed cases, while the red lines indicate the predicted incidences by the $R_{(t)}$ model. (A and B) indicate the results for the state of Kuwait. (C and D) indicate results for citizens and residents. (E and F) indicate results for migrant workers. The red arrow indicates the highest number of daily secondary cases throughout the study period ($R_{(t)}$ = 3.5).

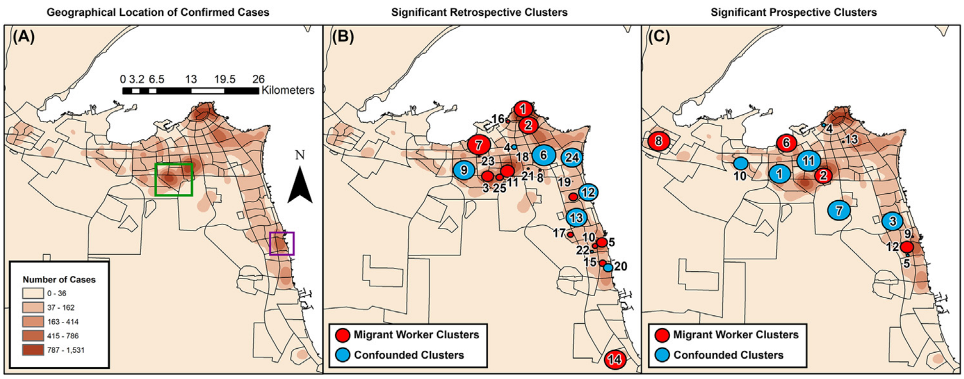

Figure 3. Geographical distribution of COVID-19 cases and their most likely significant spatiotemporal clusters in the State of Kuwait between 23 February and 07 May 2020.
(A) Spatially smoothed geographical locations of confirmed cases by a kernel density function (case per 5 m^2). The green square indicates the Aljleeb neighborhood, while the purple square indicates the Mahboula neighborhood.
(B) Significant clusters identified by the retrospective scan statistic model.
(C) Significant clusters identified by the prospective scan statistic model. The radius of the circles (km^2) is proportional to the predicted spatial extent of a given cluster. The clusters are rank-ordered according to their significance (1 = the primary most likely cluster). Confounded clusters indicate clusters caused by both migrant workers and citizen/resident cases.

Table 1
Significant spatiotemporal clusters identified by the retrospective multivariable permutation scan statistic model of COVID-19 cases in the State of Kuwait between 23 February and 25 April 2020. Clusters caused by migrant workers alone are highlighted in grey.

Cluster importance	Type of cases	Radius (km^2)	Temporal frame		[a]O_c	[b]E_c	O_c/E_c	*p*-value
			From	To				
1	[c]MW	1.55	29 March	18 April	536	210.96	2.54	<0.001
2	MW	1.62	23 February	21 March	87	60.0	1.45	<0.001
3	MW	1.00	29 March	11 April	134	51.27	2.61	<0.001
4	MW	0.44–	17 March–	21 March–	9	0.15	61.81	<0.001
	[d]CR				5	0.40	12.52	
5	MW	0.89	29 March	04 April	46	10.00	4.60	<0.001
6	MWCR	1.99–	23 February–	28 March–	27	4.04	6.68	<0.001
					23	11.23	2.05	
7	MW	1.93	26 April	02 May	85	31.61	2.69	<0.001
8	MW	0.08	12 April	14 April	23	2.65	8.68	<0.001
9	MWCR	1.80–	05 May–	07 May–	62	28.47	2.18	<0.001
					42	18.76	2.24	
10	MW	0.45	26 April	02 May	43	12.16	3.54	<0.001
11	MW	1.16	26 April	02 May	164	91.33	1.80	<0.001
12	MWCR	1.62–	17 March–	28 March–	8	0.30	26.72	<0.001
					3	0.63	4.80	
13	MWCR	1.76–	03 May–	07 May–	43	16.87	2.55	<0.001
					41	23.38	1.75	
14	MW	0. 82	22 March	28 March	12	0.29	41.37	<0.001
15	MW	0.60	05 April	11 April	16	1.96	8.17	<0.001
16	MW	0.32	03 May	07 May	26	5.06	5.13	<0.001
17	MWCR	0.48–	22 March–	28 March–	4	0.10	39.01	<0.001
					4	0.32	17.23	
18	MWCR	0.06–	22 March–	28 March–	3	0.038	78.01	<0.001
					3	25.35	16.92	
19	MW	0. 02	17 March	28 March	8	0.56	14.28	<0.001
20	MW	0.78	19 April	25 April	26	6.42	4.05	<0.001
21	MWCR	0.02–	23 February–	29 February–	3	0.03	121.901	<0.001
					2	0.01	30.29	
22	MW	0. 02	03 May	07 May	25	6.44	3.88	<0.001
23	MW	0. 04	08 March	14 March	4	0.03	142.71	<0.021
24	MWCR	1.81–	08 March–	21 March–	10	1.38	7.26	<0.029
					10	3.26	3.07	
25	MW	0.61	29 March	04 April	11	1.18	3.88	<0.042

[a] Observed cases.
[b] Expected cases.
[c] Migrant worker.
[d] Citizens and residents.

ranging 6–13 days and a spatial extension ranging 0.02–2 km^2 (Figure 3C, Table 2). Similar to the retrospective analysis, significant clustering events were either caused by migrant workers alone or by both socioeconomic categories, with no significant clustering events caused by citizens-residents alone (Table 2). Nevertheless, all significant active clustering events were detected in residential areas shared by both migrant workers and citizens-residents (Figure 3C). No substantial differences were seen in the O_c/E_c estimates for citizens-residents and migrant workers within the adjusted clusters (Table 2). Finally, nine

Table 2
Significant spatiotemporal clusters identified by the prospective multivariable permutation scan statistic model of COVID-19 cases in the State of Kuwait between 23 February and 25 April 2020. Clusters caused by migrant workers alone are highlighted in grey.

Cluster importance	Type of cases	Radius (km^2)	Temporal frame		[a]O_c	[b]E_c	O_c/E_c	*p*-value
			From	To				
1	[c]MW	1.80	03 May	07 May	62	28.47	2.18	<0.001
	[d]CR				42	18.76	2.24	
2	MW	1.46	19 April	07 May	292	196.78	1.48	<0.001
3	MW	1.76	03 May	07 May	43	16.87	2.55	<0.001
	CR				42	23.38	1.75	
4	MW	0.32–	03 May	07 May	23	5.06	4.54	<0.001
	CR				4	1.23	3.25	
5	MW	0.24–	03 May	07 May	14	2.95	4.74	<0.001
	CR				11	3.38	3.25	
6	MW	1.68	26 April	07 May	89	46.67	1.91	<0.001
7	MW	1.89	03 May	07 May	33	11.81	2.79	<0.001
8	MW	1.84	03 May	07 May	32	11.18	2.86	<0.001
9	MW	0.02	03 May	07 May	14	2.95	4.74	<0.001
10	MW	1.20–	03 May	07 May	20	6.54	3.06	<0.001
	CR				5	1.85	2.71	
11	MW	1.99–	26 April	07 May	76	45.71	1.66	<0.001
	CR				25	16.46	1.52	
12	MW	1.10	26 April	07 May	58	31.27	1.85	<0.001
13	MW	0.05–	03 May	07 May	8	1.69	4.74	<0.001
	CR				8	2.46	3.25	

[a] Observed cases.
[b] Expected cases.
[c] Migrant worker.
[d] Citizens and residents.

clustering events maintained their geographical proximity to the earlier clusters (Figure 3B and C), while four clusters emerged in new geographical areas located in Jahra and Farwaniya governorates (Figure 3C).

Discussion

Since the first case of COVID-19 was reported in Kuwait, the size has remained significantly small with sporadic infections for approximately a month (Figures 1 and 2). There were no significant signs of active community transmission events between 23 February and 17 March 2020 (Figure 2). This could be attributed to the government's aggressive intervention measures of testing and forced institutional quarantine of arriving travellers after observing the rapid spread of the pandemic in neighbouring countries. However, during the implementation of such measures, four significant clustering events were detected and comprised citizens-residents and migrant workers cases (Table 1; Figure 3B) in areas shared by the two communities (Figure 3B). This was followed by a significant wave of spreading ($R_{(t)}$s >1) and clustering ($p < 0.001$) events initiated after 17 March 2020 (Figure 2A and Table 1). The continuous implementation of strict control measures on infected cases appeared to help in lowering the general community transmission events in Kuwait on 07 April 2020 ($R_{(t)}$s $\leq$1; Figure 2A). Despite these efforts, seven significant clustering events still occurred between 25 March and 11 April, in which five were strictly in migrant workers' areas and two were in areas shared between the two communities (Figure 3B; Table 1). On 07 April, the government imposed a complete zonal quarantine on Aljleeb and Mahboula neighbourhoods for 28 days, where the highest density of migrant workers is located (Figure 3A). Further, a 28-day targeted house quarantine was enforced on migrant workers living in scattered dormitories in Eastern Asima governorate. Around the same time, the government imposed a partial curfew law at a national level, which temporarily limited significant spreading and clustering events for approximately 1 week (Figure 2A; Table 1). Pandemic progression then notably regressed to an exponential growth phase (Figure 2B), which was reflected by the significant spread of events (Figure 2A) and occurrence of newly emergent clusters (Figure 3C; Table 2) until the end of the study period.

This study found that COVID-19 transmission dynamics substantially differed between migrant workers and citizens-residents' communities (Figure 2C, D, E, F; Table 1). The immediate institutional quarantine of arriving travellers, relatively low population density (Rocklov and Sjodin, 2020; Team, 2020) and the high socioeconomic status may have limited the spreading and clustering of events within the citizen-resident community during the initial phase of the pandemic (Figure 2C and D; Table 1). In contrast, significant spreading and clustering events were seen among migrant worker communities across Kuwait (Figure 2E and F; Table 1). This is to be expected, as the high population density and low socioeconomic status of migrant workers are likely to be important drivers for COVID-19 transmission and circulation among such a community (Cristina Rapone, 2020; Liem et al., 2020; Organization, 2020; Rocklov and Sjodin, 2020; Team, 2020). Despite that, targeted and aggressive government intervention measures toward migrant worker communities were effective in temporarily lowering spreading and clustering events (Figure 2E and F; Table 1). The prospective cluster analysis results corroborated this finding, as a substantial decline in the number of active clustering events in the quarantined areas and dormitories was observed (Figure 3C). Notably, both migrant worker and citizens-residents' communities appeared to be following similar trends in spreading and clustering of infection, according to both analysis methods that were used in this study (Figure 3; Table 2). This is unsurprising since migrant workers from nonquarantined areas were resuming their daily manual labour jobs and consequently had frequent contact with citizens and residents. Another potential reason for the newly established infection within the citizens-residents' community might have been due to the frequent violation of social distancing measures prior to the holy month of Ramadan (e.g. family visits and massive grocery shopping activities). That said, the number of daily detected cases among migrant workers remained five times higher than in the citizens-residents community as of 01 April to the end of the study period (Figure 1).

The high population density and poor living conditions in migrant workers' housing areas will continue to challenge the success of the currently implemented intervention measures in Kuwait and in other countries with similar social structures (Cristina Rapone, 2020; Liem et al., 2020; Organization, 2020; Rocklov and Sjodin, 2020; Team, 2020). Unless major policy changes are implemented to improve the housing situation and wages for migrant workers, their geographical areas will become established hotspots for virus circulation and re-emergence. This will result in more depletion of Kuwait's already overburdened healthcare resources (Cristina Rapone, 2020; Liem et al., 2020; Organization, 2020).

Limitations of this study included the fact that it did not account for the direct effect of population density in the analyses. That said, it attempted a discrete Poisson model of the scan statistic test, which used population density data to estimate relative risks for the most likely clusters (Desjardins et al., 2020; Kulldorff, 1997). Unlike the permutation model, the Poisson model did not detect clusters in the areas with low population densities but with a high prevalence of migrant worker dormitories, particularly in Eastern Asima governorate. While the analytical methods relied on simplistic assumptions, they provided epidemiologically plausible insights into the dynamics of the COVID-19 pandemic in Kuwait. Unlike some models, which require extensive data preparation or computational resources, the selected analytical tools are easy to implement, making them well suited for near-real-time surveillance and decision-making. Additionally, the overparameterisation and heterogeneity of COVID-19 characteristics within countries are the main limitations affecting the reliability of more complex models in predicting rapid pandemic dynamics (Roda et al., 2020). Nevertheless, accounting for susceptible population characteristics, asymptomatic cases and negative tests would significantly improve these results, as well as risk-based surveillance efforts (Alkhamis et al., 2012; Desjardins et al., 2020; Lipsitch et al., 2020). The end date of the present study (i.e. 07 May) might be considered another limitation, as the pandemic reached its exponential growth phase by the end of the study period. Therefore, as the number of cases continues to increase, the number and magnitude of spreading events and emerging clusters are likely to be higher than what was seen.

Conclusions

This study helped the understanding of the temporal and spatiotemporal pandemic dynamics of COVID-19 in Kuwait, and highlighted the distinct spreading and clustering events within and between migrant workers and citizens-residents communities. Despite these aggressive measures, substantial pandemic growth was seen by the end of the study period, which was reflected by the predicted cases and number of emerging clusters. Densely populated areas and poor living conditions of migrant workers resulted in the highest number of significant spreading and clustering events within their communities. Nevertheless, targeted intervention measures within migrant worker communities substantially lowered the magnitude and number of spreading and clustering events, respectively. The importance of maintaining migrant workers' health and living conditions is crucial in limiting the transmission of COVID-19 in Kuwait. Importantly, this study demonstrated the use of selected analytical methods for rapid decision-making related to the allocation of surveillance and intervention resources. It is believed that the approach presented in this study in rapidly analysing temporal and spatiotemporal dynamics of the COVID-19 pandemic has not been widely used in the Middle East.

Ethical approval

This study was approved by the State of Kuwait Ministry of Health ethics committee. We anonymously obtained the data from the public health department's surveillance records at Jaber Al-Ahmad Al-Sobah Hospital.

Acknowledgments

This research was funded by the Kuwait Foundation for the Advancement of Science (Project No: 2020/1428).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2020.06.078.

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