# The Epidemiological and Spatiotemporal Characteristics of 2019 novel coronavirus diseases (COVID-19) in Libya

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# Abstract

**Background:** COVID-19 is a global pandemic that affectedaffects all aspects of life. Studies on understanding the geographical and epidemiological characteristics become particularly important in controlling the spread of the pandemic. Such studies are lacking in Northern African countries, particularly in Libya, which is considered being, the second largest country in Africa, with the longest coast facing Europe. The objectives of this study are to; determine the epidemiological parameters and spatiotemporal patterns of COVID-19 in this large country and outline the needed strategies to contain the spread and the consequences of the pandemic.

**Methods:** This comprehensive study included all the confirmed cases of COVID-19 since its emergence in Libya, from early April 2020 until July 31$^{th31}$. The epidemiological characteristics of COVID-19 were analyzed, and the spatial dynamic trends were explored**.** A region Region-based counts of weekly reported cases were used to characterize and quantify the spatial dynamics of COVID-19.

**Results:** A total of 3695 of confirmed cases of OVID-19 were collected,; 2515 (68.1%) were males , and 1180 (31.9%) were females with a male-to-female (M:F) ratio of 2.1:1. Aged between 2 -and 78 years old. Older age patients infected with COVID-19 are at higher severity and mortality. A broad geographic variability and spatiotemporal spread variation of the COVID-19 pandemic in Libya was observed. Indicating. This indicates a more significant increase ofin COVID-19 from the middle of July, particularly in the West and Southern regions, although it was consistently observed in the Meddle and Southern regions.

**Conclusion:** Evaluating the epidemiological data and the spatiotemporal dynamic trends of COVID-19 at early stages are particularly important in understanding the pandemic spread**.** These parameters are essential in designing effective prevention and control programs aimed at reducing the impact of the COVID- 19 pandemic, particularly in countries with limited resources.


# Background

The ongoing coronavirus disease (COVID-19) pandemic has reached each country in the world, and no one can be considered safe. The pandemic affects all aspects of life, socially, economically, politically and even morally. Since its emergence, countries and health authorities have responded comprehensively but differently[1]. However, the impact may vary both between and within countries, partly because of the degree to which control strategies are adopted and executed. Countries , such as Sweden and Germany responded early and successfully. Though others such as Italy, Spain and France, the action was different and thus resulted in a high number of deaths [2-4]. The impact was even worse in developing countries such as Iran and Brazil, as early action was improper and influenced by virtual local understanding [5,6]. Hence, the epidemiology and the impact of COVID-19 varies greatly from one country to another, and thus, understanding these epidemiological parameters became particularly important to each country.

In Africa, the incidence of COVID-19 varies considerably between countries, possibly reflecting variations in volumes of air travel and differences in coverage of SARS-CoV-2 testing [7]. The preparation of tackling COVID-19 is becoming increasingly difficult in Northern and sub-Saharan countries, where the effects of internal armed conflicts and the emergence of other viral epidemics on the economy and health structures are still being felt [8,9]. However, only a few African states have been successful in implementing detection, prevention, and control measures. However, the COVID-19 pandemic poses a challenge not only for fragile African countries but also for those with well-functioning health systems. Until now, studies evaluating the epidemiological and spatial spread of the COVID-19 pandemic in Africa have been limited. However, understanding the spread of the COVID-19 outbreak is critical to predicting local outbreaks and developing public health policies during the early stages of COVID-19[10,11].

Libya, the second largest country in Africa with the longest coast in the Mediterranean facing Europe, has been involved in an armed conflict since 2011. The country is considered vulnerable to the spread of infectious diseases such as COVID-19. Armed conflicts and internal instability challenge disease control and have a very deleterious effect on the provision of health services [12,13]. Due to low levels of international commerce and travel in the country , the seeding of COVID-19 was delayed compared to other Northern African countries [ 14]. The first few cases of COVID-10 embarked in Libya and arrived from Italy and Egypt as early March this year. Now that COVID-19 has taken a strong hold in the country, displaced people and immigrants can help spread from one city to another[15,16]. Accordingly, it is expected that COVID-19 is likely spreading rapidly and undetected in the Libyan community. Hence, understanding the epidemiological manifestations and local variation in the dynamics of the pandemic is a crucial step in developing more effective strategies for mitigating the risk of infection in vulnerable communities. Unfortunately, to date, there is not a global and standard response to the pandemia, and each country is facing the crisis based on their own possibilities, expertise and hypotheses [17].

Different studies have been performed to analyze the epidemiological manifestations and geographic mapping of COVID-19[10,18]. Such information is particularly important not only in framing and controlling COVID-19 but also for planning how to combat the consequences and aftermath of this vital pandemic. However, there is a lack of information regarding the epidemiology and clinical features of COVID-19 patients in North Africa, particularly Libya. Therefore, the objectives of this study were to evaluate the epidemiological and spatiotemporal distribution of COVID-19 in Libya and highlight the needed strategies and how to appropriately allocate healthcare resources to combat the spread of the pandemic.

# Methods

## Patient information and data collection

The demographic data and epidemiological information, clinical symptoms and outcomes from all reported cases of COVID-19 between March 24, 2020 and July 31,2020 allocated by the National Centre for Disease Prevention (NCDC) were collected. All investigations, contact tracing, and quarantine were conducted by the NCDC at the regional or district level. The data were recruited from all registered patients, extracted from the hospital records and checked by a clinical epidemiologist. Furthermore, the daily updated numbers were cumulated from all confirmed COVID-19 cases across all the Libyan regions.

### Case definitions

The definitions of the confirmed cases of COVID-19 were based on our previous publication [14,19]. Among all confirmed cases, the degree of clinical severity was categorized  according to the following criteria :mild cases were defined as those with only mild symptoms, without evidence of pneumonia and even without requiring oxygen therapy. Moderate cases are those with fever, and respiratory tract symptoms, and imaging shows pneumonia. Severe cases are those who have  of the following signs: (a) respiratory distress, respiratory rate 30 beats / min; (b) in the resting state, finger oxygen saturation 93%) arterial blood oxygen partial pressure (PaO2/oxygen concentration (FiO2) 300 mmHg (1 mmHg = 0.133 kPa). Critical cases were defined as those exhibiting, respiratory failure requiring mechanical ventilation and septic-shock. ICU admission is required with multiple organ dysfunction/failure.

### Laboratory testing of COVID-19

Laboratory confirmation of COVID-19 is being  performed by the National Center for Disease Control. Nasopharyngeal and oropharyngeal swab samples were collected following standard safety procedures. RNA was extracted using a QIAamp™ viral RNA mini kit from Qiagen™ according to the manufacturer's instructions, as previously published [20]. Analysis was performed by real-time reverse transcriptase-polymerase chain reaction (RT-PCR) for all suspected cases following the protocol established by the WHO. Biosafety cabinets are used, and the work is done according to laboratory biosafety guidelines [21].

### Statistical analysis

A descriptive statistical analysis was performed to analyze the epidemiological characteristics of confirmed cases of COVID-19 using computer software version 11.0 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP). Logistic regression was conducted to identify the factors associated with COVID-19 infection. Data are expressed as the means ± standard deviation (SD) and as numbers and percentages with 95% confidence intervals (CIs), as appropriate. Spatiotemporal analysis and geographic mapping of COVID-19 cases was carried out using GraphPad Software as previously described[22-24]

## Results

The study population consisted of all confirmed cases of COVID-19 reported in Libya by July 31 (12.00 AM) 2020. A total of 3695 cases  were reported, , and the epidemiological and clinical characteristics of these cases are illustrated in Table 1. Of 3695 cases, 2515 (68.1%) were males, and 1180 (31.9%)  were females, with a male-to-female (M:F) ratio of 2.1:1. Aged between 2  and 78 years old. The number of  live cases was reported to be 3621 (98%), and only 74 (2%) cases died. The case fatality rate was higher among males 53 (71.6%), though it was only 21 (28.4%) among females. Of the deceased cases, 39 (7%) ≥ 55 years of age were included, particularly over 66 years, although only 5 (6.6%) cases were below 40 years of age and 21 (28.4%) cases were between 41 -and 55 years of age. Epidemiological investigations indicated that of these cases, 782 (21.2%) were imported, though 2913 (78.8) cases acquired locally (*p*= <0.001). The imported cases were mainly from Egypt 257 (32.9%), Turkey 219 (28%), Tunisia 209 (26.7%) and Saudi 96 (12.3%) cases. The largest number of cases was reported in the Western Region, with a total of 1755 (47.5%) cases with 23 (31.1%) deaths, followed by Southern Region1133 (30.7%) cases with 31 (41.9) deaths. However, the Eastern Region reported 738 (20%) cases and 9 (12.2%) deaths, and the Meddle region had 429 (11.1%) cases and 11 (14.9%) deaths. Of all confirmed case-patients, 2330 (36.1%) were mild, 1108 (30%) were moderate, 128 (3.5%) were severe and 91 129 (3.5%) were critical. The highest mortality rate was reported among critical and severe cases, which was found to be 38 (51.4%) and 26 (35.1%),respectively (P>0.001), while it was only moderate 7 (9.5%) and mild 3 (4.1%) and cases.

The age distribution of patients stratified by sex is shown in Fig 1. The median age of the infected cases was 55 years. A total of 26 (7%)were aged sixty or above, and only 86 (2.4%) were children < 15 years old. The incidence of infection rates increased progressively with age, with males showing higher rates except for the latest (greater than 65 years of life) (p =< 0.001). This difference was also significant among patients above 50 years of age. The number of infected cases was higher among male patients (68%), indicating that men's cases of COVID-19 tended to be more serious than women's according to the clinical classification of severity.

The association between illness severity and age is shown in Fig. 2. It was shown that illness severity increased with age. The largest number of mild cases was reported among those aged below 45 years, followed by moderate cases. Moderate cases were higher among those aged below 45 years. A large number of severe and critical cases were reported among older patients, particularly after 60 years of age (P <0.001), which accounted for 45 (44.1%) and 51 (56%) of mild and severe cases, respectively.

Figure 3 shows the overall temporal trend of weekly counts of newly confirmed COVID-19 cases by four Libyan regions during the study period. The COVID-19 pandemic occurred sporadically until early May (first nine epi-weeks); 120 confirmed cases were reported mainly in the Western region, with 97 cases. The number of weekly confirmed COVID-19 cases subexponentially increased across the country from the 10th to 17th epi-week, followed by a slow decrease over recent weeks. During the entire observation period, the highest number was reported within the western (47.8%), followed by the southern region (30.4%) , middle (30.4%) and eastern regions (20.1%), as shown in Fig 4. However, during epi-weeks 9-16, the proportion of confirmed cases decreased in the East and Meddle, regions but highly increased in the South regions (Figure 4).

The dynamics of COVID-19 during the study period are shown in Fig 5. In the first eight epi-weeks, the emergence of the pandemic was detected in five counties in the Western region, including Tripoli, which hosted the largest number of cases, followed by Zawia, Surman, Aljalaet and Nalut. Two counties in the Meddle region, Musrata and Zleitan, and only one county in the Western region (Benghazi) and Southern region (Sebha) are illustrated in Fig. 5A.

The results from geographic clustering analysis are robust. Starting in the 9th epiweek, new clusters emerged and came out largely from the southern and western regions ($P$=< 0.001). In the following epi-weeks, pandemic spread  throughout the country, and new cases were reported in each of the 22 counties, as shown in Fig 5B. It is clearly evident that there is a positive correlation among the confirmed cases according to the geographical structure, and its spatial distribution has obvious agglomeration characteristics (Fig 5). The increase in confirmed cases in one city will inevitably lead to increasing cases in adjacent cities, which means that a positive spillover effect occurs. The highest numbers were reported in Sebha (southern region), Tripoli (western region) and Musrta (middle region).

# Discussion

The epidemiological and clinical details of the COVID19 pandemic in Libya are well characterized in this study. Up to July 31, a total of 3695 were reported, which accounted for 6.2/10000 of the population. The mean age was 53 years old, with a male to female ratio of 2.1:1. Of these patients, 74 (1.3%) died. The largest numbers were reported in the Western and Southern regions, which accounted for 1732 (47.8%) and 418 (11.5%), respectively. However, it was lower in the Eastern 729 (20.1%) and Meddle 418 (11.5%) regions. Our data showed that COVID-19 infects men more than women; these findings are in concordance with other studies reported from China and Iran [25,26]. However, there is no obvious reason for such gender variability speculation regarding hormonal and genetic variation or even social culture, particularly in Middle and African countries. However, other studies have shown similar susceptibility to SARS-CoV-2 between males and females [27].

Taking the patients’ age into consideration, children (<15 years) accounted for only 2.4, and those aged 20-50 years accounted for5%), although those aged over 60 years represented the largest number of infected cases, which accounted for 24%. This is clearly evident that COVID-19 among Libyan correspondence to a higher age. In fact, most deaths in infected individuals occurred in Italy, Spain and France in elderly people suffering from severe conditions, particularly in the early phases of epidemics[28]. However, a recent study carried out on the Libyan population demography shows that over 65% of the Libyan population is less than 60 years old[29].

Based on our data, the majority of the reported cases were mild (2327, 64.3%) and moderate (1101, 30.4%). However, only 102 (2.8%) were severe and 91 (2.5%)  were critical. The association between illness severity and age was evident in this study. It was shown that illness severity increased with age. Although the infected and deceased patients were significantly older than the patients who survived COVID-19, ages were comparable between males and females in both the deceased and the patients who survived. Furthermore, this study has shown that males tend to experience more serious cases of COVID-19 than females according to the clinical classification of severity, including mild, moderate, severe, and critical. This is in agreement with other studies carried out by Li *et al*and Jian-Min *et al.* . who showed that men's cases tended to be more serious than women's[19,30]. Therefore, gender may be considered a risk factor for higher severity and mortality in patients with COVID-19, independent of age and susceptibility.

In this study, we evaluated the spatial and temporal patterns of the COVID-19 pandemic in Libya within the first 16 Epi-weeks of the epidemic. In the early stage of the COVID-19 outbreak, few sporadic cases were reported in the first six Epi-weeks in Tripoli in the Western region. By the end of the 8th epiweek, the cases spread to cities neighboring Tripoli, such as Musrta and Zawia; the first-order neighboring cities showed a particularly increased number of confirmed cases. Since then, the number of weekly confirmed COVID-19 cases has exponentially increased across the country from the 9th to 16th epiweeks. During the entire study period, the prevalence of COVID-19 in Libyan regions showed striking variations. The epidemic was much higher and important in Western and Southern regions, although it was less important in Meddle and Eastern regions. This is more likely to depend on the different timing of the onset of the outbreak in each region [31,32].

It is clearly evident in this study that the dynamics of theS epidemic in Libya followed a geographical differentiation, with a strong West to South gradient, although no region was free of cases and deaths at the end of July. In all regions, both morbidity and mortality curves tended to depart from linear lines up and no sign of flattening with time, thus highlighting the critical situation of the epidemic. Similar trends were observed in the early stages of spread COVID-19 in Italy. Spain and France. Hence, specific strategies should be implemented to contain the soaredpandemic [33,34].

However, the study provided detailed information regarding the epidemiology of COVID-19 in Libya. The reported data suffer from many uncertainties and limitations. These may include. First, the confirmed cases of COVID-19 might not reflect the actual number of persons infected by COVID-19, as many cases were symptomatic and some went untested further to the limited testing resources in the country. Second, the study did not highlight the impact of the ongoing armed conflict on the spread of COVID-19 in Libya, which defiantly hinders the accurate number of cases in certain cities. Third, the study did not cover certain groups, such as immigrants displaced population and injured people who are prone to a higher risk of COVID-19 [35-37].

# Conclusion

This study is the first to provide information on epidemiological characterization and the spatial and temporal patterns of the COVID-19 pandemic in Libya. It is conclusively evident that the pandemic has affected the whole country, with incidence rates varying from region to another. Meanwhile, the prevention and control of COVID-19 in Libya is still a severe fight. We have seen the health system of some European countries buckled under the surge of COVID-19 and appealed for help[38,39]. The internal conflict in Libya has affected the national health care system immensely. There is a dearth of information on the capacity to provide care for critically ill patients in ICUs in Libya in addition to lack of accuracy and efficient tracing policy of COVID-19 infected cases. Hence, Swift action to control further spread of the virus and to improve the response capabilities is urgently needed[40,41]. The study demonstrated the spatiotemporal characteristics and trends of COVID-19 in Libya, which is essential to better focus on preventive efforts. The country must scale up its containment and mitigation strategies — quarantine, isolation, and social distancing. Establishing functional infection prevention and control practices that could help to detect and contain the ongoing epidemic[42,43]

# Abbreviations

COVID-19; Coronavirus diseases 2019

RT-PCR: Reverse transcriptase polymerase chain reaction

SD: standard deviation

# Declarations

The authors declare that they have no conflicts of interest.


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### Ethical approval and consent to participate

The Medical Ethics Committee at the Faculty of Medicine, University of Tripoli approved the study and waived the need for approval by the Libyan National Ethics Committee. As the study was an analysis of epidemiological data obtained at a national population level, it needed no consent from the participants.


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### Availability of data and materials

The data presented in this paper are freely available upon request.

### Authors' contributions

MD conceived and designed the study. MD and AE contributed to the analysis tools. MD designed the analysis, analyzed the data, and performed cartography. MD wrote the paper. AE and MA made substantial contributions to the conception and design, acquisition of data, or analysis and interpretation of data MD, MA, and AE provided advice and critically reviewed the manuscript. All authors read and approved the final manuscript.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

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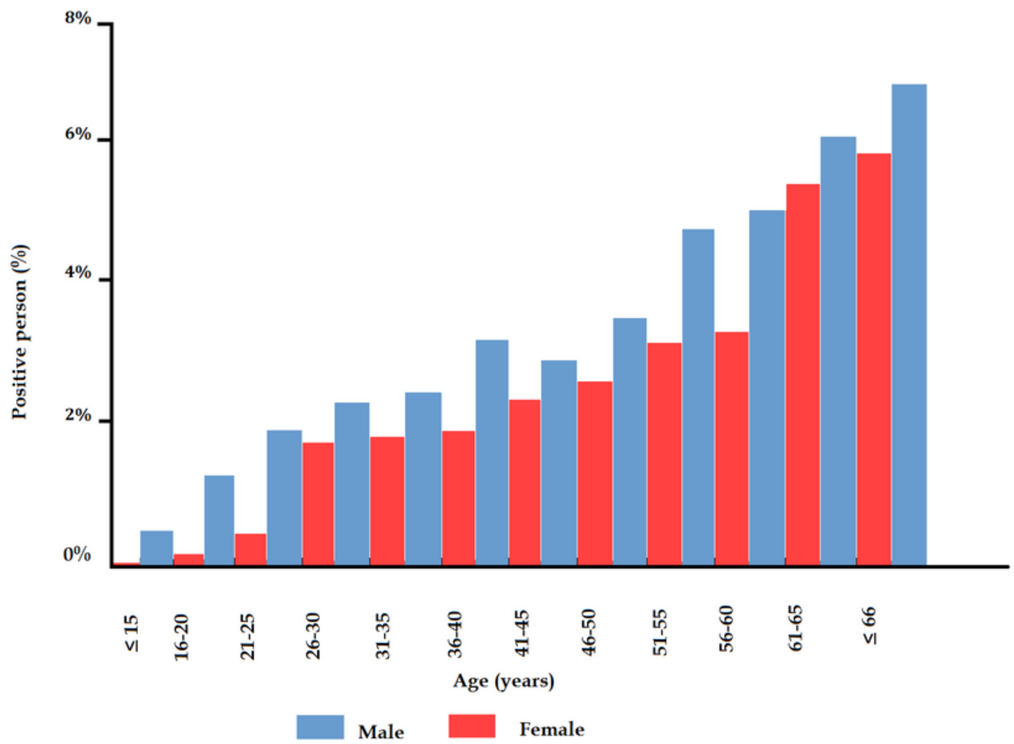
# Table

**Table 1 Epidemiologic Characteristics of 3695 confirmed case-patients with COVID-19 Infection in Libya.**

| Demographic Characteristics | Alive | Death | Total | *P* value |
|---|---|---|---|---|
| | | | | |
| | | | | |
| **Total No (%)** | **(No = 3621)** | **(No=74)** | **(No=3695)** | |
| | | | | |
| | | | | |
| **Gender** | | | | |
| Male | 2462(68) | 53(71.6) | 2515(68.1) | <0.001 |
| | | | | |
| Female | 1159(32) | 21(28.4) | 1180(31.9) | 0.01 |
| | | | | |
| **Age group** | | | | |
| ≤ 15 | 86(2.38) | 0(0) | 86(2.3) | 0.01 |
| 16-20 | 142(4) | 0(0) | 142(3.8) | 0.01 |
| 21-25 | 161(4.5) | 1(1.4) | 162(4.5) | 0.02 |
| 26-30 | 241(7.5) | 0(0) | 241(6.5) | 0.01 |
| 31-35 | 271(7.5) | 0(0) | 271(7.3) | 0.01 |
| 36-40 | 307(9) | 3(4.1) | 310(8.4) | 0.01 |
| 41-45 | 327(9) | 5(6.8) | 332(9) | 0.01 |
| 46-50 | 350(9.5) | 7(9.5) | 367(10) | 0.01 |
| 51-55 | 379(10.5) | 9(12.2) | 388(10.5) | 0.01 |
| 56-60 | 398(11) | 13(17.6) | 409(11.1) | <0.001 |
| 61-65 | 427()11.8 | 15(20.3) | 442(12) | <0.001 |
| 66 | 541(14.9) | 21(24.4) | 562(12.2) | <0.001 |

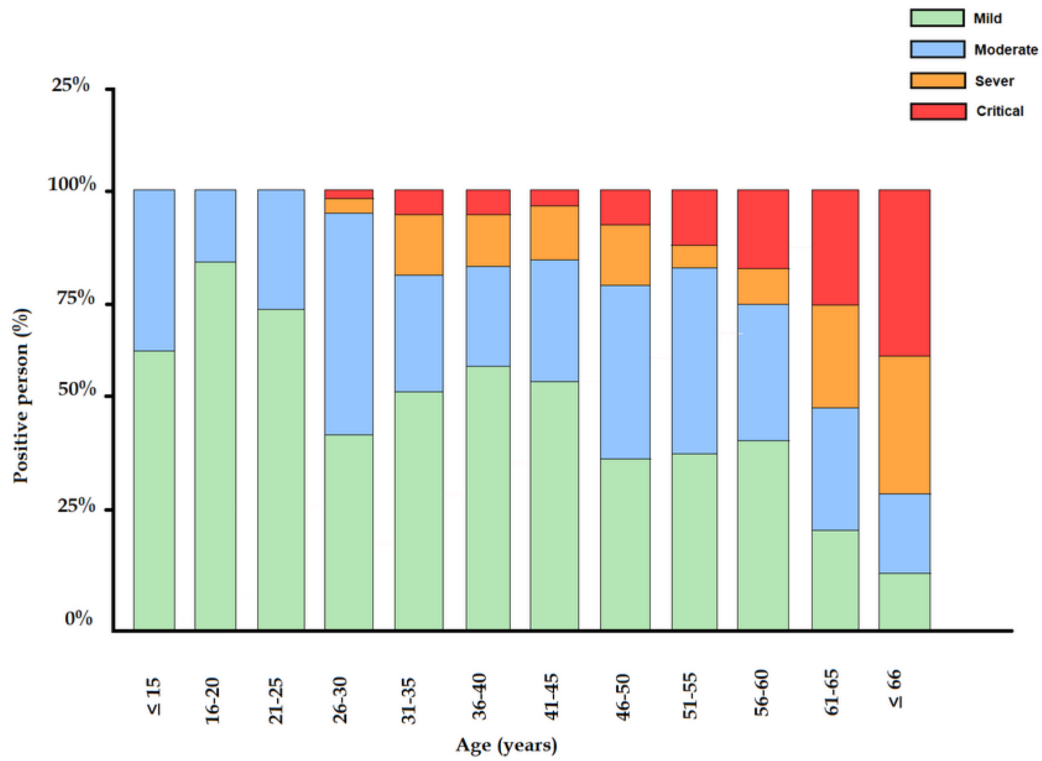
| | | | | |
|---|---|---|---|---|
| | | | | |
| **Source of Infection** | | | | |
| Imported | 751(20.2) | 31(42) | 782(21.2) | 0.01 |
| Local | 2870(79.3) | 43(58) | 2913(78.8) | <0.001 |
| | | | | |
| **Clinical severity** | | | | |
| Mild | 2327 (64.3) | 3(4.1) | 2330(36.1) | 0.01 |
| Moderate | 1101(30.4) | 7(9.5) | 1108(30) | 0.01 |
| Sever | 102()2.8 | 26(35.1) | 128(3.5) | <0.001 |
| Critical | 91(2.5) | 38(51.4) | 129(3.5) | <0.001 |
| | | | | |
| **Geographic region** | | | | |
| Western Region | 1732 (47.8) | 23(31.1) | 1755(47.5) | <0.001 |
| Meddle region | 418(11.5) | 11(14.9) | 429(11.1) | 0.01 |
| Southern Region | 1102(30.4) | 31(41.9) | 1133(30.7) | <0.001 |
| Eastern Region | 729(20.1) | 9(12.2) | 738(20) | 0.01 |

# Figures



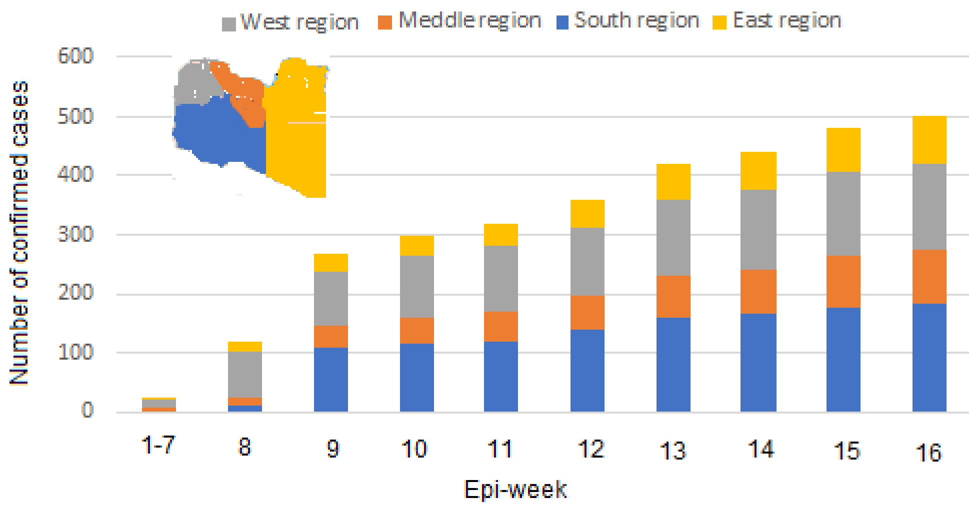

## Figure 1

The age and gender distribution of confirmed cases of CIVID-19 infection during the study period. Males (blue bars) and females (red bars)



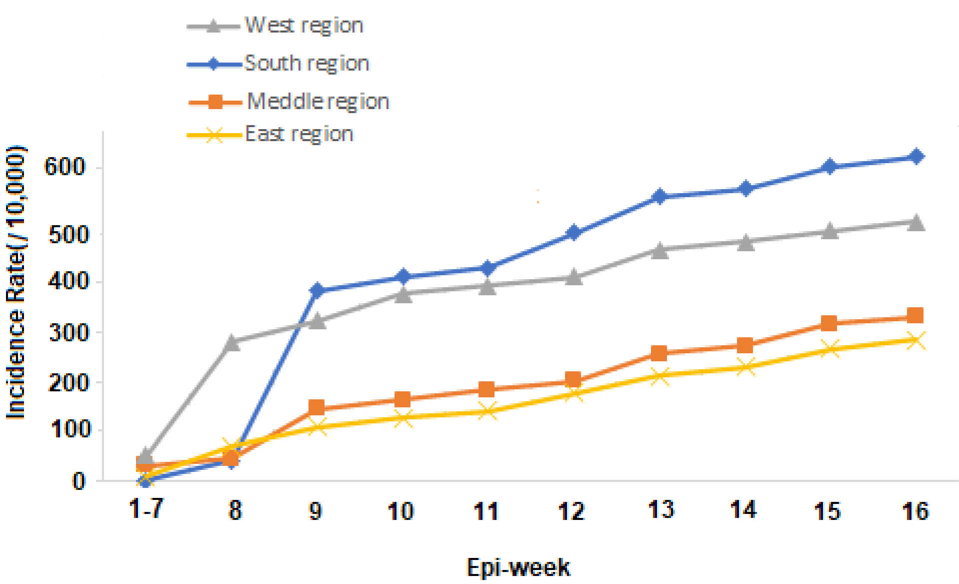

### Figure 2

The clinical severity of confirmed cases with COVID-19 infection. The different versions of the definition for confirmed cases were marked, mild, moderate, severe, and critical.



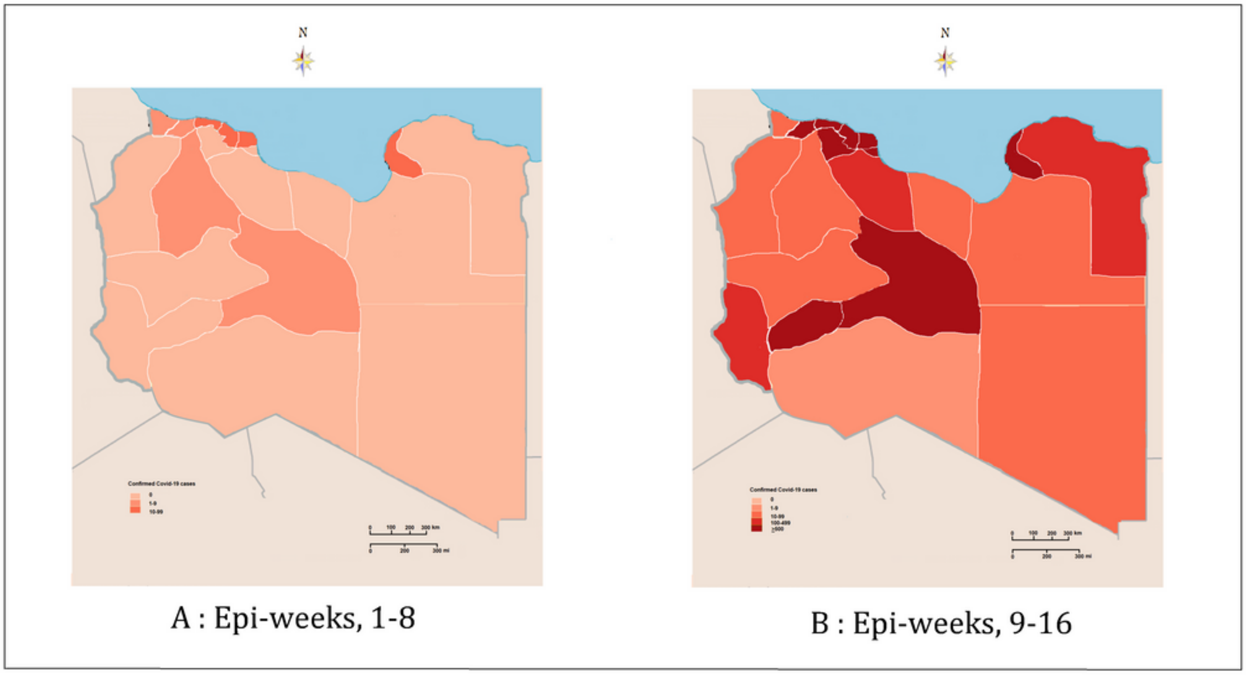

## Figure 3

The weekly incidence trends of confirmed cases of COVID-19 in each Libyan region during the study period.




## Figure 4

The prevalence of COVID-19 cases among the Libyan population across the four geographic regions over 16 epi-weeks, April 03–July 31, 2020.




## Figure 5

Geograpic and spatiotemporal distribution of the confirmed cases of COVID-19 in Libya A during the early stage of the epidemic (1- 8) epi-weeks B during the second stage of the epidemioc (9-16) epi-weeks