Spatiotemporal Distribution of Case Fatality Rate of Coronavirus Disease 2019 (COVID-19) in Libya

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التوزيع المكاني والزماني لمعدل الوفيات الناجمة عن مرض فيروس كورونا 2019 في ليبيا

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Abstract

Severe acute respiratory syndrome coronavirus 2 is the respiratory disease responsible for the COVID-19 pandemic; one of the worst pandemics reported throughout human history with a high Case fatality rate reported leading to high potential impacts and lockdown of the entire world's activities. This study assessed and determined the Case fatality rate of COVID-19 and its associated risk factors among the Libyan population. A retrospective cohort study involving 1,000 random nasal swabs from Libya between July 2020 and January 2021 examined the presence of coronavirus antigens in samples from different regions and sexes using a real-time reverse transcriptase-polymerase chain-reaction assay at the Libyan Centre for Biotechnology, Tripoli, Libya. The overall case fatality rate was estimated to be (4.7%; 3.37%-5.99%) with a 95% confidence interval (CI). The highest Case fatality rate (40.78%; 95% CI = 29.74%-51.84%) was reported among the elderly age group. The Case fatality rate among the different age groups was statistically significant (P =.00001). The highest and lowest Case fatality rate were estimated to be (5.04%; 95% CI = 3.57%-6.51%) and (4.48%; 95% = 0.00%-9.43%) in the western

and middle regions, respectively; however, there was no statistical difference (P =.4%) between the regions. The study found a high Case fatality rate of COVID-19 among Libyans, with flattened curve patterns but uneven distribution. Age-related factors significantly influenced the case fatality rate, with the elderly reporting higher rates.

Keywords: COVID-19, Case Fatality Rate, Spatiotemporal, Libya.

الملخص

فيروس المتلازمة التنفسية الحادة الوخيمة فيروس كورونا 2 هو مرض الجهاز التنفسي المسؤول عن جائحة كوفيد-19؛ واحدة من أسوأ الأوبئة التي تم الإبلاغ عنها عبر تاريخ البشرية، مع ارتفاع معدل الوفيات المبلغ عنها والذي أدى إلى تأثيرات عالية وإغلاق أنشطة العالم بأكمله. تم إجراء هذه الدراسة لتقييم وتحديد معدل الوفيات لحالات الإصابة بفيروس كورونا وعوامل الخطر المرتبطة به بين السكان الليبيين. دراسة إسترجاعية شملت 1000 مسحة أنف عشوائية من ليبيا بين يوليو 2020 ويناير 2021، فحصت وجود مستضدات فيروس كورونا في عينات من مناطق وجنسين مختلفين باستخدام اختبار تفاعل البوليميراز المتسلسل العكسي، في ليبيا. مركز التقانات الحيوية، طرابلس، ليبيا. تم تقدير معدل الوفيات الإجمالي للحالات ليكون (4.7%؛ 3.37%-5.99%) مع فاصل ثقة 95% (CI). تم تسجيل أعلى معدل وفيات (40.78%؛ 95% CI = 29.74%-51.84%) بين الفئة العمرية لكبار السن. وكان معدل الوفيات بين الفئات العمرية المختلفة ذا دلالة إحصائية (P=.00001). تم تقدير أعلى وأدنى معدل وفيات للحالات بـ (5.04%؛ 95% CI = 3.57%-6.51%) و(4.48%؛ 95% = 0.00%-9.43%) في المنطقتين الغربية والمتوسطة، على التوالي؛ ومع ذلك، لم يكن هناك فرق إحصائي (P=.4٪) بين المناطق. وجدت الدراسة ارتفاع معدل الوفيات بسبب فيروس كورونا بين الليبيين، مع أنماط منحنى مسطح ولكن توزيع غير متساوي. أثرت العوامل المرتبطة بالعمر بشكل كبير على معدل الوفيات، حيث سجلت في كبار السن معدلات أعلى.

الكلمات المفتاحية: كوفيد-19، معدل الوفيات، الزمان والمكان، ليبيا.

Introduction

Coronavirus disease 2019 (COVID-19) originated in Wuhan, China, and the first cases of COVID-19 were reported in December 2019 in Hubei Province, central China. Globally, the pandemic of COVID-19 is rapidly growing, with fatal acute viral respiratory disruptions caused by a novel human coronavirus (Atzrodt et al., 2020). It is life-threatening to human livelihoods and the nation's survival and sustainability. It has shown considerable morbidity and mortality rates. By the beginning of February 2020, around 25 countries had developed the viral infection. This included the United States of America, Canada, Germany, France, Australia, Thailand, and the Republic of Korea (WHO, 2020). Since then, the disease has spread to almost every country worldwide, leading the World Health Organization to declare a pandemic in 2020. Furthermore, it has spread to more than 200 countries, with 28 thousand confirmed cases and about two million deaths worldwide, including in Africa. In Africa, confirmed cases were reported in all countries, including Libya, with a moderate importation risk ranking as most African countries strengthened their preparedness against COVID-19 importations (Gilbert et al., 2020). Early in the epidemic, several studies assessed the case fatality ratio (the percentage of symptomatic cases or confirmed diseases who die from the infection) of coronaviruses using a range of different statistical and modeling methods. However, the exact case fatality rate (CFR) of COVID-19 infection is currently underestimated due to limited population longitudinal recorded data (WHO, 2020).

Age Factor (Variables)

The severity of COVID-19 is significantly influenced by various risk factors, including the age of the patients affected. A large retrospective cohort survey in 2020 summarized that older age is considered a potential risk factor for COVID-19 death (Al-Mudhaffer et al., 2020; Gesesew et al., 2021). At the beginning of the outbreak, most cases were observed among older adults. However, younger populations with COVID-19 disease had higher morbidity and mortality rates. In addition, the epidemiological patterns of the COVID-19 pandemic in Libya were the highest among the vulnerable age category between 30-65 years (Mahmoud et al., 2021). As the outbreak continued, the number of cases among 65 aged people and older increased with some increases among children (<18 years) were also recorded. Moreover, the older age and presence of comorbidities, including diabetes, showed a severe negative effect on COVID-19 with a more severe course and a higher case fatality rate. Furthermore, the case fatality rate reported in Wuhan among older age groups (<75) was the highest, especially compared to the other 0–9-year age groups (Mahmoud et al., 2023; Al-Sawafi, 2020). The incidence in children is much lower than in older cases, with no need for medical intervention except for the necessity of supportive therapy. In comparison to adults, pediatric disease cases showed a relatively mild prognosis with symptomatic clinical features and a rare mortality rate with unknown

causes. Dong, et al., 2020 mentioned in the largest pediatric survey that most of the children virologically confirmed were asymptomatic. At the same time, the reason why children and youths are less severely affected may be due to immune system variations and/or changes in gene expression against coronavirus. Interestingly, in Libya, one theory suggested the 'trained immunity phenomenon'. This is associated with the immunological benefits of the Calmette-Guérin (BCG) compulsory national vaccination program relating to COVID-19 antigen. Susceptibility to virion was high in elderly people; this may be due to qualitatively altered immune reaction, 'immunosenescence', as viral receptors such as ACE2 are not well defined Moreover, exposure to prenatal pollution, smoking, and obesity have a significant effect compared to severely susceptible elderly patients (Balasubramanian et al., 2020).

Sex Variables

The United States is experiencing a variety of ongoing infection scenarios due to the significant epidemiological magnitude of coronaviruses. By June 2020, the pandemic had recorded the highest number of infected cases, with over 2 million cases between deaths, recoveries, and confirmed cases. The infection rate among males and females was 2.1:1 (Daw et al., 2021). Many factors including advanced age, and sex, raise the risk of infection and amplify the effects of COVID-19. In addition, the CFR of males was roughly doubled versus for females. Significantly, the CFR was also higher among men than women, with no clear significant sex difference; this may be due to some patients remaining asymptomatic. Moreover, early in the COVID-19 disease, it was prominent and interesting that higher case-fatality rate (CFR) degree and stability were observed in males than females in different age groups. Surprisingly, COVID-19 CFR revealed consistent increases in severity in males of all ages due to gender differences. Furthermore, adolescents displayed higher CFR, which could be related to hormonal factors. In addition, male positive cases outnumbered female positive ones in June 2020 (Shah et al., 2021).

Regions Variables

Despite the spatio-temporal distribution of COVID-19 in Northern African countries, the pandemic spread quickly, and most imported cases were mainly from neighboring African and Asian regions. This included Algeria, Tunisia, Egypt, Morocco, Turkey, and Saudi Arabia. Furthermore, the tempo-spatial distribution of COVID-19 in different Libyan parts was difficult to estimate and resulted in an unclear epidemiological picture of COVID-19 in the country (Mahmoud et al., 2021). The higher number of cases were from northwest Tripoli, the capital of Libya, compared to other cities in the country. Furthermore, the vast majority of Western Libyan cases came from the western region of Libya, with the eastern and southern parts coming in second and third, respectively.

Notably, the epidemiology of COVID-19 in Libya was varied across the country. However, the Western region was responsible for the greatest number of infections, followed by the Southern, Eastern, and Central regions, respectively. On the other hand, Mortality rates were highest in the Southern and Central regions and lowest in the Western and Eastern regions. This may be related to social habits in Libyan populations and border barriers (Mahmoud et al., 2023). In addition, as a consequence of the ongoing conflict, the outbreak situation in Libya was blurred and underreported at the beginning of 2020; however, the majority of cases were reported in the western east area (Middle), especially in Misrata, due to their only operational airport. Meanwhile, the suspected cases in the Eastern region, which include Benghazi and Tubruk, came from Albtanan's operating bounds, while the majority of Southern Libyan reported cases, particularly in the West Mountain area and Sebha, came from the main entry borders (Daw, 2020).

On May 26, 2020, two cases were reported for the first time in Libya's southern region (Sabha province), returning from neighbouring countries (Saudi Arabia). Following that, the first woman died as a result of interaction with asymptomatically infected immigrants crossing the southern Libyan border from neighboring countries. Comparatively, the number of COVID-19 confirmed cases in the southern region was higher than in the western region, which was attributed to multifactorial factors, including the province's unconstrained social lifestyle. However, from mid-July to the beginning of August, the epidemiological situation of COVID-19 across the country significantly changed, with high transmission, high importation risk, and positivity rates in all cities (Mahmoud et al., 2021).

In Tunisia, the Investigation findings and data collected between March and May 2020 indicate that the epidemic's initial infected people came from Italy. Following that, cases with known contacts and travel histories were recorded (Talmoudi et al., 2020). The first case was discovered in Morocco on March 2, 2020, was of a Moroccan resident returning from Italy, a few days later, more cases were reported, followed by deaths. During the 1st wave, the most positive cases and the highest mortality rates were observed in the Marrakech-Safi region. After that, in the Mid-quarantine the highest cumulative incidence was registered in Draa-Tafilalet city, and beside the utmost case fatality rate was registered the in Souss-Massa region (El Otmani et al., 2022). Iran, Spain, and France were the countries with the highest fatalities after Italy and China. However, according to the data gathered, Algeria had the highest

CFR, followed by Morocco. Notably, Individuals' largest annual travel patterns occur during festivals and holidays, including China (Chinese Spring Festival), Spain on March 8 in Madrid (Women's Day), and Iran, which coincided with the Nowruz festival (the Persian New Year) (Al-Sawafi, 2020). In Turkey, the first case was reported on March 11, 2020. As expected, Istanbul, with its larger population, had the highest number of cases among all Turkish regions. They were followed by the cities of Ankara, İzmir, and Konya. At the same time, the incidence rates were highest in the regions of Marmara, Middle Black Sea, and Eastern Anatolia, compared to the regions of Southeastern Anatolia and the southern part of Eastern Anatolia, which had the lowest rates (Kırlangıçoğlu, 2022).

Early in the COVID-19 outbreak, Nigeria appears to have had a low incidence. However, a few weeks later, the pandemic became a hotspot with over 500 cases and spread diagonally in the most urbanized places, from the south (Lagos) to the central (Abuja) and northern (Kano) states (Osayomi et al., 2022). In Nigeria, particularly in the first quarter (March/May), there was significant spatial autocorrelation between the occurrence of COVID-19 and its risk factors, including high population density and international airport closures. There was also a difference in sub-Saharan Africa (SSA) and Nigeria, due to high disease exposure and weaknesses in health infrastructure (Bayode et al., 2022).

In Sudan, since the first case was reported in March 2020, the situation has been syndemic and riskier than in other countries in the world. The highest number of confirmed cases and deaths were reported in Khartoum State; followed by the state of Gezira. In contrast, the lowest mortality rate was reported in Khartoum compared to the states of South and North Darfur (Ahmed et al., 2021). In Chad, the 2020 pandemic situation is similar to that of most sub-Saharan African countries, with a higher prevalence in urban than rural areas.

In the Middle East and North Africa (MENA) regions, Iran and Gulf Cooperation Council (GCC) countries had the highest number of cases and deaths, respectively. Meanwhile, Egypt had the highest number of confirmed cases and losses. Moreover, the situation in the conflict countries of Syria, Libya, and Yemen had the lowest numbers of reported cases among the African nations. Overall, the average CFR was about 2.5% in the MENA area, with Yemen having the highest rate and Qatar having the lowest (Younis et al., 2021). As of April 23, 2020, 0.5% of COVID-19 patients died in the Muscat governorate, with older patients being more likely to die. The mortality rate was not significantly different between Omani and non-Omani patients, despite the small sample size (Khamis et al., 2020).

Genetic variables

Coronaviruses are highly mutated and recombinant single-stranded RNA viruses that can rapidly spread from animals (pets and wild) to humans. RNA viruses have a high error rate in replication, allowing them to adapt to environmental pressures but also generating numerous self-eliminating deleterious mutations (Mukherjee and Satardekar, 2021). Early studies of the pandemic have highlighted the live tracking ranges of genomic characterization and clinical characteristics. According to various molecular analyses of the millions of genomes of SARS-CoV-2 published in public databases such as the GISAID platform, the data revealed a genetic variability of SARS-CoV-2 with wide spillover across the world of mutated variants, resulting in highly virulence-transmissible viral lineages that could lead to severe clinical course and increased hospitalizations of the patients.

The World Health Organization classified these variants as variants of concern (VOCs), variants of interest (VOIs), variants under monitoring (VUMs), or variants under investigation (VUIs), Alpha (B.1.1.7), Beta (B.1.351), Gamma (P.1), and Delta (D.1) are the previous four VOCs (B.1.617.2) WHO has identified Omicron (B.1.1.529) as the fifth variant of concern, causing widespread concern, but its origins remain unknown (Lambrou et al., 2022).

The dynamic trend of these variants potentially impacts the susceptibility and severity of the disease; therefore, the CFR of COVID-19 is significantly influenced by genetic variants of SARS-CoV-2. Genetic risk variables may play a vital role in disease evolution and symptomology, but not all affect viral physiology. For instance, the B.1.525 variant in Nigeria had the highest number of mutations but no significant changes. The dynamic trend of these variants potentially impacts the susceptibility and severity of the disease; therefore, the CFR of COVID-19 is significantly influenced by genetic variants of SARS-CoV-2. Genetic risk variables may play a vital role in disease evolution and symptomology, but not all affect viral physiology. For instance, the B.1.525 variant in Nigeria had the highest number of mutations but no significant changes (Mukherjee and Satardekar, 2021). This includes two genomic regions: one on chromosome 3, which contains six genes, and one on chromosome 9. They identified the risk rate of the GA allele of the lead SNP (rs11385942), insertion-deletion at chromosome 3p21.31, gene cluster, as a genetic susceptibility locus.

These SNPs were found to be higher in patients with COVID-19 who suffered from respiratory failure and were on mechanical ventilation compared with those receiving oxygen supplementation, with confirmation of the potential involvement of the ABO blood-group gene system (Gebhard et al., 2020). Moreover, the role of host genetics in impacting susceptibility and severity has also been highlighted in

previous work. It supports the effect of human leukocyte antigen (HLA) in susceptibility and severity for several viral infections, including the role of host factors such as a variant in the IFN-induced trans-membrane protein-3 gene in increasing the severity of SARS-CoV infection (Wang et al., 2020).

Materials and Methods
Study design and study area
The study is a retrospective cohort study. It included random nasal swab samples (1000). The study was conducted in the period between July 2020 to January 2021, from different Libyan regions among different age groups and of both sexes (male and female) participants. The specimens were thoroughly examined and evaluated in the laboratory for positivity or negativity against coronavirus antigens using real-time reverse transcriptase polymerase chain reaction (RT-PCR) assay at the Libyan Biotechnology Research Centre (BTRC), Tripoli, Libya**.**
Ethics statement
Ethical considerations were conducted throughout the study to obtain all the relevant information by informed consent from all the tested patients. However, during this study we followed all the criteria considering basic ethical principles in the research, like, providing anonymity and confidentiality.
Statistical Analysis
All relevant data were entered into the Microsoft Excel spreadsheet and coded for analysis. Descriptive analyses frequency and percent were measured for numerical data and number and percent for qualitative data using SPSS version 22. The Chi-square test was used to investigate the level of association among variables at the significance level of $p < 0.05$.

Results
The overall case fatality rate was estimated to be (4.7%; 3.37%-5.99%) with 95% Confidence interval (CI). The highest CFR (40.78%; 95% CI= 29.74%-51.84%) was reported among the elderly age group. While 0% CFR was reported among (18-30 years) the young age group (Fig. 1 and table). The CFR was estimated to be (1.2%, 95% CI= 0.00%-2.93%) among both age groups (31-45 years) and 46-75 years, while (4%; 95% CI= 0.97%-6.14%) of CFR was reported among age group (61-75 years). The CFR among the different age groups was statistically significant (P=.00001).
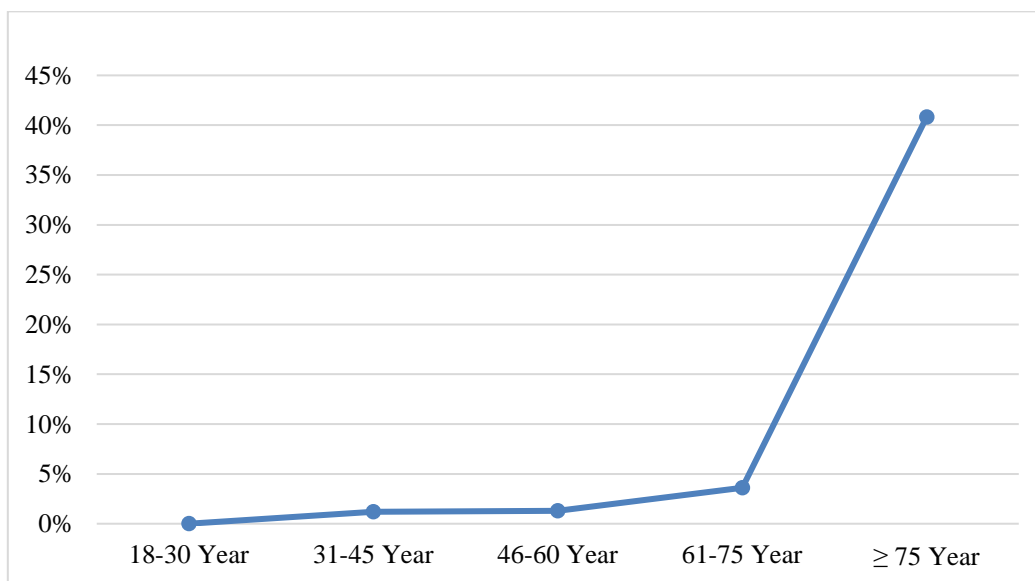

Figure 1: The case fatality rate of COVID-19 among age group.

Table 1: The univariates analysis of the independent variables associated with CFR.

Risk Factors	Samples Tested	Seropositive (%)	DF	X^2	p-value
Age Groups			4	114.5	**.0001**
18-30 Year	14	0%			
31-45 Year	162	1.2%			
46- 60 Year	555	1.2%			
61-75 Year	197	3.6%			

≥ 75 Year	76	40.78%			
Sex			1	2.30	.085
Males	493				
Females	511				
Regions			3	2.674	.445
Western Region	853	5.04%			
Eastern Region	67	0%			
Northern Region	27	4.5%			
Southern Region	57	1.6%			
Total	1004				

The highest and lowest CFR were estimated to be (5.04%; 95% CI= 3.57%-6.51%) and (4.48%; 95%= 0.00%-9.43%) in the western and middle regions respectively. In the southern region, the CFR was estimated to be (1.7%; 95% CI= 0.00%-5.16%), while in the eastern region, the result reported 0% CFR (Fig.2). There was no statistical difference (P=.4%) between the regions.
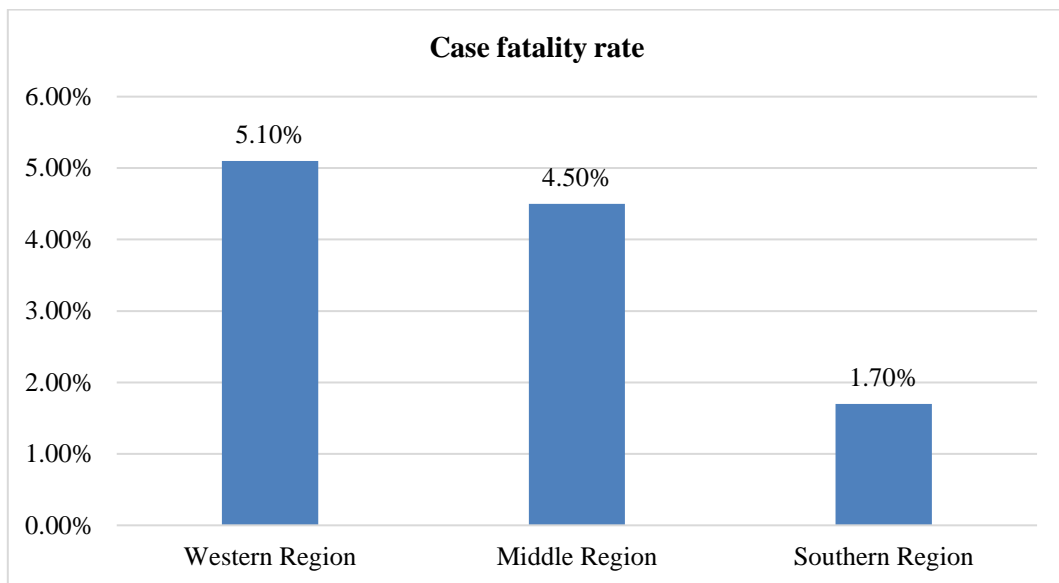

Figure 2: The case fatality rate according to the regions.

Regarding sex difference, the CFR rate was estimated to be (3.7%; 59% CI= 2.00%-5.31%) and (5.7%; 95% CI= 3.67%-7.68%) among males and females respectively (Fig. 3). The results reported a statistical difference between males and females (P=.03). The ratio of the male to female CFRs, case-fatality rate ratio (CFRR) was estimated to be 0.65%.
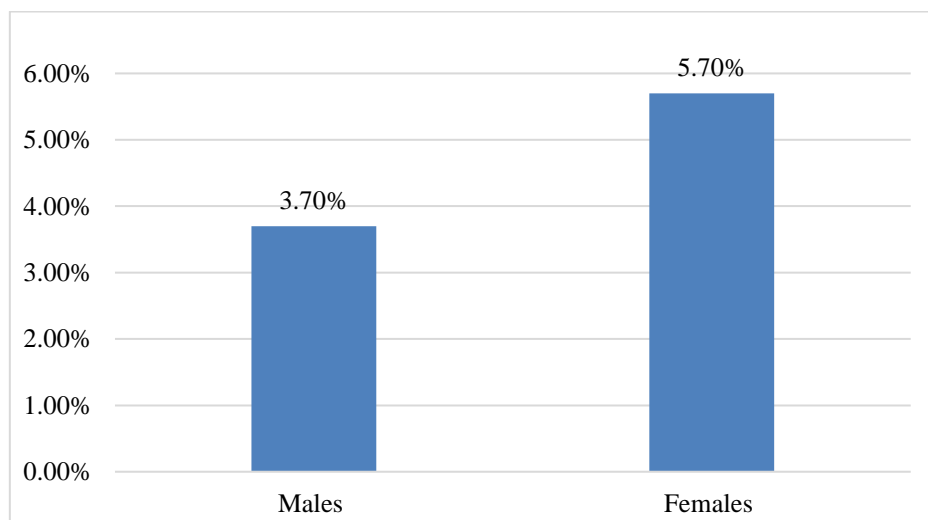

Figure 3: The case fatality rate of COVID-19 according to sex.

Discussion

SARS-CoV-2 is considered one of human history's worst pandemics with a CFR reported across the world. The unexpected rate of death from COVID-19 and excess above the threshold level in some parts of the world. Compared with other parts of the world, Libya is considered one of the countries affected by the COVID-19 pandemic. The CFR of COVID-19 in Libya was somewhat very low as compared to other countries were reported higher CFR of COVID-19 (Mahmoud et al., 2021). The first case of COVID-19 in Libya was reported on 24 March 2020 (NCDC, 2020), while on the regional level of most countries connected with Libya, the first confirmed case of COVID-19 in Tunisia was reported on 4th March 2020, in Algeria on 25 February 2020, in Morocco on 2nd March 2020 (WHO, 2020), and in Egypt on 14th February 2020 (Mahmoud et al., 2021).

This study reported a relatively higher CFR of COVID-19 among the Libyan population and assessed some risk factors associated with CFR. Comparatively, the CFR in Libya during the COVID-19 pandemic is lower than in the rest of the neighboring countries and compared also to some countries that were afflicted by the COVID-19 pandemic, as the CFR rose to very high rates, especially in the first wave of the pandemic. This variability was clear with the emergence of the first case of COVID-19 in Libya at the beginning of the pandemic, compared to the emergence of the COVID-19 cases that were relatively reported early in the neighboring countries (Fig. 4) (Mahmoud et al., 2021). Special in those countries connected with the different portal entrances of Libyan airports, and Libyan borders where travelers returning from most infected countries. Globally, epidemiological data from Italy have shown the highest rate of CFR of COVID-19 approximately up to 9%-12%, especially in critically ill hospitalized patients (Grasselli et al., 2020).

Similarly, the highest CFR was reported across different European countries (Fig. 5) (WHO, 2020). Regarding the age groups, the results revealed high CFR of COVID-19 among the different age groups, however, CFR was higher in the elderly age as compared to other age categories. In agreement with other studies older ages are frequently affected as compared to younger ages (Green et al., 2021). The youthful structure of the Libyan population might be a factor influencing the grade of the CFR in the country. The average youth age in the country represented 41.57% (young adult population), and the median age in Libya is 26.8 years (BSC, 2021).

According to global epidemiological data, age factor greatly influences the CFR of COVID-19 in infected people, therefore, the advanced age group (elderly group) is the most susceptible to infection and the least resistant, and this is consistent with our results, the highest CFR of COVID-19 was reported in the elderly age >70, while 0% CFR was reported among young age group (18-30 year), and this does not negate that death from the COVID-19 pandemic also recorded high rates in young old age and that might be related to other factors such as the virulence of variants of SARS CoV-2 that have a significant impact on the occurrence of severe infections and admission to resuscitation. SARS-CoV-2 infection in some infected people is associated with very mild symptoms (asymptomatic) (for people infected in the same area and time period). In agreement with our findings, the age groups revealed a significant difference in the CFR, in Spain and Italy, CFR was 12% in patients admitted to ICU and older than 50 years.

While CFR reached up to 52.3 in patients more aged than 80 years and 35.6 in 70-79 years old (Onder et al., 2020).The correlation of the CFR with the age group is greatly of concern, therefore, immune status plays a major role in resistance to infection, and it is known that the elderly groups have a weak immune system than younger age groups, and the symptoms and clinical manifestation of COVID-19 infection may be more severe, especially in comorbidities could be a potential predisposing factor contributing to high CFR in the old age groups.

The present study results showed a significant difference in the CFR among males and females in the country, the relatively higher CFR reported among females might be attributable to the diversity in the immunity status of both sexes (Sex-based difference) (Alimohamadi et al., 2021). According to the last Libyan national count, the total population in Libya is 6,900,369 and the ratio of male/female is approximately 101.85 males per 100 females, and the percentage of the female population is 49.54% compared to 50.46% male population (UN, 2021). In agreement with others, studies reported that, the high-frequency CFR of COVID-19 among females than males (Mahmoud et al., 2023). The difference in CFR among males and females is consistent with several studies in which a higher CFR for males was reported than for females. In contrast to other literature in which higher CFR was reported in males than females, there are several factors affecting the high incidence and differences in CFR between the sexes. Therefore, this variable might be related to sex-dependent factors that potentially influence the severity of diseases (Green et al., 2021).
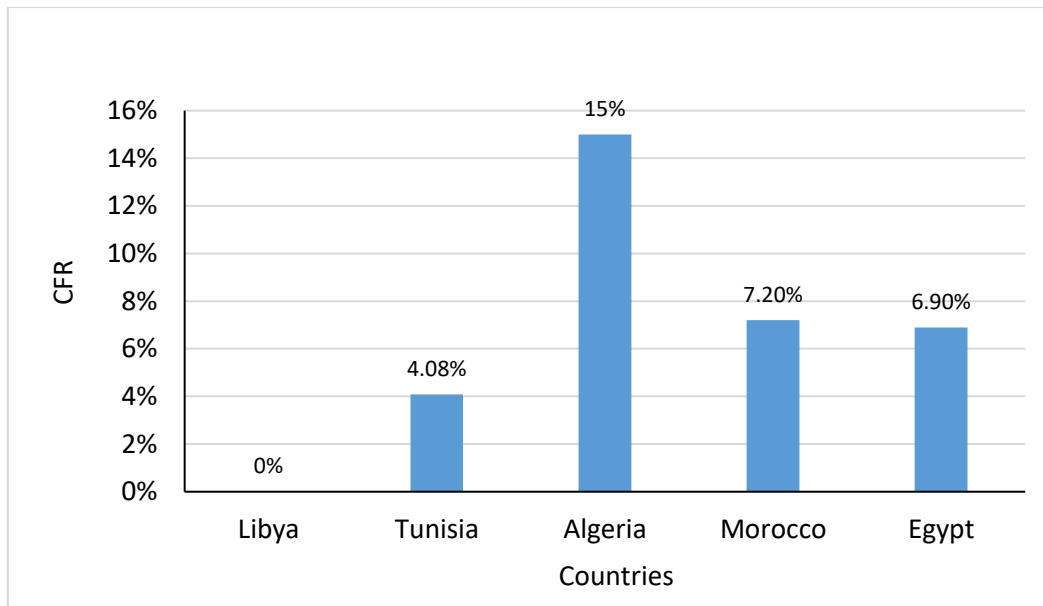
Figure 4: Case fatality rate in some North African Countries as of 11 April 2020.
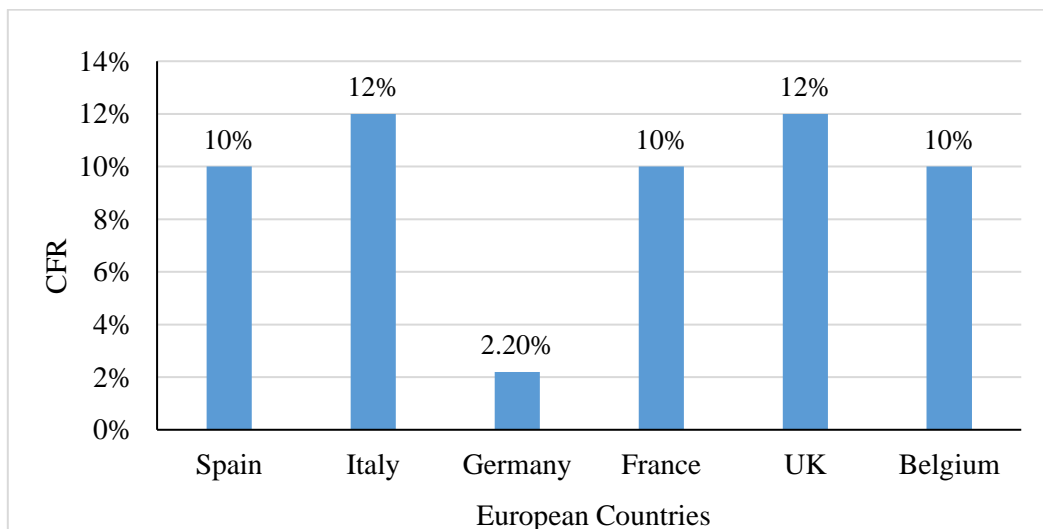

Figure 5: The CFR in some European countries reported the most cases of COVID-19 as of 10 April.

The present study reported spatial differences in the patterns of the CFR of COVID-19, a higher CFR of COVID-19 reported in the Western region was highly considerable as compared to other regions of the country. Libya is a huge country with an area of almost 1.8 million km^2. Therefore, the CFR of COVID-19 could be considered as the regional diversity that influences the actual estimations of the COVID-19 CFR across the country. However, the results of the present study reported a clear difference in the CFR between the different regions under study, in the western region of the country, the CFR was reported higher rate as compared to other regions that witnessed a relatively low CFR at the beginning of the COVID-19 pandemic, and this may be attributed to several reasons. Among the most important are the precautionary measures that were taken at the beginning of the pandemic, including a partial or complete lockdown, following the announcement on 16 April 2020, due to the recommendation of the Scientific Advisory Committee (SAC), where the Libyan authorities imposed a complete lockdown for one week, starting from 17 April 2020 (Mahmoud et al., 2021).

Some areas showed a complete lockdown, on the contrary, other regions were difficult to implement and apply strictly precautionary measures. Moreover, the population density and the carrying on of some commercial activities played a major role in the spread of the infection among the population in those regions (Mahmoud et al., 2023). In fact, the instability of the country makes it difficult to operate the well-integrated surveillance system and perform sufficient testing capacity to trace COVID-19-infected cases resulting in an underestimation of the cases (iceberg phenomena), consequently, the estimation of the CFR is very crucial during the COVID-19 pandemic. Therefore, most of these cases

were not included in the CFR estimation and could lead to an overestimation of CFR (Mahmoud et al., 2023). Yet, we are aware of these difficulties and limitations. Nonetheless, the present study results are valuable and provide a piece of information about COVID-19 CFR among the Libya population.

Conclusion
Our results reported a relatively high CFR of COVID-19 among the Libyan population concerned in this study. Comparatively, CFR during the COVID-19 pandemic in Libya has patterns of flattened curve characteristics. Nevertheless, the country's spatiotemporal distribution of the CFR of COVID-19 was not uniformly distributed. The age-related factors had a significant influence on CFR in this study, furthermore, the elderly age reported high CFR as compared to other age categories.

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