Journal of Oral Biology and Craniofacial Research 12 (2022) 165–176

Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

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

Research Paper

Comparative study of COVID-19 situation between lower-middle-income countries in the eastern Mediterranean region

Sokaina El Khamlichi [a], Amal Maurady [a,b,*], Abdelfettah Sedqui [a]

[a] Laboratory of Innovative Technologies, National School of Applied Sciences of Tangier, Abdelmalek Essaâdi University, Tangier, Morocco
[b] Faculty of Sciences and Techniques, Abdelmalek Essaâdi University, Tangier, Morocco

ARTICLE INFO

Keywords:
COVID 19
Novel coronavirus
Pandemic
Risk factors
ANOVA
Epidemiology
Lower-middle-income countries
Eastern mediterranean region

ABSTRACT

Background and aims: The COVID-19 health crisis has created a disastrous situation worldwide. All nations are facing this pandemic, including eastern Mediterranean countries. The aim of this study is to assess and compare the impact of this devastating pandemic on lower-middle-income countries in the eastern Mediterranean region, identify the leading causes of its spread, examine the various risk factors associated with its virulence in each country, and provide effective intervention strategies to contain it.
Methods: Using the analysis of variance method, this research compares infection, case fatality, recovery, and positivity rates in seven countries, namely, Morocco, Tunisia, Egypt, Djibouti, Pakistan, Sudan, and Palestine. It focuses on their daily reported confirmed incidents, recoveries, deaths, and tests.
Results: The results highlight the significant differences in the effect of COVID-19 in these countries. Regarding the infection rate, Djibouti and Palestine have the highest rate, which could be related to the high poverty and the young population in these countries. However, it has been demonstrated that Tunisia, Djibouti, Egypt, and Sudan have the greatest case fatality rate in this comparison, which might be attributed to the relatively old population in Tunisia, the co-morbidity in Egypt, and the deficiency of the healthcare system in Djibouti and Sudan. Furthermore, the comparison of the recovery rate in these countries indicates that Djibouti has the highest recovery rate, which might be due to the young population.
Conclusion: This work allows us to come up with recommendations that could support policymakers to act efficiently in containing the pandemic flare-up.

1. Introduction

The novel Coronavirus pandemic COVID-19 is a potentially critical infectious disease that attacks the respiratory system. It is engendered by SARS-CoV-2 which is a severe acute respiratory syndrome.[1] In December 2019, the first reported case was discovered in the city of Wuhan, in China. Then, it has spread quickly all over the world. On March 11th, 2020, the World Health Organization declared this infection as a pandemic.[2] This disease has a variety of symptoms including coughs, sore throats, fever, headaches breathing problems which may sometimes lead to death.[3,4] Coronavirus can expand via respiratory drops, made from the sneeze or the cough of a sick person, containing the virus on it and touching a surface or a body.[5] The first confirmed cases of Covid-19 were reported on March 2nd, 2020 in Morocco and Tunisia. Besides, the first cases were identified on February 14th, February 26th, March 5th, March 13th, and March 17th, 2020 in Egypt, Pakistan, Palestine, Sudan, and Djibouti respectively.[2,6–9] The lockdown was started on March 20th, 2020 in Morocco and Tunisia. Whereas, containment was not imposed in Egypt.[2] Furthermore, the lockdown took place on March 23rd and March 24th in Djibouti and Pakistan respectively.[9,10] Besides, on March 5th, 2020, the same day when the first cases were detected, a state of emergency was declared in Palestine.[6] Moreover, a partial lockdown was announced on April 13th, 2020 in Sudan.[8]

From the onset of the pandemic until September 11, 2020, the total number of COVID-19 positive cases reached around 79767 in Morocco, 5882 in Tunisia, 100557 in Egypt, 13437 in Sudan, 5394 in Djibouti, 300371 in Pakistan, and 37214 in Palestine. As for the total number of deaths, 1491 deaths were recorded in Morocco, 99 in Tunisia, 5590 in Egypt, 833 in Sudan, 61 in Djibouti, 6370 in Pakistan, and 224 in Palestine. Additionally, 64194 recoveries were reported in Morocco, 1956 in Tunisia, 82473 in Egypt, 6731 in Sudan, 5327 in Djibouti, 288536 in Pakistan, and 19788 in Palestine. However, data for the total

* Corresponding author. Laboratory of Innovative Technologies, National School of Applied Sciences of Tangier, Abdelmalek Essaâdi University, Tangier, Morocco.
E-mail addresses: sokaina.elkhamlichi@gmail.com (S. El Khamlichi), amal.maurady.ma@gmail.com (A. Maurady), abdelfettah.sedqui@gmail.com (A. Sedqui).

https://doi.org/10.1016/j.jobcr.2021.10.004
Received 28 March 2021; Received in revised form 2 June 2021; Accepted 4 October 2021
Available online 9 October 2021

number of tests were not available for all studied countries in the above-mentioned period. They were available only in four countries, namely, Morocco, Tunisia, Pakistan, and Palestine. Indeed, the total number of tests, up to September 11, 2020, reached around 2138164 in Morocco, 162095 in Tunisia, 2879655 in Pakistan, and 77107 in Palestine.[11,12]

In the absence of effective treatment of this virus, many protective actions are taken by different countries to slow down the outbreak of the pandemic. For instance, wearing masks, staying away from infected individuals, cleaning hands frequently with soap or alcohol-based sanitizer which is made of 60% alcohol least and respecting social distancing.[13] Besides, the identification of infected people, isolating and tracking them as well as environmental disinfection are fundamental measures to contain the spread of this morbidity.[14] On the other hand, the infection spread is associated with several risk factors such as sex, age, and morbidity conditions like cardiovascular diseases (CVD), cancer as well as diabetes.[15] Indeed, many low and middle-income countries have generally a young population. COVID-19 protective measures are expected to be equally difficult to respect among young people. This can be due to a personal fable, which is an aspect of adolescent egocentrism involving exclusivity and invincibility and leading probably to risky and careless behavior, like non-respect of lockdown situations. The personal conviction that one will not become sick is more expected to occur among young than old people in society. Therefore, people in Low- and Middle-income countries are more exposed to danger than the population of high-income countries.[16] Furthermore, regular hand washing, which is a vital recommendation for alleviating infections, is a defy in several Low- and Middle-income countries as well as running water which is not available regularly in households.[16]

Furthermore, precautionary measures vary from a country to another making the propagation of the virus and its virulence different between countries. Therefore, a pandemic situation comparison and the impact of the risk factors in each country play an essential role in identifying the similarities and the differences between countries. Consequently, this could assist policymakers in taking the right decisions and actions to contain this pandemic. In this context, several researches were conducted to compare the COVID-19 situation between different countries. Khan et al.[17] analyzed the impact of the pandemic on the most affected countries in the world. Ouchetto et al.[2] compared and assessed the effectiveness of preventive measures taken in North African countries. Boufkhed et al.[18] assessed the level of readiness and ability to react to the COVID-19 pandemic in the Middle-East and North African countries in terms of palliative care services. Musa et al.[19] reveiwed the pandemic situation in Africa and proposed potential explanations behind the present trends, such as the wide experience of African countries with infectious diseases and their youth population along with presenting recommendations to avoid a quick expansion in Covid-19 number of cases later on. Likewise Chitungo et al.[20] presented some explanations of the low number of Covid-19 infections in Africa. Moreover Alanezi et al.[21] examined and compared the control policies implemented to curb the pandemic in the Gulf Cooperation Council and European Union countries. Alshammari et al.[22] evaluated and appraised the early preventive measures and patterns adopted by 175 countries across six continents to tackle the pandemic spillover. Piovani et al.[23] investigated how early social distancing measures affected Covid-19 cumulative mortality over the first wave of the pandemic in the 37 states that make up the Organization for Economic Cooperation and Development. Further studies forcasted COVID-19 trends. For instance, Takele et al.[24] focused on predicting COVID-19 infection spread in some East African Countries using the Autoregressive Moving Average modeling. Similarly ArunKumar et al.[25] predicted the epidemiological patterns of COVID-19 pandemic in the top-16 countries which accounts for 70%–80% of total cumulative number of cases and consequently, assisted these countries in developing health care strategies to tackle the current pandemic.

The present study focuses on analyzing and comparing the situation of Covid-19 in lower-middle-income countries in the eastern Mediterranean region, namely, Morocco, Tunisia, Egypt, Djibouti, Pakistan, Sudan, and Palestine. In order to determine the similarities and the differences between these countries, a statistical method, called the Analysis of variance (ANOVA), was used for comparing the means between the above-mentioned countries.

2. Data & methods

The "Our World in Data" dataset was used to calculate the infection, case fatality and positivity rates. This dataset is updated day by day from the World Health Organization situation reports. More information concerning this dataset can be found at https://ourworldindata.org/coronavirus-source-data. Daily data of new cases, new deaths, new tests, and the population of each country were utilized to compute infection, case fatality, and positivity rates. On the other hand, recovery rate was calculated using data of new recovered and new cases taken from the dataset found on the following website: https://www.worldometers.info/coronavirus/. The current work deals with daily data from seven lower-middle-income countries in the eastern Mediterranean region, specifically, Morocco, Tunisia, Egypt, Djibouti, Pakistan, Sudan, and Palestine. Infection, case fatality, and recovery rates were calculated for all the above-mentioned countries. However, since the data of new tests were not available for Egypt, Djibouti, and Sudan, the positivity rate was computed only for Morocco, Tunisia, Pakistan, and Palestine. The data covered the period from the first appearance of the pandemic in each country till September 11, 2020.

The Analysis of variance (ANOVA) was used to identify the similarities and the differences between the countries. Actually, the analysis of variance is a statistical test commonly used in statistics. It is applied to examine the differences between at least three groups. There are three main assumptions in ANOVA; the populations, from which the samples are taken, are normally distributed, they have the same variances and the samples are selected randomly and independently from each other.[26] Although ANOVA is applied to test the null hypothesis, which is all sampled populations have the same mean, against the alternative hypothesis which is, at least one population has a different mean comparing to the others. The fundamental matter in the implementation of the ANOVA tests is that when the null hypothesis is rejected, it does not indicate between which pair of the population the means are different. To solve this matter, the post hoc multiple comparison tests are used to determine between which pair of populations the means are different.[27]

In the present study, three assumptions were tested before the application of the Analysis of Variance (ANOVA). In particular, Independence of samples, normality, and homogeneity of variances. For the Independence of samples, it is assumed that the data were collected independently from a country to another. However, the other two assumptions were checked. Actually, the normality and the homogeneity of variance were not satisfied. The normality was checked using Kolmogorov-Smirnov and Shapiro-Wilk tests. As to the homogeneity of variance, Levene's test was utilized to verify it. In order to get normally distributed data, a two-step transformation to normality was applied. This approach comprises two steps; the first one consists in changing the variable into rank of percentile resulting in uniformly distributed probabilities. The second step aims to create a new variable made up of normally distributed z-scores using the inverse-normal transformation of the first step's resulting variable.[28] Regarding the homogeneity of variance assumption, ANOVA is robust to the violation of homogeneity of variances. Therefore, due to the heterogeneity of variances between the groups and unequal sample sizes, robust tests of equality of means, namely Welch test and Brown-Forsythe test, were used for the ANOVA instead of the ANOVA F test[29] (Fig. 1). All the above-mentioned tests and analysis were performed using IBM SPSS Statistics 22 software.

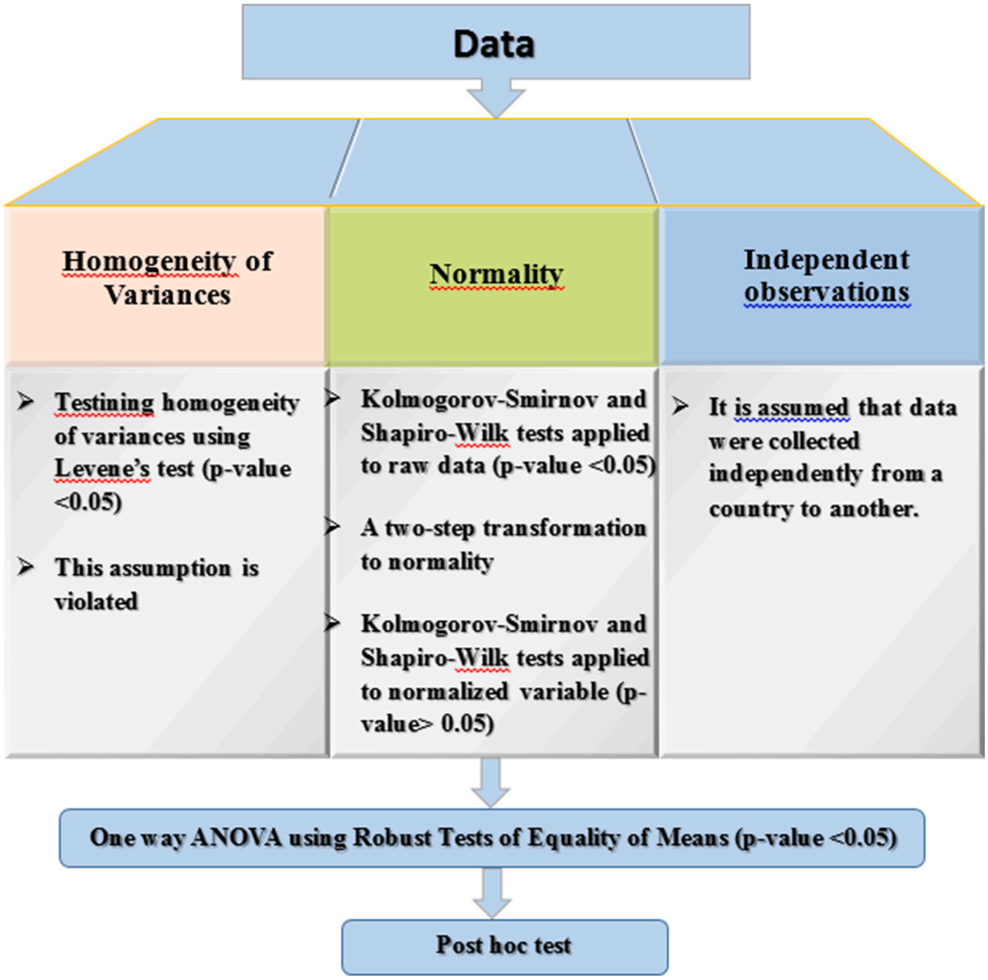

Fig. 1. Graph summarizing the study methodology.

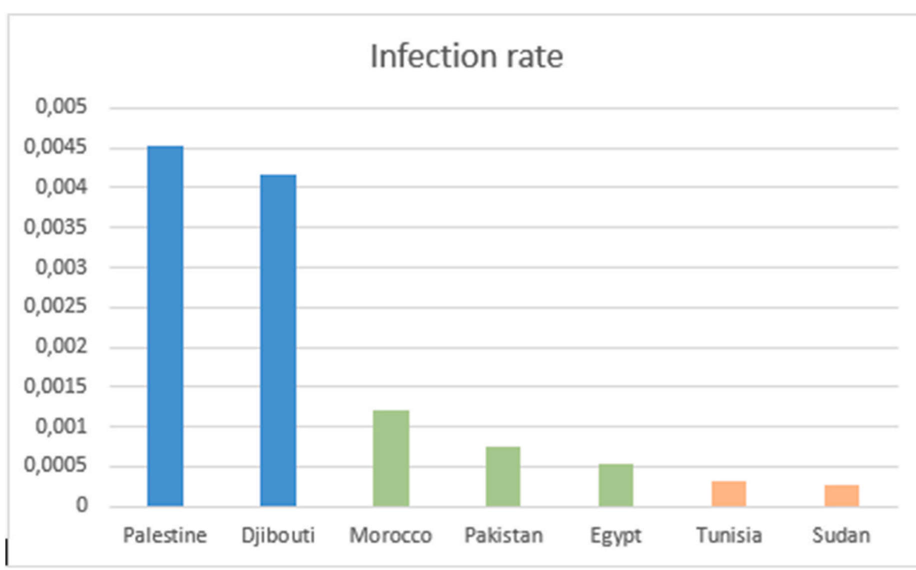

Fig. 2. The mean of the infection rate in the studied countries.

3. Results

This section presents the findings of our analysis. Infection, case fatality, recovery and positivity rates are compared in the studied countries. Before applying the One way ANOVA, normality and homogeneity of variances assumptions were checked for each rate considering that the independent observations assumption was met. First, the distribution of each rate was not normal. In order to meet the normality assumption, a two step transformation was done. The variable after the first step of the transformation was not normal. Whereas, after the second step of the transformation the variable had a normal distribution. Therefore, the normality assumption is accomplished. As for the homogeneity of variances assumption, it is violated (p-value < 0.05). Consequently, the one way ANOVA is applied using Welch and Brown-Forsythe tests, since they are robust to the non-homogeneity of variances. As the one way ANOVA shows only whether there is a difference of the means between at least one country and the others, Games-Howell Post hoc test is used to determine the differences between which countries is occurred.

4. Infection rate

The infection rate is the proportion of infected individuals to the overall population. It is calculated using the following formula:

Infection Rate = 100 * (New Cases / Population of the Country)

4.1. Testing normality of data

Hypothesis

- Null hypothesis — H0: The data are normally distributed.
- Alternative hypothesis — H1: The data are not normally distributed.

Based on Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 1):

- The “infection_rate” variable, which is the variable before the transformation, and “Fractional Rank of infection_rate”, which is the variable after the first step of the transformation, have statistically significant results (p-value < 0.05). Therefore, the null hypothesis is rejected which implies that both of these two distributions are not normal.
- The normalized infection rate variable “norm_infection_rate” has a non statistically significant result (p-value > 0.05). So, the null hypothesis is accepted which means that the distribution is normal.

4.2. Testing homogeneity of variances

4.2.1. Levene’s test

Hypothesis

- Null hypothesis — H0: The infection rate in the countries we are comparing has equal variances.
- Alternative hypothesis — H1: The infection rate in the countries we are comparing has different variances.

According to Levene’s test, the p-value is 0 which is less than 0.05. Thus, the null hypothesis is rejected. This means that the infection rate in the countries we are comparing has different variances and the assumption of homogeneity of variances is violated (Table 2).

Table 1
Tests of Normality for the infection rate.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
infection_rate	,314	1105	,000	,510	1105	,000
Fractional Rank of infection_rate	,060	1105	,000	,955	1105	,000
norm_infection_rate	,007	1105	,200*	,999	1105	,986

df: degree of freedom, Sig: significance.

Table 2
Test of Homogeneity of Variances for the infection rate variable.

norm_infection_rate			
Levene Statistic	df1	df2	Sig.
29,447	6	1098	,000

df: degree of freedom, Sig: significance.

4.3. One way ANOVA

Hypothesis

- Null hypothesis — H0: The means of the infection rate in all countries are equal.
- Alternative hypothesis — H1: At least one mean is different.

In order to apply the Analysis Of Variance (ANOVA), Welch and Brown-Forsythe tests, which are robust to the non-homogeneity of variances assumption, were used for comparing the means. In both tests, the significance is 0 (p-value < 0.05). Hence, the null hypothesis is rejected. This means that at least the mean of the infection rate in one country is different from that in the other countries (Table 3).

4.4. Post hoc test for infection rate

In order to detect between which countries the differences occurred regarding the infection rate, a Games-Howell Post hoc test was used for multiple comparisons. According to the results of multiple comparisons, it is shown that (Table 4):

- Pakistan is very similar in the infection rate to Morocco, because of the insignificant p-value which is equal to 0.901. Also, it is relatively close to Egypt with a p-value equals to 0.259.
- Tunisia and Sudan have moderately similar infection rates due to the p-value which is equal to 0.259.
- Djibouti and Palestine are slightly similar with a p-value equals to 0.151
- Djibouti and Palestine have relatively a higher infection rate, followed by Morocco, Pakistan, and Egypt, and then Sudan and Tunisia have a relatively very small infection rate (Fig. 2).

5. Case fatality rate

The case fatality rate is a measure used to assess the impact of COVID-19 on humans by calculating the percentage of the dead individuals to the total number of infected ones.[30] It is calculated using the following formula:

Case fatality Rate = (New Deaths / New Cases)

5.1. Testing normality

Hypothesis

- Null hypothesis — H0: The data are normally distributed.
- Alternative hypothesis — H1: The data are not normally distributed.

According to Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 5):

Table 3
Robust Tests of Equality of Means for the infection rate.

norm_infection_rate				
	Statistic[a]	df1	df2	Sig.
Welch	53,166	6	468,511	,000
Brown-Forsythe	49,294	6	920,249	,000

df: degree of freedom, Sig: significance.
[a] Asymptotically F distributed.

Table 4
Multiple comparisons for the infection rate. Dependent Variable: norm_infection_rate, Games-Howell.

(I) country_code	(J) country_code	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Morocco	Tunisia	,00273[a]	,00030	,000	,0019	,0036
	Egypt	,00102[a]	,00029	,008	,0002	,0019
	Pakistan	,00036	,00030	,901	-,0005	,0012
	Djibouti	-,00238[a]	,00033	,000	-,0033	-,0014
	Sudan	,00200[a]	,00032	,000	,0011	,0029
	Palestine	-,00130[a]	,00040	,021	-,0025	-,0001
Tunisia	Morocco	-,00273[a]	,00030	,000	-,0036	-,0019
	Egypt	-,00170[a]	,00029	,000	-,0026	-,0008
	Pakistan	-,00237[a]	,00030	,000	-,0033	-,0015
	Djibouti	-,00510[a]	,00033	,000	-,0061	-,0041
	Sudan	-,00073	,00032	,259	-,0017	,0002
	Palestine	-,00403[a]	,00040	,000	-,0052	-,0028
Egypt	Morocco	-,00102[a]	,00029	,008	-,0019	-,0002
	Tunisia	,00170[a]	,00029	,000	,0008	,0026
	Pakistan	-,00067	,00030	,272	-,0015	,0002
	Djibouti	-,00340[a]	,00032	,000	-,0044	-,0024
	Sudan	,00098[a]	,00031	,034	,0000	,0019
	Palestine	-,00232[a]	,00040	,000	-,0035	-,0011
Pakistan	Morocco	-,00036	,00030	,901	-,0012	,0005
	Tunisia	,00237[a]	,00030	,000	,0015	,0033
	Egypt	,00067	,00030	,272	-,0002	,0015
	Djibouti	-,00273[a]	,00033	,000	-,0037	-,0017
	Sudan	,00164[a]	,00032	,000	,0007	,0026
	Palestine	-,00166[a]	,00041	,001	-,0029	-,0005
Djibouti	Morocco	,00238[a]	,00033	,000	,0014	,0033
	Tunisia	,00510[a]	,00033	,000	,0041	,0061
	Egypt	,00340[a]	,00032	,000	,0024	,0044
	Pakistan	,00273[a]	,00033	,000	,0017	,0037
	Sudan	,00437[a]	,00035	,000	,0033	,0054
	Palestine	,00107	,00042	,151	-,0002	,0023
Sudan	Morocco	-,00200[a]	,00032	,000	-,0029	-,0011
	Tunisia	,00073	,00032	,259	-,0002	,0017
	Egypt	-,00098[a]	,00031	,034	-,0019	,0000
	Pakistan	-,00164[a]	,00032	,000	-,0026	-,0007
	Djibouti	-,00437[a]	,00035	,000	-,0054	-,0033
	Palestine	-,00330[a]	,00042	,000	-,0045	-,0021
Palestine	Morocco	,00130[a]	,00040	,021	,0001	,0025
	Tunisia	,00403[a]	,00040	,000	,0028	,0052
	Egypt	,00232[a]	,00040	,000	,0011	,0035
	Pakistan	,00166[a]	,00041	,001	,0005	,0029
	Djibouti	-,00107	,00042	,151	-,0023	,0002
	Sudan	,00330[a]	,00042	,000	,0021	,0045

Std. Error: Standard Error.
Sig: Significance.
[a] The mean difference is significant at the 0.05 level.

Table 5
Tests of Normality for the case fatality rate.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
case_fatality_rate	,292	722	,000	,415	722	,000
Fractional Rank of case_fatality_rate	,059	722	,000	,955	722	,000
norm_fatality_rate	,005	722	,200*	,999	722	,968

df: degree of freedom, Sig: significance.

- The “case_fatality_rate” variable, which is the variable before the transformation, and “Fractional Rank of case_fatality_rate”, which is the variable after the first step of the transformation, have statistically significant results (p-value < 0.05). Therefore, the null hypothesis is rejected which implies that both of these two distributions are not normal.
- The normalized case fatality rate variable “norm_fatality_rate” has a non statistically significant result (p-value > 0.05). So, the null hypothesis is accepted which means that the distribution is normal.

5.2. Testing homogeneity of variances

5.2.1. Levene’s test

Hypothesis

- Null hypothesis — H0: The case fatality rate in the countries we are comparing has equal variances.
- Alternative hypothesis — H1: The case fatality rate in the countries we are comparing has different variances.

According to Levene’s test, the p-value is 0 which is less than 0.05. Thus, the null hypothesis is rejected. This means that the case fatality rate in the countries we are comparing has different variances and the assumption of homogeneity of variances is violated (Table 6).

5.3. One way ANOVA

Hypothesis

- Null hypothesis — H0: The means of the case fatality rate in all countries are equal.
- Alternative hypothesis — H1: At least one mean is different.

Table 6
Test of Homogeneity of Variances for the case fatality rate.

norm_fatality_rate			
Levene Statistic	df1	df2	Sig.
22,007	6	715	,000

df: degree of freedom, Sig: significance.

Table 7
Robust Tests of Equality of Means for the case fatality rate.

norm_fatality_rate				
	Statistic[a]	df1	df2	Sig.
Welch	127,717	6	191,642	,000
Brown-Forsythe	71,115	6	179,298	,000

df: degree of freedom, Sig: significance.
[a] Asymptotically F distributed.

To apply the Analysis Of Variance (ANOVA), Welch and Brown-Forsythe tests, which are robust to the non-homogeneity of variances assumption, were used for comparing the means. In both tests, the significance is 0 (p-value < 0.05). Hence, the null hypothesis is rejected. This means that at least the mean of the case fatality rate in one country is different from that in the other countries (Table 7).

5.4. Post hoc test for the case fatality rate

A Games-Howell Post hoc test was used for multiple comparisons of the case fatality rate to detect between which countries the differences occurred. According to the results of multiple comparisons (Table 8), it is revealed that:

- Morocco is very similar to Pakistan, because of the insignificant p-value which is equal to 0.992. Moreover, it is slightly close to Djibouti with a p-value equals to 0.052.

Table 8
Multiple comparisons for the case fatality rate.

Dependent Variable: norm_fatality_rate						
Games-Howell						
(I) country_code	(J) country_code	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Morocco	Tunisia	-,11124[a]	,02283	,000	-,1806	-,0419
	Egypt	-,14529[a]	,01068	,000	-,1771	-,1135
	Pakistan	-,00720	,01020	,992	-,0376	,0232
	Djibouti	-,09579	,03094	,052	-,1922	,0006
	Sudan	-,14147[a]	,01271	,000	-,1793	-,1036
	Palestine	,13087[a]	,01469	,000	,0870	,1748
Tunisia	Morocco	,11124[a]	,02283	,000	,0419	,1806
	Egypt	-,03405	,02164	,699	-,1002	,0321
	Pakistan	,10404[a]	,02141	,000	,0385	,1696
	Djibouti	,01544	,03621	1,000	-,0950	,1259
	Sudan	-,03023	,02271	,835	-,0993	,0388
	Palestine	,24211[a]	,02388	,000	,1699	,3144
Egypt	Morocco	,14529[a]	,01068	,000	,1135	,1771
	Tunisia	,03405	,02164	,699	-,0321	,1002
	Pakistan	,13809[a]	,00715	,000	,1169	,1593
	Djibouti	,04949	,03007	,655	-,0448	,1438
	Sudan	,00382	,01043	1,000	-,0273	,0349
	Palestine	,27616[a]	,01277	,000	,2378	,3146
Pakistan	Morocco	,00720	,01020	,992	-,0232	,0376
	Tunisia	-,10404[a]	,02141	,000	-,1696	-,0385
	Egypt	-,13809[a]	,00715	,000	-,1593	-,1169
	Djibouti	-,08859	,02991	,075	-,1825	,0053
	Sudan	-,13427[a]	,00993	,000	-,1640	-,1046
	Palestine	,13807[a]	,01237	,000	,1008	,1754
Djibouti	Morocco	,09579	,03094	,052	-,0006	,1922
	Tunisia	-,01544	,03621	1,000	-,1259	,0950
	Egypt	-,04949	,03007	,655	-,1438	,0448
	Pakistan	,08859	,02991	,075	-,0053	,1825
	Sudan	-,04567	,03085	,754	-,1419	,0505
	Palestine	,22667[a]	,03172	,000	,1283	,3250
Sudan	Morocco	,14147[a]	,01271	,000	,1036	,1793
	Tunisia	,03023	,02271	,835	-,0388	,0993
	Egypt	-,00382	,01043	1,000	-,0349	,0273
	Pakistan	,13427[a]	,00993	,000	,1046	,1640
	Djibouti	,04567	,03085	,754	-,0505	,1419
	Palestine	,27234[a]	,01451	,000	,2289	,3158
Palestine	Morocco	-,13087[a]	,01469	,000	-,1748	-,0870
	Tunisia	-,24211[a]	,02388	,000	-,3144	-,1699
	Egypt	-,27616[a]	,01277	,000	-,3146	-,2378
	Pakistan	-,13807[a]	,01237	,000	-,1754	-,1008
	Djibouti	-,22667[a]	,03172	,000	-,3250	-,1283
	Sudan	-,27234[a]	,01451	,000	-,3158	-,2289

Std. Error: Standard Error.
Sig: Significance.
[a] The mean difference is significant at the 0.05 level.

- Tunisia is identical to Djibouti as the p-value is equal to 1, followed by Sudan with a p-value equals to 0.835, and Egypt with a p-value equals to 0.699.
- Egypt is identical to Sudan, quite similar to Tunisia and Djibouti.
- Pakistan is very similar to Morocco and marginally similar to Djibouti
- Djibouti and Sudan are remarkably similar.
- Palestine is different from all the other compared countries.

It is shown that Tunisia, Djibouti, Egypt, and Sudan have the highest case fatality rates in this comparison, followed by Morocco and Pakistan with a relatively smaller rate. However, Palestine has the lowest rate (Fig. 3).

6. Recovery rate

Recovery rate is the proportion of recovered patients to the total infected individuals. It is calculated using this formula:

Recovery Rate = (New recovered/ New cases)

6.1. Testing normality

Hypothesis

- Null hypothesis — H0: The data are normally distributed.
- Alternative hypothesis — H1: The data are not normally distributed.

According to Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 9):

- The "Recovery rate" variable, which is the variable before the transformation, and "Fractional Rank of Recovery_rate", which is the variable after the first step of the transformation, have statistically significant results (p-value < 0.05). Therefore, the null hypothesis is rejected which implies that both of these two distributions are not normal.
- The normalized recovery rate variable "norm_recovery_rate" has a non statistically significant result (p-value > 0.05). So, the null hypothesis is accepted which means that the distribution is normal.

Table 9
Tests of Normality for the recovery rate.

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Recovery rate	,302	939	,000	,505	939	,000
Fractional Rank of Recovery_rate	,059	939	,000	,955	939	,000
norm_recovery_rate	,008	939	,200[a]	1,000	939	1,000

df: degree of freedom, Sig: significance.
[a] This is a lower bound of the true significance.
[b] Lilliefors Significance Correction.

6.2. Testing homogeneity of variances

6.2.1. Levene's test

Hypothesis

- Null hypothesis — H0: The recovery rate in the countries we are comparing has equal variances.
- Alternative hypothesis — H1: The recovery rate in the countries we are comparing has different variances.

According to Levene's test, the p-value is 0 which is less than 0.05. Thus, the null hypothesis is rejected. This means that the recovery rate in the countries we are comparing has different variances and the assumption of homogeneity of variances is violated (Table 10).

6.3. One way ANOVA

Hypothesis

- Null hypothesis — H0: The means of the recovery rate in all countries are equal.
- Alternative hypothesis — H1: At least one mean is different.

Table 10
Test of Homogeneity of Variances for the recovery rate.

norm_recovery_rate			
Levene Statistic	df1	df2	Sig.
5.406	6	932	,000

df: degree of freedom, Sig: significance.

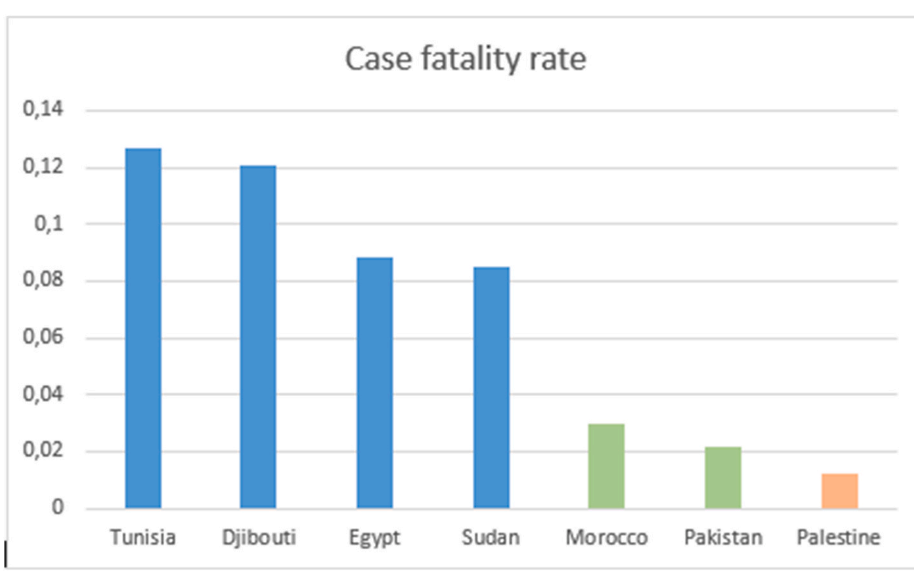

Fig. 3. The mean of the case fatality rate in the studied countries.

Table 11
Robust Tests of Equality of Means for the recovery rate.

norm_recovery_rate	Statistic	df1	df2	Sig.
Welch	11,230	6	382,309	,000
Brown-Forsythe	10,504	6	760,084	,000

df: degree of freedom, Sig: significance.
a. Asymptotically F distributed.

To apply the Analysis Of Variance (ANOVA), Welch and Brown-Forsythe tests, which are robust to the non-homogeneity of variances assumption, were used for comparing the means. In both tests, the significance is 0 (p-value < 0.05). Hence, the null hypothesis is rejected. This means that at least the mean of the recovery rate in one country is different from that in the other countries (Table 11).

6.4. Post hoc test for the recovery rate

A Games-Howell Post hoc test was used for multiple comparisons, for the sake of identifying the similarities and the differences between the countries regarding the recovery rate. The results of this test (Table 12) illustrate that:

- Morocco is identical to Pakistan, very similar to Tunisia with a p-value equals to 0.999, very close to Palestine with a p-value equals to 0.992 as well as Egypt with a p-value equals to 0.972.
- Tunisia is identical to Pakistan and Palestine and very similar to Morocco and Egypt with a p-value equals to 0.999 and 0.920 respectively.
- Egypt is very similar to Morocco, Pakistan, Tunisia, and Palestine with a p-value equals to 0.972, 0.964, 0.920, and 0.830 respectively.
- Pakistan is identical to Morocco and Tunisia (p-value = 1) and very close to Palestine and Egypt with a p-value equals to 0.995 and 0.964 respectively.

Table 12
Multiple comparisons for the recovery rate.

Dependent Variable: norm_recovery_rate
Games-Howell

(I) Country_Code	(J) Country_Code	Mean Difference(I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Morocco	Tunisia	,20003	,43037	,999	−1,0823	1,4824
	Egypt	-,30649	,33926	,972	−1,3128	,6998
	Pakistan	,02263	,32071	1,000	-,9289	,9741
	Djibouti	−1,95655[a]	,42453	,000	−3,2213	-,6918
	Sudan	1,60109[a]	,34284	,000	,5812	2,6210
	Palestine	,31028	,43884	,992	-,9997	1,6203
Tunisia	Morocco	-,20003	,43037	,999	−1,4824	1,0823
	Egypt	-,50652	,45073	,920	−1,8479	,8349
	Pakistan	-,17740	,43694	1,000	−1,4789	1,1241
	Djibouti	−2,15658[a]	,51796	,001	−3,6974	-,6157
	Sudan	1,40106[a]	,45343	,036	,0505	2,7516
	Palestine	,11025	,52975	1,000	−1,4669	1,6874
Egypt	Morocco	,30649	,33926	,972	-,6998	1,3128
	Tunisia	,50652	,45073	,920	-,8349	1,8479
	Pakistan	,32912	,34755	,964	-,7019	1,3602
	Djibouti	−1,65006[a]	,44515	,005	−2,9747	-,3254
	Sudan	1,90757[a]	,36807	,000	,8136	3,0015
	Palestine	,61677	,45882	,830	-,7508	1,9844
Pakistan	Morocco	-,02263	,32071	1,000	-,9741	,9289
	Tunisia	,17740	,43694	1,000	−1,1241	1,4789
	Egypt	-,32912	,34755	,964	−1,3602	,7019
	Djibouti	−1,97918[a]	,43118	,000	−3,2633	-,6950
	Sudan	1,57845[a]	,35105	,000	,5343	2,6226
	Palestine	,28765	,44528	,995	−1,0410	1,6163
Djibouti	Morocco	1,95655[a]	,42453	,000	,6918	3,2213
	Tunisia	2,15658[a]	,51796	,001	,6157	3,6974
	Egypt	1,65006[a]	,44515	,005	,3254	2,9747
	Pakistan	1,97918[a]	,43118	,000	,6950	3,2633
	Sudan	3,55764[a]	,44789	,000	2,2237	4,8915
	Palestine	2,26683[a]	,52501	,000	,7037	3,8300
Sudan	Morocco	−1,60109[a]	,34284	,000	−2,6210	-,5812
	Tunisia	−1,40106[a]	,45343	,036	−2,7516	-,0505
	Egypt	−1,90757[a]	,36807	,000	−3,0015	-,8136
	Pakistan	−1,57845[a]	,35105	,000	−2,6226	-,5343
	Djibouti	−3,55764[a]	,44789	,000	−4,8915	−2,2237
	Palestine	−1,29081	,46147	,082	−2,6673	,0857
Palestine	Morocco	-,31028	,43884	,992	−1,6203	,9997
	Tunisia	-,11025	,52975	1,000	−1,6874	1,4669
	Egypt	-,61677	,45882	,830	−1,9844	,7508
	Pakistan	-,28765	,44528	,995	−1,6163	1,0410
	Djibouti	−2,26683[a]	,52501	,000	−3,8300	-,7037
	Sudan	1,29081	,46147	,082	-,0857	2,6673

Std. Error: Standard Error.
Sig: Significance.
[a] The mean difference is significant at the 0.05 level.

- Palestine is analogous to Tunisia (p-value = 1), very similar to Pakistan, Morocco, and Egypt with a p-value equals to 0.995, 0.992, and 0.830 respectively.
- Sudan and Palestine are slightly similar with a p-value equals to 0.082.

According to Fig. 4, it is illustrated that Djibouti has the highest recovery rate, followed by Tunisia, Egypt, Palestine, Morocco, and Pakistan with a relatively high recovery rate, and finally, Sudan with the lowest recovery rate in this comparison (Fig. 4).

7. Positivity rate

The positivity rate is the ratio of infected individuals to the number of tests done. It is calculated using this formula:

Positivity Rate = 100* (New cases/New tests)

7.1. Testing normality

Hypothesis.

• Null hypothesis	H0: The data are normally distributed.
• Alternative hypothesis	H1: The data are not normally distributed.

According to Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 13):

- The "positivity_rate" variable, which is the variable before the transformation, and "Fractional Rank of positivity_rate", which is the variable after the first step of the transformation, have statistically significant results (p-value < 0.05). Therefore, the null hypothesis is rejected which implies that both of these two distributions are not normal
- The normalized positivity rate variable "norm_positivity_rate" has a non statistically significant result (p-value > 0.05). So, the null hypothesis is accepted which means that the distribution is normal.

Table 13
Tests of Normality for the positivity rate.

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
positivity_rate	,186	513	,000	,783	513	,000
Fractional Rank of positivity_rate	,059	513	,000	,955	513	,000
norm_positivity_rate	,004	513	,200[a]	,999	513	1,000

df: degree of freedom, Sig: significance.
[a] This is a lower bound of the true significance.
[b] Lilliefors Significance Correction.

7.2. Testing homogeneity of variances

7.2.1. Levene's test

Hypothesis

• Null hypothesis	H0: The positivity rate in the countries we are comparing has equal variances.
• Alternative hypothesis	H1: The positivity rate in the countries we are comparing has different variances.

According to Levene's test, the p-value is 0 which is less than 0.05. Thus, the null hypothesis is rejected. This means that the positivity rate in the countries we are comparing has different variances and the assumption of homogeneity of variances is violated (Table 14).

7.3. One way ANOVA

Hypothesis

• Null hypothesis	H0: The means of positivity rate in all countries are equal.
• Alternative hypothesis	H1: At least one mean is different.

To apply the Analysis Of Variance (ANOVA), Welch and Brown-

Table 14
Test of Homogeneity of Variances for the positivity rate.

norm_positivity_rate			
Levene Statistic	df1	df2	Sig.
7.187	3	509	,000

df: degree of freedom, Sig: significance.

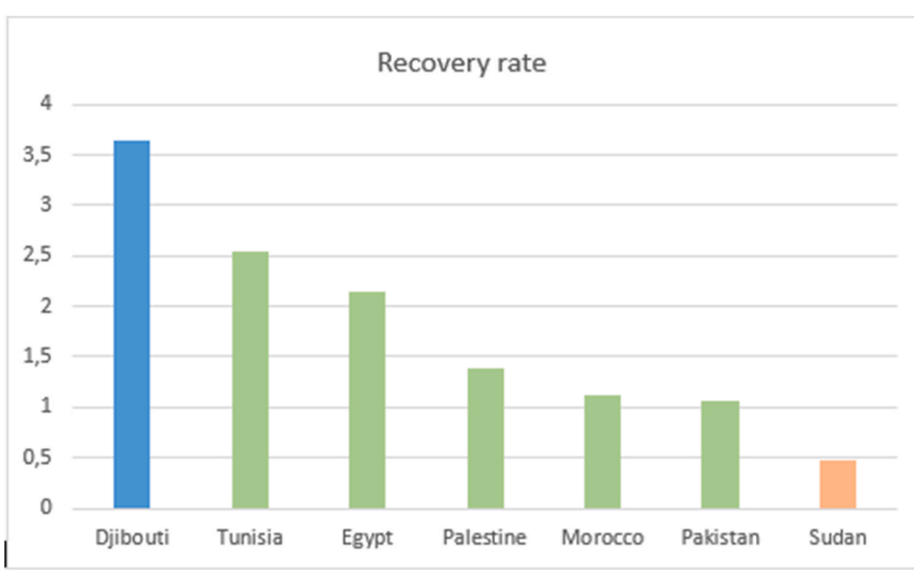

Fig. 4. The mean of the recovery rate in the studied countries.

Table 15
Robust Tests of Equality of Means for the positivity rate.

norm_positivity_rate				
	Statistic[a]	df1	df2	Sig.
Welch	97,397	3	107,921	,000
Brown-Forsythe	70,425	3	496,054	,000

df: degree of freedom, Sig: significance.
[a] Asymptotically F distributed.

Forsythe tests, which are robust to the non-homogeneity of variances assumption, were used for comparing the means. In both tests, the significance is 0. Hence, the null hypothesis is rejected. This means that at least the mean of the positivity rate in one country is different from that in the other countries (Table 15).

7.4. Post hoc test for positivity rate

Data for the number of tests, in the studied period, are found only in four countries. Explicitly, Morocco, Tunisia, Pakistan, and Palestine. A Games-Howell Post hoc test is used for multiple comparisons for the sake of identifying the differences between the countries. Based on the results of multiple comparisons, it is indicated that each country has a different positivity rate from the others (Table 16).

Pakistan has the greatest positivity rate and the highest number of tests in the studied period. However, Tunisia has the lowest positivity rate and a relatively slight number of tests comparing with Pakistan and Morocco (Table 17) and (Fig. 5).

8. Discussion

Regarding the infection rate, Djibouti and Palestine have a relatively higher infection rate. Palestine has a higher population density and young population suffering from poverty, hand washing and sanitation guidelines seem to be very difficult or even impossible to be applied.[15] Likewise, the young population in Djibouti could explain its higher infection rate. Actually, as indicated by the newest Statistical Yearbook 2019 of Djibouti, the median age of the population is 20 years old and 86.5% of the population under 49 years old.[9] This population structure could explain the increase of confirmed cases since the majority of habitants is active and vulnerable to be infected by the virus in their daily life. On the other hand, the greatest percentage of extreme poverty (22.5%) in Djibouti could explain its high infection rate comparing to the other studied countries (Table 18). However, the low infection rate in Tunisia might be attributed to its relatively old population compared to the other studied countries. Actually, the median age is 32.7 years old, the share of the population that is 65 years and older is equal to 8.001% and the share of the population that is 70 years and older is equal to 5.075% (Table 18). This could explain the low infection rate because old people are more confined to their homes and have less contact with others or they could be more stringent regarding the preventive measures. Furthermore, In Sudan, the lack of testing laboratories induces a smaller number of reported infections and the partial respect of the precautionary measures might be the reasons for the low infection rate.[8]

Table 17
Total number of tests by country from the beginning of the pandemic till September 11th, 2020.

Country	Palestine	Pakistan	Tunisia	Morocco
Total Number of tests	77107	2879655	162095	2138164

The case fatality rate is relatively high in Tunisia, Djibouti, Egypt, and Sudan compared with the other countries. However, the lowest rate is in Palestine. The high case fatality rate in Tunisia could be due to the old population compared with the other countries, as mentioned before. In Djibouti, the lack of medical resources which is reported in Takele et al.[24], the greatest percentage of extreme poverty as well as the lowest human development index (0.476) might raise the case fatality rate (Table 18). Moreover, the high case fatality rate in Egypt could depend on the co-morbidity that influences Covid-19 infection. Actually, the highest death rate from cardiovascular diseases (525.432) and the highest diabetes prevalence (17.31%) could explain this highest rate in Egypt (Table 18). On the other hand, the precautionary measures in Egypt were less stringent.[2] This could spread the virus to more people, especially the elderly and people suffering from obesity, diabetes, or cardiovascular diseases. Additionally, the co-morbidity risk factor could be present in Sudan, which comes after Egypt with a death rate from cardiovascular diseases equal to 431.388 and a diabetes prevalence equal to 15.67%. Moreover, the lowest life expectancy (65.31 years old) could explain this relatively high rate (Table 18). However, Palestine has the lower case fatality rate, which might be attributed to the young population.

Regarding recovery, Djibouti recorded the highest rate. This might be due to the young population and the stringent strategy of isolating patients, including testing suspected people who could be infected by the virus and contact tracing of the patients.[9] However, Sudan represents the lowest recovery rate. This could be attributed to the

Table 16
Multiple Comparisons for the positivity rate.

Dependent Variable: norm_positivity_rate						
Games-Howell						
(I) Country_Code	(J) Country_Code	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Morocco	Tunisia	22,54950*	4,40581	,000	11,1725	33,9265
	Pakistan	−26,72501*	4,23097	,000	−37,6498	−15,8002
	Palestine	−40,14388*	4,20692	,000	−51,1901	−29,0977
Tunisia	Morocco	−22,54950*	4,40581	,000	−33,9265	−11,1725
	Pakistan	−49,27451*	3,95914	,000	−59,5006	−39,0484
	Palestine	−62,69338*	3,93342	,000	−73,0784	−52,3083
Pakistan	Morocco	26,72501*	4,23097	,000	15,8002	37,6498
	Tunisia	49,27451*	3,95914	,000	39,0484	59,5006
	Palestine	−13,41887*	3,73655	,004	−23,3301	−3,5076
Palestine	Morocco	40,14388*	4,20692	,000	29,0977	51,1901
	Tunisia	62,69338*	3,93342	,000	52,3083	73,0784
	Pakistan	13,41887*	3,73655	,004	3,5076	23,3301

The mean difference is significant at the 0.05 level.
Std. Error: Standard Error.
Sig: Significance.

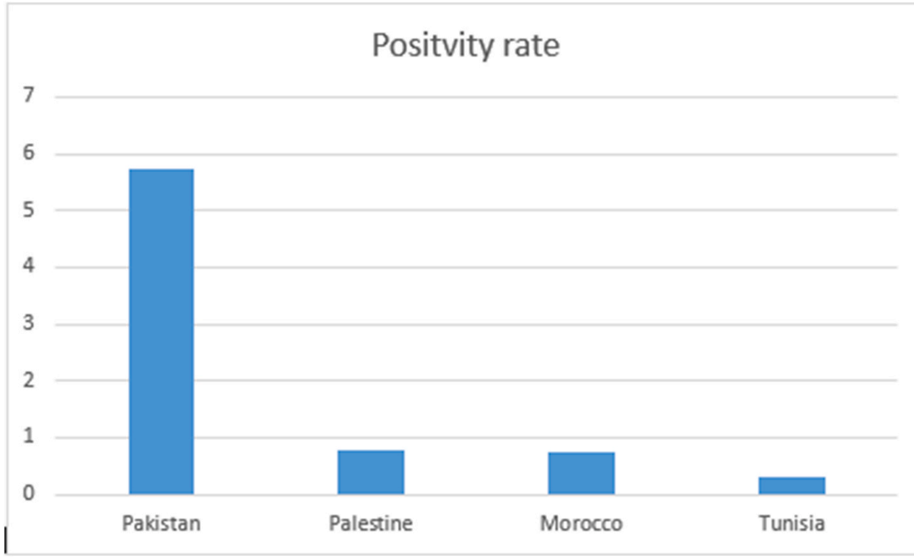

Fig. 5. The mean of the positivity rate in the studied countries.

Table 18
Demographic and economic data of lower-middle-income countries in the eastern Mediterranean region.

Country	Djibouti	Egypt	Morocco	Pakistan	Palestine	Sudan	Tunisia
population_density	41.285	97.999	80.08	255.573	778.202	23.258	74.228
median_age	20[a]	25.3	29.6	23.5	20.4	19.7	32.7
aged_65_older	4.213	5.159	6.769	4.495	3.043	3.548	8.001
aged_70_older	2.38	2.891	4.209	2.78	1.726	2.034	5.075
extreme_poverty	22.5	1.3	1.0	4.0	1.0	–	2.0
cardiovasc_death_rate	258.037	525.432	419.146	423.031	265.91	431.388	318.991
diabetes_prevalence	6.05	17.31	7.14	8.35	10.59	15.67	8.52
hospital_beds_per_thousand	1.4	1.6	1.1	0.6	–	0.8	2.3
life_expectancy	67.11	71.99	76.68	67.27	74.05	65.31	76.7
human_development_index	0.476	0.696	0.667	0.562	0.686	0.502	0.735

All other data are taken from "Our World in Data" dataset[11]
[a] This data is taken from Statistical Yearbook 2019 of Djibouti.[31]

co-morbidity risk factor and the lowest life expectancy of its population (Table 18).

This study has some limitations that must be noted. The data about the number of tests are not available in some countries and relatively few in others. This could affect the accuracy of the positivity rate comparison. On the other hand, since the number of tests is a key factor to determine the number of cases, the new infections could not be accurately identified. Therefore, the situation of the pandemic might not be appraised effectively in each country.

9. Conclusion

The Coronavirus pandemic has presented a threat to the whole world since it has not only affected the fundamental aspects of our life, such as the health security, psychological and social well-being of people, but also the world economy. Statistical analysis of Covid-19 carried out in various countries are based on the official data of each country. The studied countries have taken different precautionary measures to control the pandemic and, in this manner, contain the spread of the virus, reduce the burden on the health system and minimize the number of deaths. This study allows us to find out the relationships in the lower-middle-income countries in the eastern Mediterranean region, between controlling the spread of the virus and different factors, such as preventive measures, demographic aspects, poverty, health system, and co-morbidity like diabetes, cardiovascular diseases, and cancer. Since the precautionary measures are the most effective factors to contain the infection and alleviate its impact, people need to be aware of the importance of respecting social distancing, avoiding gatherings, wearing masks, and washing hands frequently. Moreover, the number of tests is a key factor to determine the number of cases. Hence, more efforts should be made to create more testing facilities in order to be more accurate in identifying the new infections and effectively appraise the situation of the pandemic in each country. On the other hand, the old population and co-morbidity conditions can increase the fatality rate. For this reason, old people and those suffering from other chronic diseases, such as cardiovascular diseases, diabetes and cancer should keep their distance from people and apply all the strict sanitary precautions. Additionally, countries should increase their hospital capacities, the efficiency of their healthcare system as well as reduce poverty.

In this context, further studies can be done. The notion of time can be introduced in the investigation and conduct an exploratory panel data analysis. Other studies can focus on comparing the precautionary measures and their economic effects as well as the direct demoghraphic effects of Covid-19 on the population.

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