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Exploring the statistical significance of Africa covid-19 data

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Abstract

It has been cited by different researchers that COVID-19 infections in Africa is insignificant. This paper delves into the regional data to scrutinize the statistical significance of COVID-19 in Africa. The data of all regions, according to World Health Organization (WHO) classification, is compared to that of Africa. The paper explores COVID-19 infections data including cases, fatality, case fatality rates, recovery, and recovery rates. These are compared to COVID-19 status in Africa on May 9, 2020. First, the COVID-19 regional data is taken through logarithmic transformation, normality tests and One-way ANOVA analysis of mean infections, fatality, case fatality rates, recoveries, and case recovery rates. Then Tukey post hoc method is used to identify which regions exhibit statistical difference in, cases, fatality, case fatality rates, recoveries, and case recovery rates. Estimation of linear models of various parameters with regions as factor is done. The residuals of the linear models are tested for normality using Q-Qplots, residual-fitted plots, and histograms. Lastly, 95% family-wise confidence level of regional mean differences in COVID-19 infections and resultant effects is estimated and plotted. In this paper selected countries in the East, West, and mid-west Mediterranean, and Oceania regions are referred to as OCEA. In the statistical analysis the regions are denoted as Americas (AMER), Europe (EURO), Africa (AFRO), and OCEA. Results indicate that the mean COVID-19 infection cases are significantly different from Americas, Europe, and OCEA at 95% confidence level. Also, the mean COVID-19 case fatality in Africa is significantly different from Europe and Americas but not OCEA. In addition, mean COVID-19 case fatality rate in Africa is not statistically different from Americas, Europe, and OCEA at 95% confidence level. Further, the mean COVID-19 recoveries in Africa is significantly different from Europe and OCEA but not Americas at 95% confidence level. Interestingly, all regional recovery rates are not significantly different from each other at 95% confidence level.

Keywords: Exploring, statistical significance, covid-19

Introduction

The coronavirus disease 19 (COVID-19) was reported in China in December 2019 Alanagreh *et al.* (2020) [4]. During that month China became the epicenter of COVID-19 outbreak as the disease spread to other parts of the world with rotating sequence of epicenters in Italy, Germany, United Kingdom and United States of America. In the evolution of the pandemic Africa has not being identified as COVID-19 epicenter by WHO and other disease surveillance authorities. Azeem *et al.* (2020) attributes the low rate of infections in Africa to disparities limiting travel to and movement within the continent. These include political instability, inadequate infrastructure, inadequate information technology, and kidnapping. These factors hinder tourism. The ease of doing business index which is deemed low is also cited to limit travelling to African nations for business.

There could be interaction of many non-risks factors whose multiplicity may have resulted in low rates of infection. Few studies (if any) have investigated the influence of healthy African food consumed in rural villages without access to fast food outlets, the existence of herbal medicines used frequently as good health protection therapy, and the general good physical health resulting from non-mechanized agricultural and fishing activities. There is emerging accelerated use of plants with medicinal value traditionally used for other disease therapies in Africa. Madagascar uses Artemisia plant while Kenyans in rural villages rely on neem plant herbs for protection. Although Alex *et al.* (2020) [2] alluded to melatonin reducing severity of

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COVID-19, microbial factors bearing etiological relations with COVID-19 are beyond the scope of this paper.

This paper investigates the statistical significance of COVID-19 data in Africa in relation to other regions. With access to pandemic worldometer (<https://www.covidvisualizer.com>), researchers have used data for descriptive analysis of case fatality rate, infection rata and graphical comparison of cases. There are studies on forecasting and predicting cases, fatalities, and recoveries by various researchers. Andrei *et al.* (2020) [6] estimated actual coincidence of coronavirus in emergent hotspot in Japan and commented that many considerable numbers of infected persons may not have been recognized as cases because they exhibited mild or no symptoms. This could also have been the situation in Africa where countries have low testing capacity. Also, Dahesh *et al.* (2020) used ARIMA model to forecast COVID-19 cases in Europe, West Pacific, Easter Mediterranean, and South East Asian regions but did not include Africa due to perceived insignificant infections. There is also questions of data quality and validity as observed by Chakraborty *et al.* (2020) [1] noting that China has some data gaps because Chinese Authorities revised the reporting of cases at least six times. The revision of cases data may not be unique to China. Cabana *et al.* (2020) [5] also examined the possibility of phenomenon of under-reporting of cases resulting in highly biased inferences and invalidation of assumptions of classical models. These factors necessitate investigation of statistical significance of COVID-19 data, especially in Africa where researchers inaccurately claim “insignificance”. Moreover, Guidotti & Ardia (2020) [11] observe in a May 2020 publication that there exist more than 23,000 research papers which double after every 20 days in the absence of application that collects *fine grained* data on COVID-19 globally.

To investigate significance of severity and prevalence of COVID-19 infections in Africa, it is important to verify if the African disease data is statistically different from other regions. This will give insights into mathematical models developed around CODID-19 pandemic concerning, rates of infection, recoveries, and forecasts on case fatality among others.

Methodology

In this paper, we rely on observation data provided by (<https://www.covidvisualizer.com>) on May 9, 2020 at 1159HRS. The study has considered countries in this manner; Europe 22, Africa 22, Americas 22, and combination of 22 countries from Oceania, East and Midwest Mediterranean referred to as OCEA in this paper. These countries are selected in no particular order. In Africa the following countries are considered; Senegal, South Africa, Egypt, Morocco, Algeria, Cameroon, Ghana, Nigeria, Ivory Coast, Guinea, Djibouti, Tunisia, Bukinafaso, Somalia, Congo, Mali, Kenya, Mauritania, Tanzania, Sudan, Botswana, Zambia, and Madagascar. The countries selected in the Americas include USA, Brazil, Canada, Ecuador, Peru, Mexico, Chile, Dominican Republic, Panama, Columbia, Argentina, Cuba, Bolivia, Costa Rica, Honduras, Paraguay, Uruguay, Guatemala, Venezuela, Jamaica, El salvado, Haiti, and Paraguay. In Europe the countries selected are Spain, Germany, France, Russia, Netherlands, Portugal, Sweden, Austria, Romania, Ukraine, Ireland, Finland, Denmark, Bulgaria, Hungary, Greece, Norway, Italy, Lithuania, Switzerland, Belgium, and United Kingdom. The following countries are selected from Oceania, Mid East and Western Mediterranean; Iran, Saudi Arabia, Pakistan, UAE, Qatar, Kuwait, Cyprus, Oman, Iraq, Afghanistan, Maldives, Jordan, Cambodia, China, Japan, Israel, Korea, Philippines, Malaysia,

India, Indonesia, and Thailand. Other than separation by region, these countries are chosen in no particular order.

To test that Africa COVID-19 cases, case fatality, case fatality rates, recoveries, and case recovery rates are significantly different or equal to other regions we use One-way ANOVA. Further we identify with precision the different regional COVID-19 means using post hoc Tukey method. First, the data is tested for normality conditions using boxplots. The data is logarithmically transformed and /or standardized when normality condition is not satisfied. Logarithmic transformation is a monotonically increasing function that reduces outlier effects while retaining the underlying data attributes. Tukey method is used for post hoc analysis of pair wise regional COVID-19 means. Tukey method is used because it outlines which regional means are statistically different and proceeds to give coefficients of pair wise mean differences. Also, linear models of COVID-19 cases, case fatality, case recoveries, case fatality rates, case recovery rates with regions as factor are estimated. The residuals of those models are standardized and subjected to Q-Q plots, residualsvsfitted plots, and histogram for normality tests.

Empirical Review

In this paper selected countries in each region represents COVID-19 prevalence in which case we have 4 regional block cases: Africa (AFRO), Europe (EURO), AMERICAS (AMER), Oceania and the Mediterraneans (OCEA). This helps us to study the variations within regions (SSW) and between regions (SSB). SSW is sum of squares withing regions and SSB denotes sum of squares between regions. The total variations denoted SST -standing for Total sum of squares. The analysis procedure is:

$$SST = \sum_{i=1}^T \sum_{j=1}^{n_i} (y_{ij} - \bar{y})^2 = (n_T - 1)s_T^2$$

$$SSW = \sum_{ij} (y_{ij} - \bar{y}_i)^2 = (n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 + (n_3 - 1)s_3^2 + (n_4 - 1)s_4^2$$

$$SSB = \sum_i n_i (\bar{y}_i - \bar{y})^2$$

Where T is an integer ≥ 2 , in our case $T = 4$
 \bar{y} is overall mean
 y_{ij} is data observation
 n_i is sample size, i and $j = 1, 3, \dots, n$
 s_i^2 , sample standard deviation
 \bar{y}_i is sample mean
 $e = y_i - \bar{y}_i$ residuals we test for each treatment
 $e_i = y_i - \hat{y}_i$, fitted residuals for linear models

1. Exploring regional COVID-19 Cases significance

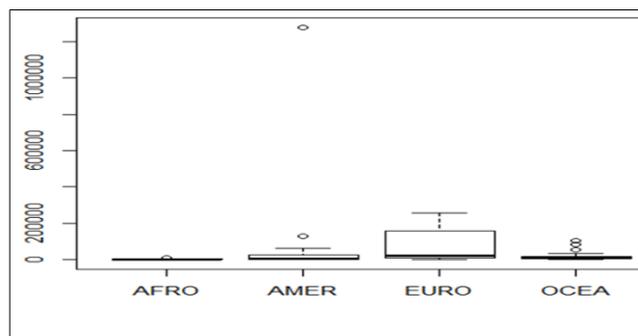


Fig 1: Normality of COVID-19 cases regional data

As depicted in *Figure 1*, raw data does not give precise and clear picture of data distribution in the quartiles and makes it difficult to interpret with accurately. For instance, the above boxplot normality test reveals that Europe COVID-19 data is not normal although regional means are *relatively* equal. At this point we have three options: transforming the COVID-19 regional cases data, proceeding to estimate ANOVA to verify equality of the means, or test the residuals for normality Lyman *et al.*, (2010) [9] and estimate ANOVA test using residuals. Raw data does not give clear and precise information about the regional cases data. We transform that data logarithmically to give us results in *Figure 2*.

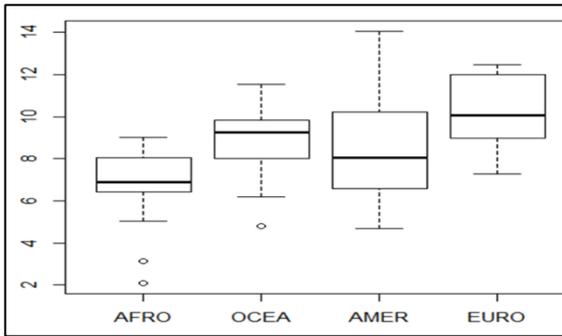


Fig 2: u Boxplot after logarithmic transformation

In *figure 2* above, following logarithmic transformation, the distribution of data is clear. The media points in bold are different but distributed within a close range. The regional data is not normally distributed. We estimate a linear model of cases separated by regions and test the residuals for normality (*Figure 4*) and even distribution (*figure 3*) between the upper and lower boundaries as shown below.

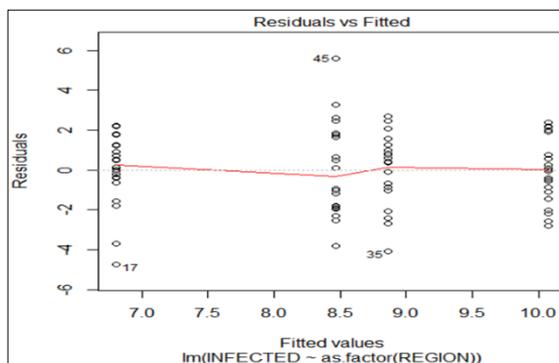


Fig 3: Residuals of Infected~Region Model

The residuals in *Figure 3* are evenly distributed in the lower and upper boundaries revealing normality condition.

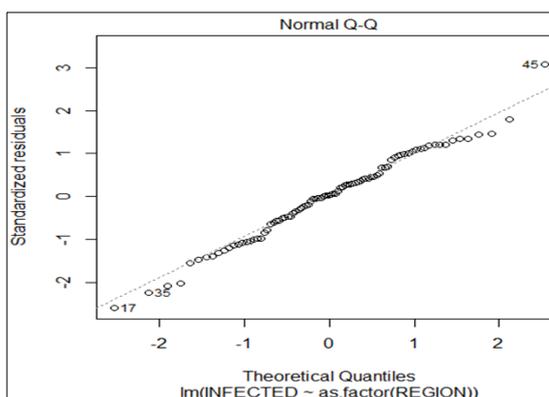


Fig 4: Q-Qplot of Infected~Region model residuals

In *figure 4*, the Q-Q plot shows that the residuals of model are normally distributed. We proceed to plot a histogram of residuals to further support normality condition. *Figure 5* further confirms normality condition.

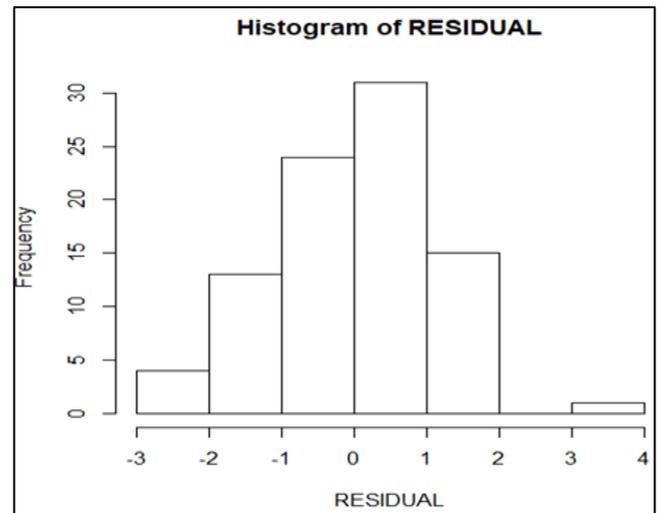


Fig 5: Histogram of Infected~Region residuals

Table 1: Tukey method pair wise comparison and identification of regional COVID-19 cases means

Region pairs	Difference	Lower	Upper	p-value
Amer-afro	1.6620658	0.1862448	3.1378869	0.0209239
Euro-afro	3.2701049	1.7942838	4.7459260	0.0000007
Ocea-afro	2.0636622	0.5878411	3.5394833	0.0023970
Euro-amer	1.6080390	0.1322180	3.0838601	0.0271950
Ocea-amer	0.4015964	-1.0742247	1.8774175	0.8915693
Ocea-euro	-1.2064427	-2.6822637	0.2693784	0.1481715

The Africa mean COVID-19 cases are statistically different from Americas, Europe, and OCEA at 95% confidence level. Also, mean COVID-19 cases for Europe and Americas is statistically different at 0.05% significance level. At 95% confidence level both OCEA-Americas and OCEA-Europe are not significantly different.

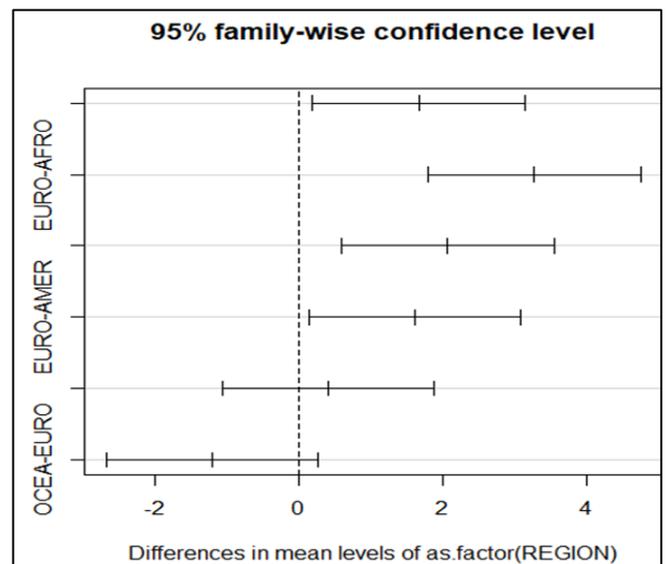


Fig 6: pair wise differences in regional COVID-19 cases mean levels

2. Exploring regional of case fatality

We are going to see how using untransformed data is theoretically and statistically misleading.

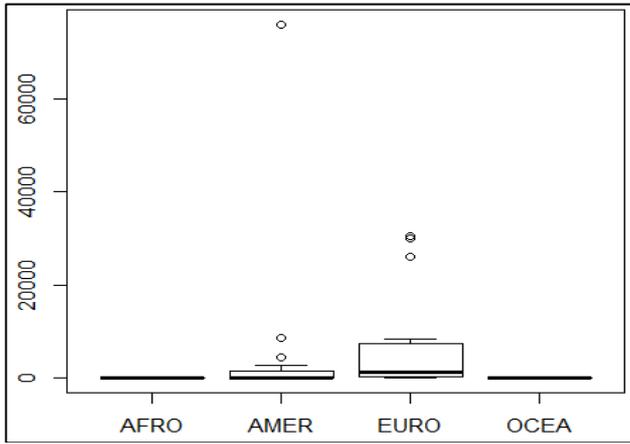


Fig 7: boxplot test of regional COVID-19 case fatality

From the untransformed data in figure 7, the 1st and 3rd quartile for Africa and OCEA are equal. The median for all the regions' COVID -19 case fatality are equal. In Americas and Europe there are four outlier data points which are USA, Brazil, Italy, and France. Something interesting Europe's case fatality data is the disproportionate distribution with 3rd quartile taking the larger share. The Africa's and OCEA's data are consistent. The Americas data is inconsistent. The Europe's COVID-19 death data is largely inconsistent. However, the striking aspect is the equality or similarity of medians in bold. The Africa's COVID-19 case fatality data is

not unique at all. This data tells us very little about normality condition.

Table 2: ANOVA test for equality of regional fatality means, using untransformed data

	DF	Sum of Squares	Mean Square	F	P-value
Region	3	712448.9589	241286202	2.577	0.0591
Residuals	84	63722.5201	93622487		

The results of ANOVA test for regional COVID-19 mortality data present fresh challenges:

1. The means squares are greater than sum of squares.
2. The F critical at 0.05 significance level is 2.76 whereas the computed F is 2.577. These suggest that means are equal. However, p-value of 0.0591 is greater than $\alpha = 0.05$. These results are inconclusive and misleading.

Transformation of Regional COVID-19 Case Fatality

The data is taken through logarithmic transformation which reduces the outlier data effects while retaining underlying structure. The boxplot of the transformed data is presented in figure 8 below. The Africa COVID-19 fatality data is consistence. Judging from the whisker on the 3rd quartile of Americas' data, it is evident that Americas deaths is inconsistent. In both Europe and Americas case fatality data is concentrated in the third quartile. The OCEA data is concentrated in the second quartile, inconsistent and unpredictable.

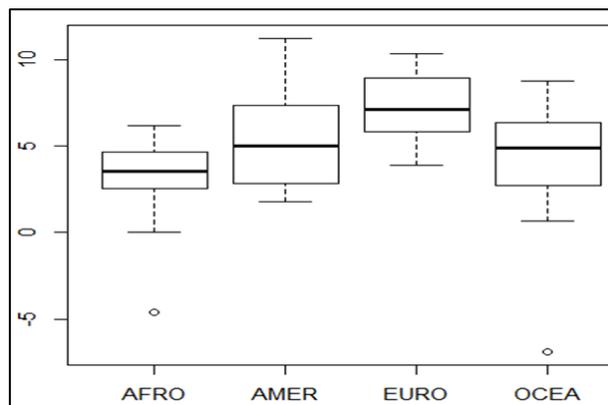


Fig 8: Boxplot of transformed regional COVID-19 death data

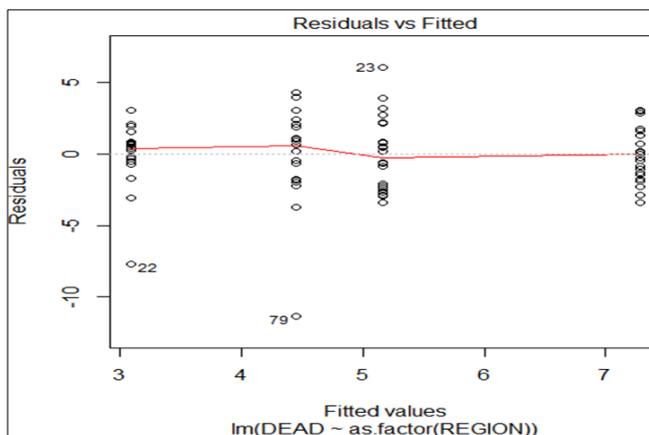


Fig 9: Normality of Case Fatality~Region residuals

We estimate the linear model of Case Fatality~Regions(as factor) and test residuals for normality and even distribution between the upper and lower boundaries as shown in figures 8,9 and 10. The residuals are normally and evenly distributed.

We proceed to use Tukey method to estimate and identify the pair wise regional case fatality differences as shown in table 3.

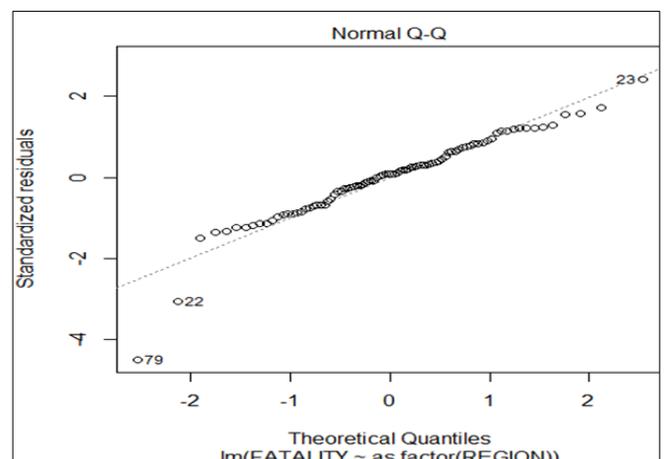


Fig 10: Q-Qplot of Case Fatality~Region model residuals

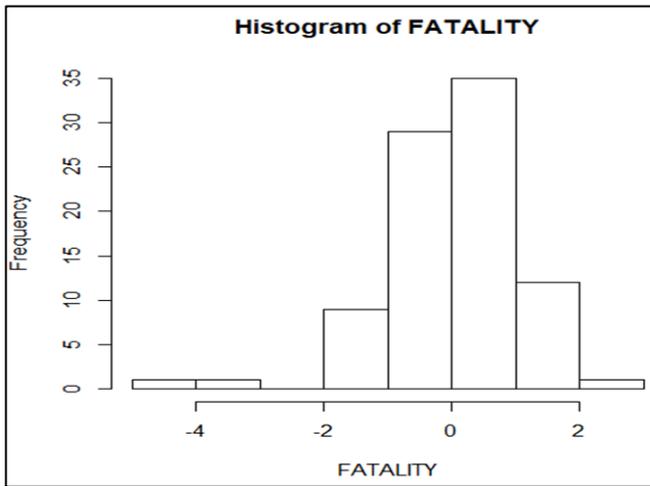


Fig 11: Histogram of Case Fatality~Region model residuals

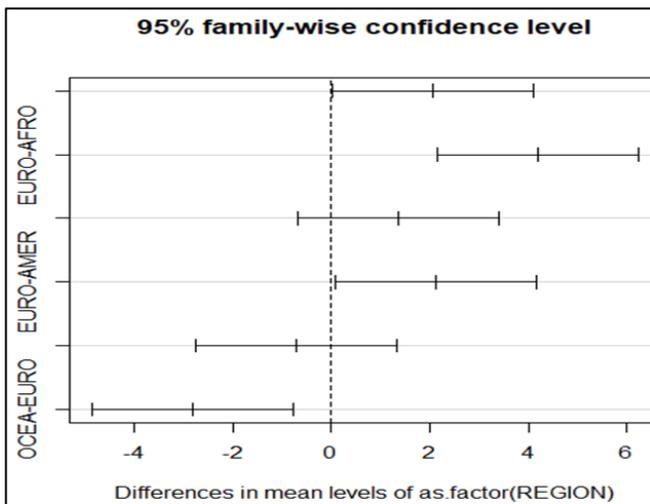


Fig 12: Regional mean differences in COVID-19 Case Fatality

Table 3: Tukey method for pair wise identification of differences in COVID-19 regional case fatality

region pairs	difference	lower	upper	p-value
africa-america	2.0703155	0.02692802	4.1137029	0.0458523**
africa-europe	4.1846500	2.14126259	6.2280375	0.0000041***
africa-oceania	1.3570819	-0.68630551	3.4004694	0.3093491
america-europe	2.1143346	0.07094713	4.1577220	0.039707**
america-oceania	-0.7132335	-2.75662097	1.3301539	0.7969504
europe-oceania	-2.8275681	-4.87095554	-0.7841907	0.0027157***

From table 3, mean COVID-19 case fatality pair wise difference in Africa-Americas, Africa-Europe, and Africa-OCEA are statistically different at 95% confidence level. Also, Europe-OCEA and Americas-Europe are significantly different at 95% confidence level. However, OCEA-Americas is not significantly different.

3. Exploring case fatality rates

From untransformed data, figure 12 reveals that all regions have inconsistent COVID-19 case fatality rate data. However, Europe has the eccentric data which is largely inconsistent and unpredictable. The countries in various regions with high death rates are Mauritania (12.5), Haiti (11.11111), France (14.867), and Indonesia (7.279). These are the outliers in their respective regions. The medians are different. The untransformed data does not give clear and clear information.

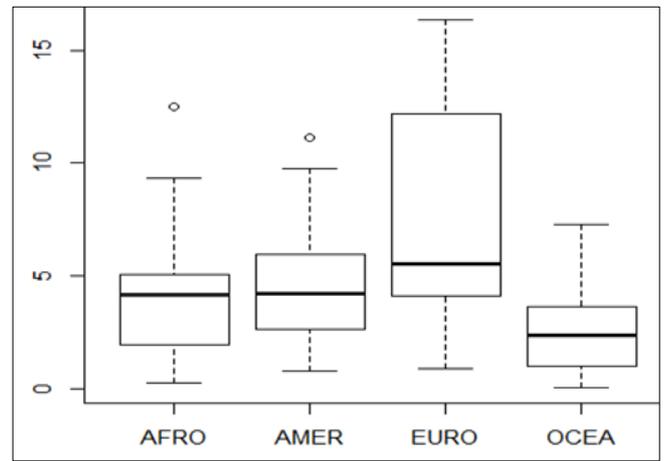


Fig 13: Boxplot of raw regional COVID-19 case fatality rate data

COVID-19 case fatality rate data transformation

The data is taken through logarithmic transformation to reduce outlier effects and boxplot test run again.

As presented in Figure 13 below, all regions have inconsistent unbalanced data but relatively less eccentric. Apart from Europe all most data points are concentrated below the media. We proceed to conduct ANOVA test for regional death rates.

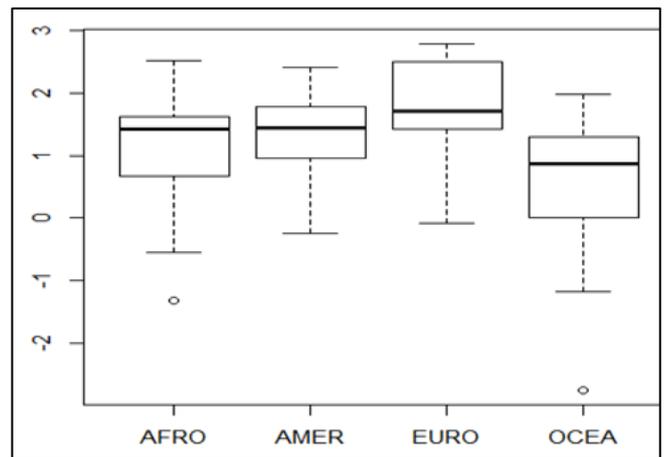


Fig 14: Boxplot of transformed case fatality rate data.

The median points are relatively similar although Europe data still appears eccentric.

Table 4: ANOVA test for COVID-19 regional death rates

	DF	Sum of Squares	Mean Square	F	P-value
Region	3	16.16	5.385	6.531	0.000524
Residual	80	65.95	0.825		

The computed $F = 6.531$ is greater than critical $F = 2.76$. The p -value 0.000524 is less than significant level of $\alpha = 0.05$. The null hypothesis of equality of means is rejected. We conclude that at least one regional case fatality rate mean is different. The means for the regions are as follow; Africa (4.1651), Americas (4.5164), Europe (7.27000), and OCEA (2.7089). We must identify which regional mean is statistically different. We fit Case Fatality rate~Region linear model and test residuals for normality and even distribution in both lower and upper boundaries. Figures 14, 15, and 16 below show that the residuals are normal, evenly distributed.

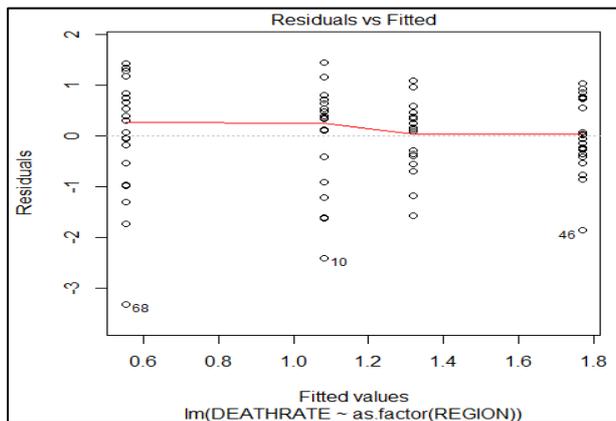


Fig 15: Case fatality Rate residual-fitted residuals

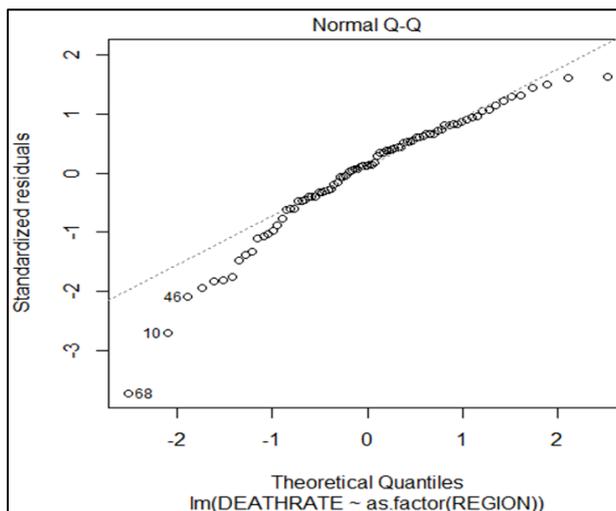


Fig 16: Q-Q plot for Fatality rate~region residuals

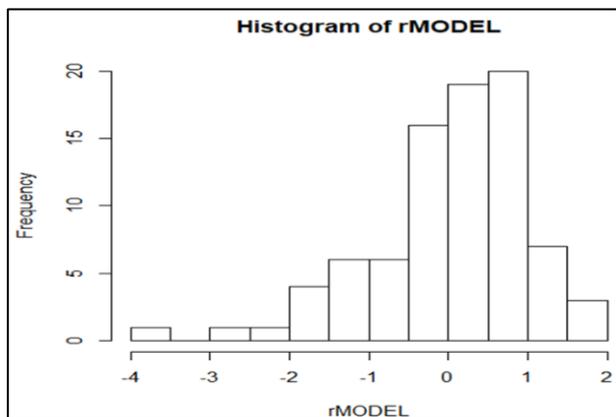


Fig 17: Histogram of Fatality Rate~region model residuals

Table 5: Tukey method pair wise identification of regional differences in case fatality rates

Paired Regions	Differences	Lower	Upper	p-value
AMER-AFRO	0.2389408	-0.49636664	0.97424833	0.8290056
EURO-AFRO	0.6878037	-0.04750383	1.42311115	0.0752127
OCEA-AFRO	-0.5280983	-1.26340576	0.20720922	0.2428982
EURO-AMER	0.4488628	-0.28644467	1.18417030	0.3835137
OCEA-AMER	-0.7670391	-1.50234660	-0.03173163	0.0375335
OCEA-EURO	-1.2159019	-1.95120942	-0.48059444	0.0002391

No case fatality rate is significantly different from that of Africa.

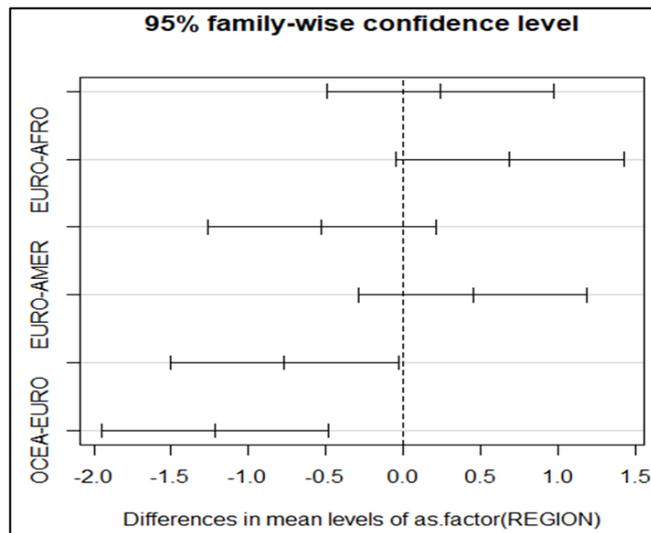


Fig 18: pair wise illustration of mean fatality rate differences.

4. Exploring regional case recoveries

As presented in the untransformed data in Figure 18 below, there are outlier data points in Americas, Europe and OCEA compared to Africa. The data of Europe, Americas and OCEA are disproportionately distributed with third quartile have larger share. The data in those regions are inconsistent.

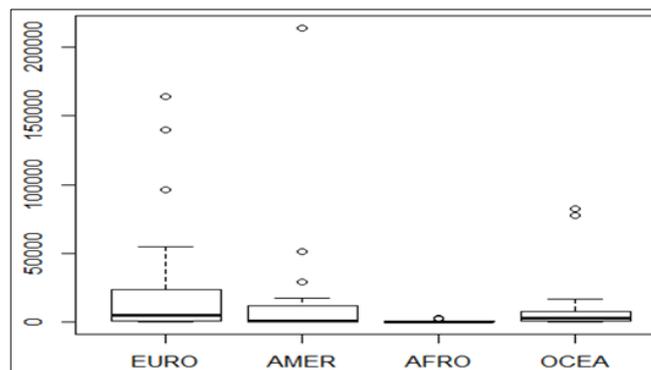


Fig 19: Boxplot of regional COVID-19 case recovery raw data

To reduce the outlier effects on regional COVID-19 recovery data, we perform logarithmic data transformation and rerun boxplot test. The results are presented in the figure 19 below.

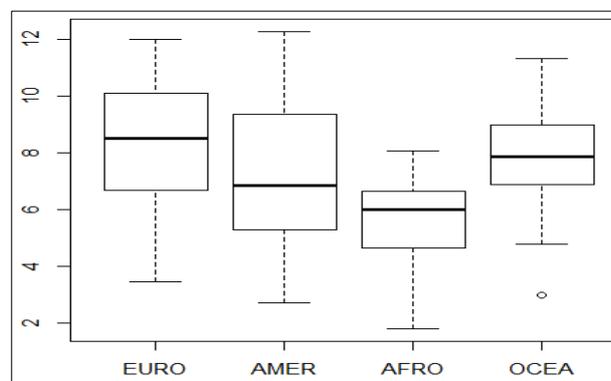


Fig 20: Boxplot of regional COVID-19 recovery transformed data

All the regions have inconsistent recovery data. All regions have more recovery in the third quartile except Africa. All the medians are not equal with Africa have the least value.

Table 8: ANOVA test of regional COVID-19 Recoveries

	DF	Sum of Squares	Mean square	F	P-value
Region	3	60781.123	20257.71	2.08	0.109
Residual	84	60472.883	9739.91		

The critical F value 2.76 is greater than the computed F value 2.08 and p-value 0.109 is greater than $\alpha = 0.05$. We fail to reject the null hypothesis and conclude that all the COVID-19 regional recovery means are equal. We must still identify which pair of means are different by estimating Recovered~Region model and use Tukey method.

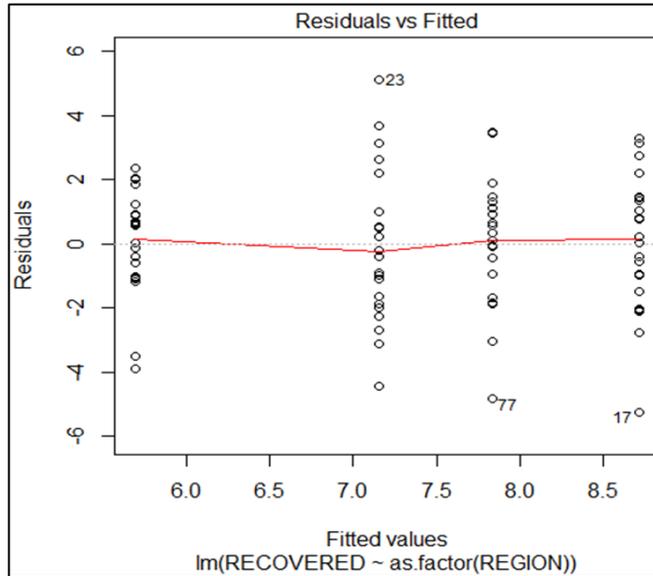


Fig 21: plot of Case Recovered~Region model residuals versus fitted

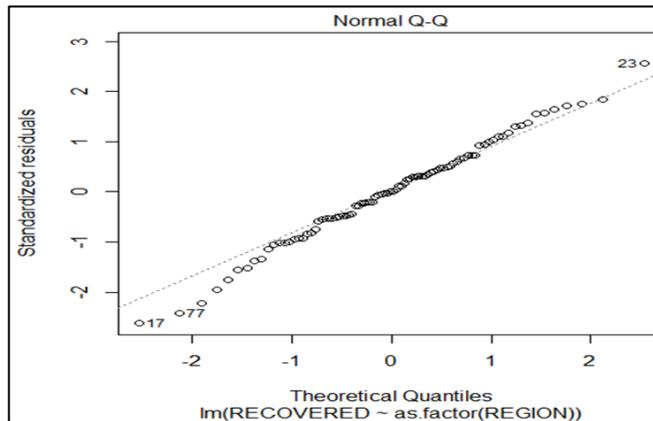


Fig 22: Q-Q plot of Case Recovery~Region Model residuals.

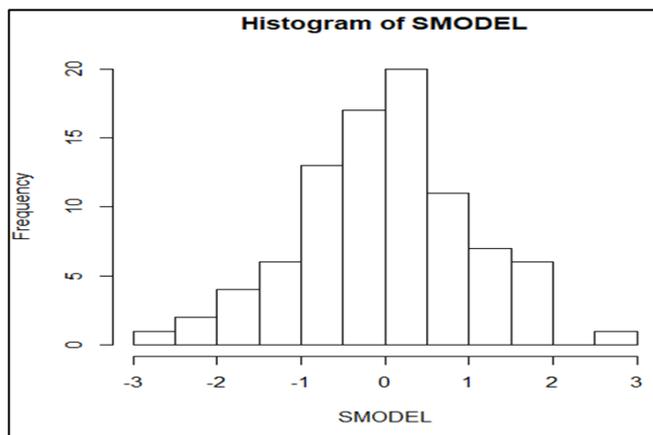


Fig 23: Histogram of residuals of Case Recovery~Region Model

Table 6: Tukey post hoc for pair wise identification of differences in COVID-19 regional case recoveries

Paired Regions	Difference	Lower	Upper	P-value
Africa-America	1.4624641	-0.15766527	3.0825809	0.0916634
Africa-Europe	3.0194325	1.3993157	4.6395492	0.0000286
Africa-Oceania	2.14000188	0.5199020	3.7601355	0.0046059
America-Europe	1.5569684	-0.0631484	3.1770851	0.0641959
America-Oceania	0.6775574	-0.9425621	2.2976715	0.6928109
Europe-Oceania	-0.879137	-2.4995304	0.7407031	0.4888204

The mean case recoveries difference for Africa_Americas, Americas-Europe, Americas-OCEA, and Europe-OCEA are not statistically different at 95% confidence level. However, mean recovery differences for Africa-Europe and Africa-OCEA are statistically different at 0.05 significance level. We proceed to illustrate the mean recovery difference levels as illustrated in figure 23 below.

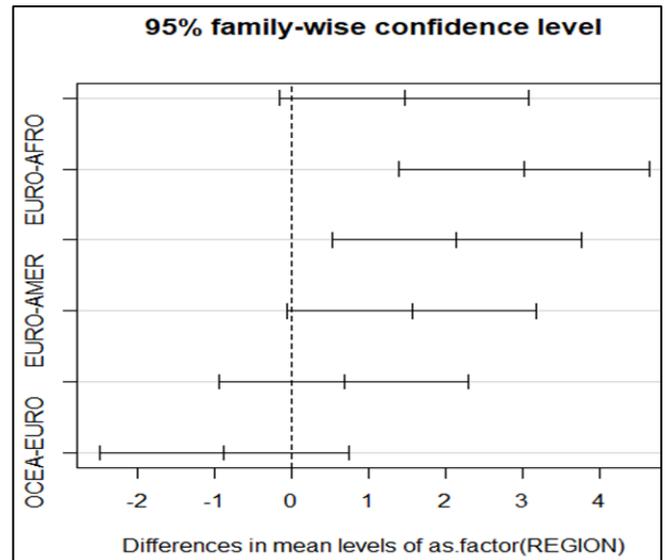


Fig 24: Illustration of mean COVID-19 case recovery confidence levels

5. Exploring regional case recovery rates

The transformed COVID-19 case recovery rate data is subjected to boxplot normality test as illustrated in figure 24 below. The regional median case recovery data is relatively equal. The data distribution is largely consistent. We have to do further test on normality, and residuals distribution.

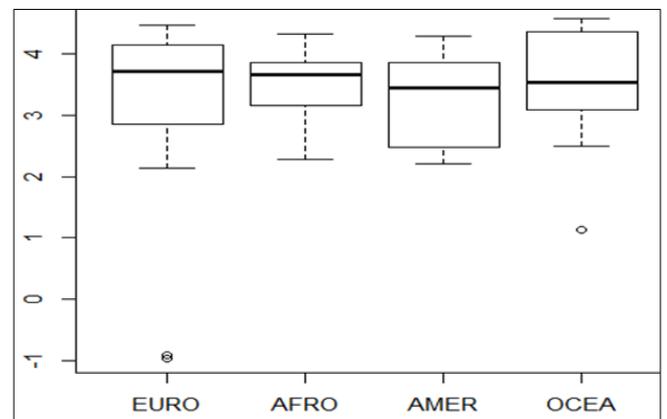


Fig 25: Boxplot of regional case recovery rates with transformed data.

Although the regional case recovery rate data is inconsistent the median rates are equal.

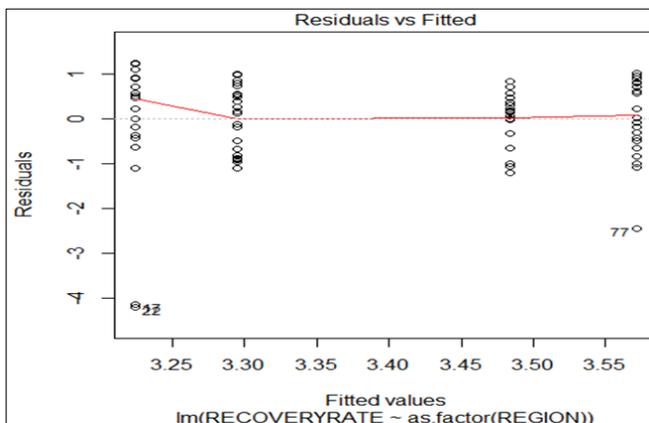


Fig 26: Residuals-fitted Case Recovery rate~Region model residuals



Fig 29: illustration of regional recovery data means difference levels

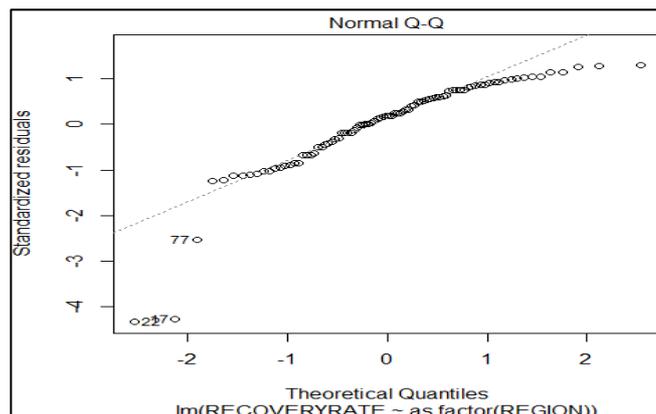


Fig 27: Q-Q plot of Case Recovery-rate~Region model residuals

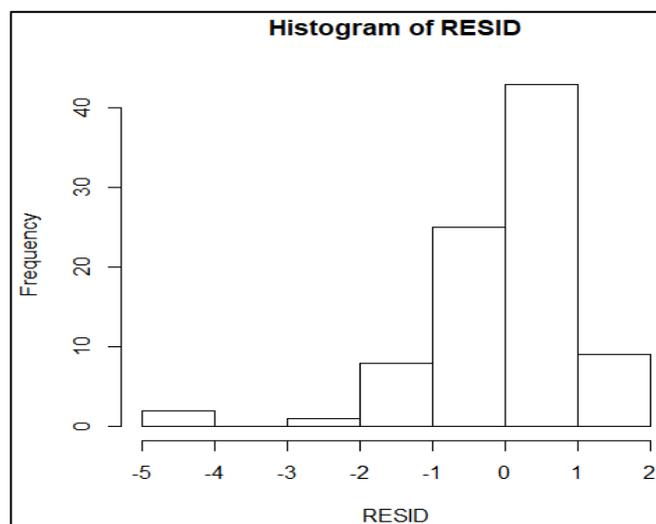


Fig 28: Histogram of Case Recovery rate~Region model residuals

Table 7: Table 6: Tukey post hoc for pair wise identification of differences in COVID-19 regional case recovery rates

Region Pairs	Difference	Lower	Upper	P-value
AMER-AFRO	-0.18846987	-0.9734540	0.5965142	0.9223332
EURO-AFRO	-0.25972875	-1.0447128	0.5252553	0.8216779
OCEA-AFRO	0.08748845	-0.6974956	0.8724725	0.9912584
EURO-AMER	-0.07125889	-0.8562430	0.7137252	0.9952239
OCEA-AMER	0.27595831	-0.5090258	1.0609424	0.7934459
OCEA-EURO	0.34721720	-0.4377669	1.1322013	0.6539179

From table 7 the p-value, all the regional case recovery rates are not statistically different at 95% confidence level. The regional case recovery rates are fairly the same as illustrated in figure 28.

Discussion

Exploratory analysis of COVID-19 regional data is conducted to establish the statistical significance of cases, case fatality, case fatality rates, case recoveries, and case recovery rates. These are done in comparison to Africa’s COVID-19 status. The data in all cases is taken through logarithmic transformation to reduce outlier effect. The transformation also has monotonic influence and dumping of data. It is very helpful in dealing with eccentric COVID-19 data in Europe and Americas. As presented in this paper, untransformed data gives misleading results when used. When linear models of cases, case fatality, recoveries and respective rates with regions as factors are estimated, the corresponding residuals are tested for normality and distribution of residuals between the upper and lower boundaries is scrutinized. The histogram of those residuals is also constructed. All residuals of the outlined linear models are normally distributed as illustrated in figures 1-28. The basic ANOVA does not identify which pair of regions have different means of cases, case fatality, recoveries, case fatality rates, and case recovery rates. In that scenario, Tukey method is employed to identify which pair of means are significantly different.

From the results of Tukey method, mean COVID-19 cases in Africa is significantly different from Americas, Europe and Oceania (including selected Mediterranean regions) regions at 95% confidence level. However, the mean COVID-19 cases in in Oceania (including Mediterranean), Europe and America are not statistically different from one another. The number of cases may be low in Africa because of low testing capacity resulting from few testing equipment and reagents. Also, the mean case fatality between Africa, Americas, and Europe is not statistically different at 0.05 significance level. This gives a pointer as to why mean COVID-19 case fatality rates in Africa is not statistically different from Europe. The finding suggests that if infections increase in Africa to the numbers realized in America and Europe, the corresponding number of case fatality will be equal. The use of case fatality and case fatality rate agrees with Backhaus (2020) [7] interpretation. There are possibility of patients dying of COVID-19 related deaths without out being tested. The unavailability of rapid tests in Africa where samples being tested wait for many hours, even days, to give conclusive results. The other argument getting traction is the high cost of testing kits among African countries with lower income populations exacerbated by dominant hard-to-regulate economies and fewer well-equipped health facilities. Advances have been made in Senegal where testing kits, costing 1\$ per patient has been developed. The Senegalese kits detect both current and

previous infections though antigens in saliva or antibody withing a period of approximately 10 minutes. Ghana also developed innovative testing technology of “pool testing” where multiple blood samples are tested. A follow-up individual test is only done if the multiple samples give positive results (Laurencin &McClinton, 2020)^[8].

The findings also reveal that the mean COVID-19 case recovery, in Africa is not statistically different from that of Europe, Americas, and Oceania (including selected Mediterranean) regions at 95% confidence level. Also, the mean recovery rates in all the regions are not statistically different. The Africa case fatality rate is not statistically different from Americas. It implies that under the same conditions, if number of infections in Africa increased to match cases in Europe and America, the number of case recoveries will be corresponding.

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