Populational Level Driving Force of COVID-19 Epidemic and Fatality: A Global Analysis

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Abstract

Background

The COVID-19 has become a pandemic worldwide. 216 countries and regions reported their occurrence of COVID-19 cases by 19th Sep 2020. Meanwhile, the COVID-19 had infected more than 30 million people and caused almost one million deaths until 19th Sep 2020.

Method

We scoped data related to reported epidemic durations, incidences, fatalities, and epidemic risk factors of the studied countries. Disease Development Speed (DDS), Population-Level Incidence (PLI), and Case-Fatality Rate (CFR) were calculated to assess the COVID-19 pandemic globally. The Spearman rank correlation was applied to further explore the relationship among DDS, PLI, CFR, and their influencing factors.

Result

216 countries and regions had reported their COVID-19 cases by 19th Sep 2020. Globally, the medians of epidemic duration, DDS, PLI, and CFR were 167 days (IQR: 158-175 days; Range: 110-221 days), 4.6 (IQR: 3.1-6.0; Range: 1.8-10.1), 17.0 (IQR: 5.3-56.0; Range: 0.36-1758.3), and 2.2% (IQR: 1.3%-3.5%) respectively. DDS, PLI, and CFR were found enjoying positive correlations with the urban population proportion, UHC (Universal Health Coverage) service coverage, the population with basic handwashing facilities at home, the number of reported deaths, and the number of doctors and nurses.

Conclusion

Nationwide development of the COVID-19, its incidence and fatality suggested regional similarity in the world. National population structure, human resources of medical staff, structure of national health expenditure, and the sanitation facility were revealed as vital risk factors for the COVID-19 in epidemiology.

Background

Globally, SARS-CoV-2 has infected more than 30 million people and caused almost one million deaths until 19th Sep 2020. The incidence and fatality rate of this world pandemic were widely reported with regional disparities [1, 2]. Previous studies indicated that age and co-morbidities were key risk factors for the incidence and fatality of the COVID-19 pandemic [3–7]. Meanwhile, other risk factors might also include the urbanisation, medical capacities, public health measures adopted and the prevalence of underlying diseases [8–12]. However, limited numbers of studies explored these risk factors of the incidence and fatality rate of the COVID-19 pandemic at a population level. Therefore, this research analysed the correlation among incidence, fatality and their risk factors. Additionally, we investigated the

development speed of the pandemic in each country. This research has a wider implication providing evidence-based suggestion in disease control of the COVID-19.

Methods

Data collection and stratification

Countries with over 1,000 and over 10,000 COVID-19 cases until 19th Sep 2020 were included for analysis separately. According to previous researches [1, 8–13], we included 21 measures subjected to 4 types in this study: population, medical capacity, national health structure, and prevalence of the underlying disease. Data in this study were obtained from the World Health Organization (WHO), World Bank and the Institute for Health Metrics and Evaluation (IHME) [14–16] (Supplement 1, 2).

Definition of indicators

The included countries in this study were classified by WHO regions (AFRO, AMRO, EMRO, EURO, SEAR, and WPRO) (Supplement 3). The epidemic durations of all included countries were divided into 4 temporal stages (Stage I: 150 days, Stage II: 151–180 days, Stage III: 181–210 days, Stage IV > 210 days), based on data temporal extension. Additionally, we measured the epidemic of the COVID-19 by three Epidemiologically-relevant features (Epi-features): Disease Development Speed (DDS), Population-Level Incidence (PLI), and Case-Fatality Rate (CFR) [17] (Supplement 4).

Statistical analysis

The skewed variables were presented as median value (IQR: 25th – 75th percentiles), and the categorical variables were presented as numbers and percentages. Spearman's rank correlation coefficient was applied to assess the correlation between outcome indicators (DDS, PLI and CFR) and variables of risk factors. Simple linear regression analysis was used to identify possible correlations between variables. All analyses were carried out in RStudio (Version 1.2.1335).

Result

Overall, 216 countries and regions globally had reported COVID-19 cases by 19th Sep 2020. 69.9% (151) countries reported over 1,000 cases, 39.4% (85) countries reported over 10,000 cases, and 13.0% (28) countries reported over 100,000 cases nationwide. The median of the epidemic duration worldwide was 167 days (IQR: 158–175 days; Range: 110–221 days). Besides, the medians of DDS, PLI, and CFR were 4.6 (IQR: 3.1–6.0; Range: 1.8–10.1), 17.0 (IQR: 5.3–56.0; Range: 0.36–1758.3), and 2.2% (IQR: 1.3%–3.5%) respectively. The distributions of DDS, PLI, and CFR of different countries are displayed in Fig. 1.

The DDS and Epidemic Duration

Countries with epidemic duration lasted to Stage IV were the United States of America (USA) (10.1), China (6.0), Japan (5.6), Republic of Korea (4.3), and Thailand (2.7). These 5 countries were also the first few

countries reported the COVID-19 case at the beginning of the world pandemic. Among countries with an epidemic duration of Stage III, India (9.5) and Russia Federation (8.4) had the top 2 highest DDSs, while Sri Lanka (2.7) had the lowest DDS. Besides, Brazil (9.9) and Tajikistan (4.4) had the highest DDSs as countries with epidemic duration subjected to Stage II and Stage I, respectively.

As a whole, AFRO countries had the lowest median value of the DDS. In addition, most AFRO countries are subjected to in Stage I and Stage II of the epidemic duration. The AMRO countries had the broadest range of DDSs and the highest median value of the DDS. Besides, most AMRO countries' epidemic duration remained in the Stage II, while only the USA and Canada entered the Stage IV.

The PLI and Epidemic Duration

Among countries with Stage IV epidemic duration, USA had a significantly high PLI (164.3), while the rest of the countries are all from Asia, with PLIs under 10 (Japan: 4.6, Korea:3.1, China:0.6, and Thailand:0.5). Most countries with Stage III epidemic duration belong to EURO (PLI:14.1–82.8), while the rest classified as SEARO and WPRO countries generally had PLIs smaller than 21, except Singapore (PLI: 98.1). For those only had a Stage II epidemic duration, countries with over 100 in PLIs included 4 EMRO countries (Qatar: 408.4, Bahrain: 289.9, Kuwait: 184.1, and Oman:156.0), 4 AMRO countries (Chile:205.2, Panama:194.4, Peru:166.6, and Brazil:159.2), and 7 EURO countries (Norway:1758.2, Czechia:170.9, Armenia:142.2, Andorra:131.2, Luxembourg:121.0, Maldives:115.9, Israel:105.0). All countries with epidemic duration within Stage I had PLIs below 20 (0.6–13.4).

Besides, countries of AMRO and EURO commonly had higher PLIs, while countries belong to AFRO and WPRO usually had lower PLIs. The national PLIs' disparities were obvious in AMRO, EMRO, and EURO regions, but unclear in AFRO, SEARO, and WPRO regions.

The CFR and Epidemic Duration

Except China (CFR: 0.052), all other Stage IV countries' CFRs were below 0.05 (USA: 0.031, Japan: 0.020, Korea: 0.019, and Thailand: 0.017). They were much smaller than the CFRs for those Stage III countries (France: 0.139, Italy: 0.139, United Kingdom: 0.129, Belgium: 0.126, Spain: 0.079, Canada: 0.074, Sweden: 0.070). Among Stage III and Stage IV countries, 10 of 12 countries with CFRs below 0.02 came from SEARO and WPRO regions. Most Stage II countries had lower CFRs. There were 9 countries of them had CFRs higher than 0.05 (Hungary: 0.123, Mexico: 0.108, Netherlands: 0.096, Ireland: 0.065, Sudan: 0.064, Liberia: 0.064, Ecuador: 0.059, Niger: 0.059, and Andorra: 0.052). Almost all countries with only Stage I epidemic duration had CFRs less than 0.05, except Yemen (0.0284).

The medians of CFRs in AMRO and EURO countries were both higher than 0.02, while the medians of CFRs in the rest 4 regions were relatively lower. The CFRs in EURO countries disparate most significantly. In contrary, CFRs of countries in WPRO regions distributed most evenly among the 6 regions.

The Correlation between Risk Factors, DDS, PLI, and CFR

Table 1

Spearman rank correlations between the risk factors and the incidence, fatality, and the DDS among countries with over 1,000 cases (n = 151) and 10,000 cases (n = 85) by 19th Sep 2020

Risk factor		DDS		PLI		CFR	
		r	p	r	p	r	p
DDS		-	-	0.601	< 0.001***		
CFR		0.170	0.040*	-0.030	0.710	-	-
<i>Number of reported deaths</i>		0.908	< 0.001***	0.475	< 0.001***	0.521	< 0.001***
Population	<i>Total Population</i>	0.547	< 0.001***	-0.270	< 0.001***	0.268	< 0.001***
	<i>Population density</i>	0.097	0.240	0.011	0.900	-0.073	0.380
	<i>Proportion of the elderly population (> 65)</i>	0.187	0.020*	0.301	< 0.001***	0.283	< 0.001***
	<i>Proportion of urban population</i>	0.256	0.002**	0.528	< 0.001***	-0.014	0.870
Medical capacity	<i>Current health expenditure</i> <i>(% of GDP)</i>	-0.007	0.930	0.183	0.030*	0.367	< 0.001***
	<i>UHC service coverage index</i>	0.312	< 0.001***	0.455	< 0.001***	0.138	0.100
	<i>Number of Hospital Beds</i>	0.103	0.210	0.328	< 0.001***	0.070	0.400
	<i>Number of doctors</i>	0.213	0.010*	0.464	< 0.001***	0.116	0.160
	<i>Number of nurses</i>	0.677	< 0.001***	0.177	0.030*	0.252	< 0.001***
	<i>Out-of-pocket expenditure</i> <i>per capita</i>	-0.034	0.690	-0.225	0.010**	0.010	0.910
National health expenditure structure	<i>Smoking prevalence</i>	0.027	0.770	0.122	0.180	0.120	0.190

Risk factor		DDS		PLI		CFR	
		r	p	r	p	r	p
	<i>Population with basic handwashing facilities at home (%)</i>	0.476	< 0.001***	0.560	< 0.001***	0.020	0.870
	<i>Risk Communication</i>	0.200	0.020*	0.226	0.010**	-0.011	0.900
	<i>Human Resources</i>	0.232	0.010**	0.114	0.170	0.109	0.200
	<i>Surveillance</i>	0.275	< 0.001***	0.126	0.130	0.276	< 0.001
	<i>National Health Emergency Framework</i>	0.353	< 0.001***	0.276	< 0.001***	0.185	0.030*
Prevalence of underlying diseases	<i>Chronic Respiratory Diseases</i>	0.083	0.320	0.307	< 0.001***	0.257	0.002**
	<i>Cardiovascular Diseases</i>	0.177	0.030*	0.354	< 0.001***	0.271	< 0.001***
	<i>Diabetes Mellitus</i>	0.087	0.290	0.389	< 0.001***	0.111	0.180
	<i>Neoplasms</i>	0.192	0.020*	0.391	< 0.001***	0.239	0.003**
	<i>Respiratory infections & tuberculosis</i>	-0.107	0.190	-0.344	< 0.001***	-0.171	0.040*

The Spearman rank correlation was applied to detect the relationship among DDS, PLI, and CFR and the risk factors. The result of the Spearman rank correlation was summarized in Table 1. The number of nurses ($r = 0.677$, $p < 0.001$) had strong positive correlations with the DDS. The total population ($r = 0.547$, $p < 0.001$) and the population with basic handwashing facilities at home ($r = 0.476$, $p < 0.001$) had moderately positive correlations with the DDS. Urban population proportion ($r = 0.528$, $p < .001$), UHC service coverage ($r = 0.455$, $p < 0.001$), the number of doctors ($r = 0.464$, $p < .001$), and the population with basic handwashing facilities at home ($r = 0.560$, $p < .001$) had moderately positive correlations with the PLI. Besides, other indicators had weakly ($0.20 < r < 0.39$) or very weakly ($r \leq 0.20$) positive correlations with PLI, DDS, and CFR. However, some indicators had weakly negative correlations with the measurements: total population and PLI ($r = -0.270$, $p < 0.001$), out-of-pocket expenditure and PLI ($r = -0.225$, $p = 0.01$), respiratory infections & tuberculosis and PLI ($r = -0.344$, $p < 0.001$), respiratory infections & tuberculosis and the CFR ($r = 0.171$, $p = 0.04$).

Overall, the DDS had strong positive correlation with PLI, but very weakly positive correlation with the CFR. Besides, the DDS also had strong positive correlation with the number of reported deaths. It was very likely that the PLI had no correlation with the CFR, but a moderately positive correlation with the number of reported deaths. Moreover, the CFR had moderately positive correlation with the number of reported death.

Discussion

Among countries entering Stage III, higher CFRs were mostly seen in European countries (i.e. France, Italy, and Spain), while lowest CFRs were found in some Asian countries (i.e. Singapore and Thailand). Some low-CFR countries shared similar control measures and medical system characteristics, including mass tests, strict social distancing measures, and free medical services for diagnosed COVID-19 patients [18–19]. A brief description of policy in different countries was shown in Supplement 5.

Of note, among countries with DDS over 0.05, substantial differences in CFRs were observed (CFR > 0.10: France, the United Kingdom, Italy, and Belgium versus CFR < 0.05: Russia, Turkey, Peru, and Germany). In addition to delayed social distancing measures [20–22], other influencing factors include higher elderly population proportions, more stringent symptom-based testing policies (i.e. in Italy and United Kingdom) [23–24], insufficient medical resources, and exceeded surge capacity due to rapidly increasing COVID patients in the former group of countries [25–26]. Germany and Turkey had lower CFRs mainly because they adopted extensive testing strategies, effective social distancing measures, and well-prepared health system [27–28]. Russia also stood out with a rather low CFR partly due to their 'early detection and early treatment' strategy implemented nationally as well as the relatively lower prevalence of co-morbidities in Russia [29]. Experiences in these countries provide important implications for other countries to control the COVID-19 pandemic.

Besides, higher urbanization might expect a higher PLI and maybe a higher DDS. Urban dwellers may have frequent social activities in dense places which is more difficult to control, but they are more likely to access better medical facilities. Population density was not significantly associated with higher incidence and DDS. This may be raised due to the national data only represented country-level population density, whereas urban population density is much higher. More granular data are however warranted to confirm these associations. In terms of correlations of PLIs and CFRs, the elderly (age > 65) proportion, the cardiovascular diseases and diabetes mellitus were found positively correlated. These findings are consistent with earlier evidences suggesting that the elderly and individuals with underlying conditions were more likely to be infected by COVID-19. The virus was especially fatal among these sub-groups [30].

The limitation of this report is lacking of deep discussion on potential confounding by multivariable analyses. As limited by the manuscript type, the multivariable linear regression model is demonstrated in the Supplement 6.

Conclusion

In the population level, regional similarity was found among DDSs, PLIs, and CFRs of different countries with same epidemic durations. Total population and urban population nationwide, human resources of medical staff (doctor and nurse), the UHC coverage and out-of-pocket expenditure in health care, the population with basic handwashing facilities at home, and the national prevalence of respiratory infections & tuberculosis were key risk factors for the epidemic of the COVID-19, in its incidence, fatality, and disease development.

Abbreviations

AFRO: Africa Region

AMRO: American Region

CFR: Case-Fatality Rate

COVID-19: Coronavirus Disease 2019

DDS: Disease Development Speed

EMRO: Eastern Mediterranean Region

Epi-features: Epidemiologically-relevant Features

EURO: European Region

IHME: Institute for Health Metrics and Evaluation

IQR: Interquartile Range

PLI: Population-Level Incidence

SEAR: South-East Asia Region

UHC: Universal Health Coverage

USA: United States of America

WHO: World Health Organization

WPRO: Western Pacific Region

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

All au-authors have went through the manuscript and agreed for publication.

Availability of data and material

The data will be shared upon reasonable request to the corresponding author.

Competing interests

The authors declare no competing interests.

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Authors' contributions

ZW, YX, DW, and LZ contributed equally to this report. ZW, YX, DW, LZ, and WT designed the study, ZW, YX collected and cleaned the data, LZ and HL analyzed the data, ZW, DW and LZ interpreted the data, ZW, DW, GM, LZ, and WT revised the manuscript. All authors reviewed and approved the final manuscript.

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Figures

Figure 1

A: Disease development speed of the COVID-19 worldwide (216 countries in total) by 19th Sep 2020. Figure 1A shows the distribution of the epidemic development rate for each country or region in different continents. The horizontal axis was the number of days since the country reported the first COVID-19

case, and the vertical axis was the log rate. The log rate was defined as the logarithm transformation for the number of cases accumulated divided by the days from the first day of reporting to the due date. B: Fatality distribution of the COVID-19 worldwide (216 countries in total) by 19th Sep 2020 Figure 1B shows the distribution of the fatality rate for each country or region in different continents. The horizontal axis was the number of days since the country reported the first COVID-19 case, and the vertical axis was the fatality rate. C: The relationship between disease development speed and the fatality rate of the COVID-19 (216 countries in total) by 19th Sep 2020. Figure 1C shows the relationship between disease development speed and the fatality rate. The horizontal axis was the log rate, and the vertical axis was the fatalities. The log rate was defined as the logarithm transformation for the number of cases accumulated divided by the days from the first day of reporting to the due date.

Figure 2

Policy distributions, reported COVID-19 cases, and the epidemic duration among countries with top 10 confirmed COVID-19 cases.

Supplementary Files

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