J PREV MED HYG 2021; 62: E261-E269 OPEN ACCESS

Research paper

The association between various indicators of hospital capacity, age category, and the number of screening tests performed with case fatality rate and recovery rate during the COVID-19 disease pandemic

MORTEZA ABDULLATIF KHAFAIE[1], AMAL SAKI MALEHI[2], FAKHER RAHIM[3*]
[1] Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran;
[2] Department of Biostatistics and Epidemiology, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran; [3] Research Center of Thalassemia & Hemoglobinopathy, Health Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Keywords

COVID-19 • Case fatality rate (CFR) • Recovery rate (RR) • Hospital resource allocation

Summary

Background. *The COVID-19-related deaths are growing rapidly around the world, especially in Europe and the United States.*
Purpose. *In this study we attempt to measure the association of these variables with case fatality rate (CFR) and recovery rate (RR) using up-to-date data from around the world.*
Methods. *Data were collected from eight global databases. According to the raw data of countries, the CFR and RR and their relationship with different predictors was compared for countries with 1,000 or more cases of COVID-19 confirmed cases.*
Results. *There were no significant correlation between the CFR and number of hospital beds per 1,000 people, proportion of population aged 65 and older ages, and the number of computed tomography per one million inhabitants. Furthermore, based on the continents-based subgroup univariate regression analysis, the population (R^2 = 0.37, P = 0.047), GPD (R^2 = 0.80, P < 0.001), number of ICU Beds per 100,000 people (R^2 = 0.93, P = 0.04), and number of CT per one million inhabitants (R^2 = 0.78, P = 0.04) were significantly correlated with CFR in America. Moreover, the income-based subgroups analysis showed that the gross domestic product (R^2 = 0.30, P = 0.001), number of ICU Beds per 100,000 people (R^2 = 0.23, P = 0.008), and the number of ventilator (R^2 = 0.46, P = 0.01) had significant correlation with CFR in high-income countries.*
Conclusions. *The level of country's preparedness, testing capacity, and health care system capacities also are among the important predictors of both COVID-19 associated mortality and recovery. Thus, providing up-to-date information on the main predictors of COVID-19 associated mortality and recovery will hopefully improve various countries hospital resource allocation, testing capacities, and level of preparedness.*

Introduction

Since the first suspected case of coronavirus-2019 disease (SARS-CoV-2/COVID-19) on December 1, 2019, in Wuhan, Hubei Province, China, a total of 4,012,857 confirmed cases and 276,216 deaths in 212 countries and territories have been reported by May 9, 2020 [1]. The COVID-19-related deaths are growing rapidly around the world, especially in Europe and the United States. Case Fatality Rate (CFR) is a measure of the ability of a pathogen or virus to infect or harm a host in infectious disease and is described as the mortality rate in a given population. Globally, the overall CFR for COVID-19 disease estimated by researchers was 3.6-4.3% [2]. There is a disparity in tactics against COVID-19 disease, which different countries used in various protocols and procedures [3]. The US government does not recommend more than 10 people gathered, but San Francisco has ordered everyone to stay home. Italy, France, and Spain, while police or the army are patrolling in some areas, have almost completely shut down their populations, but at the same time, public places were open in the UK. Like many other countries, Germany has closed its schools, but schools are open to children in Sweden.
The capacity of hospitals has long been exhausted, and medical staffs are forced to make annoying choices about who to treat and who will be saved [4]. In today's world, information guides the health care system, and the realization of this depends on the existence of accurate data and reliable information provided from various sources. Hospital indicators are one of the most important tools for measuring the efficiency and productivity of a health care service, which is collected and analyzed correctly; they play an important role in decision making and quality control of services [5]. The intensive care unit (ICU) is one of the essential and vital pillars of hospitals, which provides care to patients with severe and life-threatening conditions. Patients with severe acute respiratory infections due to COVID-19 disease may need supplemental oxygen and mechanical respiratory support. Thus, the higher the number of beds and care equipment in the intensive care unit, the lower the mortality rate in patients with COVID-19 [6, 7]. Computed tomography (CT) scans of the chest in patients

with COVID-19 are usually considered as a tool that can be very helpful in diagnosing the disease in its early stages [8]. Moreover, people of any age can be severely infected with the COVID-19, although it is more common in middle-aged and older adults, especially people older than 60 years [9]; thus, experts believe that age distribution can also play a key role in increased mortality rates.

Considering the importance of CFR and recovery rate (RR), as well as the relationship between these two variables with the number of beds in hospitals and intensive care units, the number of ventilators, the number of CT-scan apparatuses, gross domestic product (GDP), the percentage of people over the age of 60, and the number of screening tests performed during a COVID-19 disease pandemic, in this study, we attempt to measure the association of these variables with CFR and RR using up-to-date data from around the world.

Materials and methods

Data collection

Data were collected from global databases such as World meter [10], WHO [11], the Centers for Disease Control and Prevention (CDC) [12], and the Weekly Report on Complications and Deaths (prepared by the Centers for Disease Control and Prevention), based on the user guide, data sources for disease registration [13]. Due to the rapid increase in data, the analysis in this study was conducted on April 10, 2020. According to the raw data of countries, the CFR and RR and their relationship with the number of beds in hospitals and intensive care units, the number of ventilators in hospitals, the number of CT scans, the gross domestic product (GDP), the number of screening tests performed during an epidemic was compared for countries with 1000 or more cases of COVID-19 confirmed cases [2].

The number of beds in hospitals and intensive care units, the number of ventilators in hospitals, the number of CT scans, the gross domestic product (GDP), the number of screening tests performed during an epidemic were collected from American Hospital Association (AHA) fact sheet (*https://www.aha.org/statistics/fast-facts-us-hospitals*), Critical Care Statistics (*https://www.sccm.org/Communications/Critical-Care-Statistics*), Wikipedia (*https://en.wikipedia.org/wiki/List_of_countries_by_hospital_beds*), research data and infografics from Statista (*https://www.statista.com/chart/21105/number-of-critical-care-beds-per-100000-inhabitants/*) and WHO reports.

Calculate the case fatality rate (CFR) and recovery rate (RR)

The case fatality rate and recovery rate were calculated from the following formulas:

CFR = (Total number of deaths due to COVID-19 / Total number of cases of disease) * 100

RR = (Total number of cases recovered from COVID-19 / Total number of cases of the disease) * 100

Methods

Based on currently observed parameters we provide insights into the association between various indicators of healthcare systems and COVID-19 results (death or recovery) in global level. So, firstly the univariate regression analysis was performed based on these expletory variables. Furthermore, to assess the simultaneous impact of different risk indicators on the CFR, multiple regression model was fitted using all significant factors in prior step.

Statistical analysis

Linear regression analysis was performed to assess the association between recovery rate and case fatality rate as dependent variables and GPD, population, number of ICU beds, proportion of population aged 65 and older ages, number of ventilators, number of total COVID-19 tests, number of total COVID-19 tests per 1 M population and number of hospital beds as explanatory variables. Regard this process, firstly the univariate model was fitted with all the explanatory variables. Furthermore, based on the univariate findings, to assess the simultaneous impact of different explanatory variables on the recovery rate and case fatality rate, multiple linear regression model was fitted using all significant factors in prior step. However, due to the existence of a correlation between the independent variables (multicollinearity) the Ridge regression model was implemented. Since, the multicollinearity lead to definitely serious problems such as makes it hard to interpret the coefficients in multiple regression, and it reduces the power of the model to identify independent variables that are statistically significant. Furthermore, subgroup analysis was conducted based on country's origin (continent) and class of the country's economy (based on The World Bank classifies). The graphs were also plotted using the scatter plot. Data were analyzed using SPSS 22 and Stata 12. A p-value of less than 0.05 was considered to be significant.

Results

Table I showed all the data about the GDP, number of hospital beds per 1,000 people, number of ICU beds per 100,000 people, number of ventilators, % population of ≥ 65 years age, number of computed tomography apparatus per one million people, with CFR and RR of COVID-19 infection among countries with more than 1,000 infected cases.

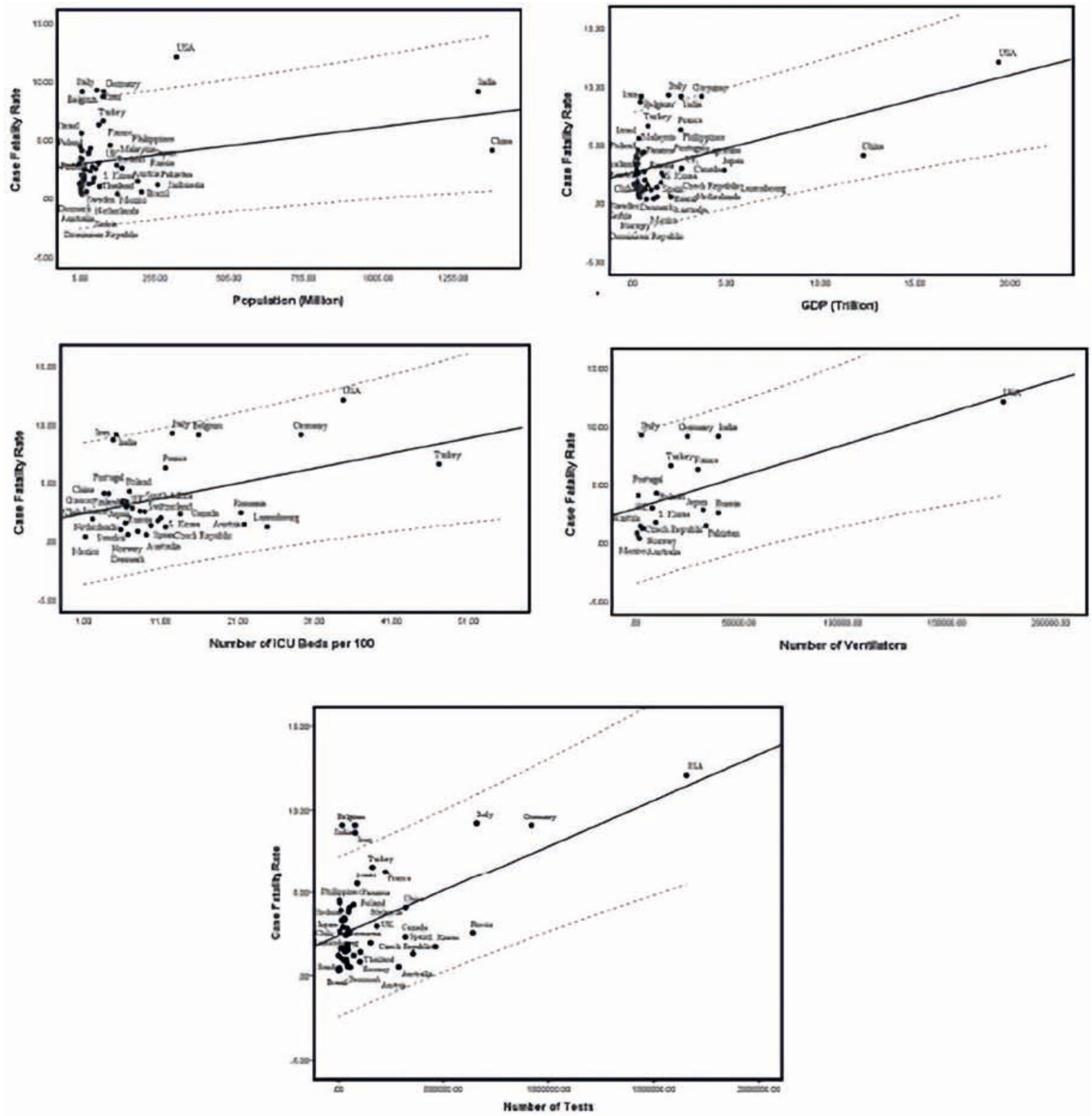
There were no significant correlations between the CFR and the number of hospital beds per 1,000 people, the proportion of population aged 65 and older, and the number of CT per one million inhabitants (Fig. 1). However, CFR was positively correlated to the country's GPD, population, number of ICU beds per 100 individuals, number of ventilators, and total COVID-19 tests performed (Fig. 1).

Furthermore, to assess the simultaneous impact of different risk indicators on the CFR, the ridge regression model was fitted using all significant variables in theunivariate regression model (Fig. 1). Based on ridge regression

Tab. I. Comparison of population, GDP, number of hospital beds per 1,000 people, number of ICU beds per 100,000 people, number of ventilators, % population of ≥ 65 years age, number of computed tomography apparatus per one million people, with case fatality and recovery rates of COVID-19 infection among countries with more than 1,000 infected cases.

Country [reference]	Population (million)	GDP (trillion)	Number of hospital beds per 1,000 people	Number of ICU beds per 100,000 people	Number of ventilators	Total cases	Total deaths	Total recovered	Case fatality rate	Recovery rate	% population ages 65 and older	Number of CT per 1 million inhabitants	Number of tests
USA [14]	327.2	19.39	2.77	34.7	177,000	245,373	6,095	10,403	12.07	4.24	16%	44.390	1,654,409
Italy [15]	60.48	1.935	3.18	12.5	3,000	115,242	13,915	18,278	9.23	15.86	22.4%	34.710	657,224
Spain[15]	46.66	1.311	2.97	9.7	NR	112,065	10,348	26,743	1.31	23.86	19.1%	18.590	355,000
China [16]	1,386	12.24	4.34	3.6	NR	84,794	1,107	22,440	4.07	26.46	11.9%	NR	320,000
Germany [15]	82.79	3.677	8.00	29.2	25,000	81,620	3,322	76,571	9.11	93.81	21.1%	35.130	918,460
France [15]	66.99	2.583	5.98	11.6	30,000	59,105	5,387	12,428	6.26	21.03	20.3%	17.690	224,254
Iran [17]	81.16	0.4395	1.5	4.8	NR	50,468	3,160	16,711	8.66	33.11	6.1%	NR	80,000
UK [15]	66.44	2.622	2.54	6.6	8,175	33,718	2,921	135	2.96	0.40	18.3%	NR	183,190
Switzerland [15]	8.57	0.6789	4.53	11.0	NR	19,106	565	4,846	1.96	25.36	18.3%	39.280	153,440
Turkey [15]	80.81	0.8511	2.81	47.1	17,000	18,135	356	415	6.59	2.29	8.8%	14.770	161,380
Belgium [15]	11.4	0.4927	5.76	15.9	NR	15,348	1,011	2,495	9.11	16.26	18.7%	NR	18,360
Netherlands [15]	17.18	0.8262	3.32	6.4	NR	14,697	1,339	250	1.53	1.70	18.9%	13.480	46,810
Austria [15]	8.822	0.4166	7.37	21.8	2,500	11,283	173	1,979	1.41	17.54	18.8%	28.640	104,134
S. Korea [16]	51.4	1.531	12.27	10.6	9,795	11,238	158	2,022	1.73	17.99	15.1%	38.180	461,233
Canada [18]	37.59	1.653	2.52	13.5	NR	10,062	174	6,021	2.31	59.84	17.2%	15.510	317,972
Portugal [15]	10.29	0.2176	3.39	4.2	1,400	9,034	209	68	4.05	0.75	20.7%	NR	52,086
Brazil	209.3	2.056	2.3	NR	NR	8,066	327	127	0.51	1.57	8.5%	NR	58,824
Israel	8.712	0.3509	3.02	NR	NR	7,030	36	338	5.53	4.81	NR	9.690	90,394
Australia	24.6	1.323	3.84	9.1	1,314	5,568	308	103	0.52	1.85	15.8%	67.200	286,786
Sweden	10.12	0.538	2.22	5.8	NR	5,350	28	585	0.96	10.93	19.6%	17.280	36,900
Norway	5.368	0.3988	3.6	8	800	5,218	50	32	0.82	0.61	17.2%	NR	101,986
Czech Republic [15]	10.65	0.2157	6.63	11.6	3,529	4,149	34	281	1.19	6.77	19.6%	15.670	74,170
Russia [19]	144.5	1.578	8.05	8.3	40,000	3,869	46	71	2.55	1.84	14.6%	13.640	639,606
Ireland	4.83	0.3337	2.96	6.5	NR	3,849	98	5	3.35	0.13	NR	20.500	30,213
Denmark	5.603	0.3249	2.61	6.7	NR	3,672	123	1,089	0.53	29.66	19%	39.780	45,270
Malaysia	31.62	0.3145	1.9	NR	NR	3,404	18	335	3.79	9.84	6.4%	NR	49,570
Chile	18.05	0.2771	2.2	2.11	NR	3,163	120	65	1.87	2.06	11.8%	24.270	44,130
Ecuador	16.62	0.1031	1.50	NR	NR	3,149	59	56	1.60	1.78	NR	NR	10,317
Philippines	104.9	0.3136	1.0	NR	NR	3,116	50	767	4.51	24.61	5.1%	NR	5,530
Poland [15]	37.98	0.5245	6.62	6.9	10,100	3,018	136	52	4.24	1.72	17.5%	16.880	72,901
Romania	19.53	0.2118	6.3	21.4	NR	2,738	116	267	2.41	9.75	18.2%	NR	36,092
Japan [16]	126.8	4.872	13.05	7.3	32,586	2,617	63	472	2.80	18.04	26%	111.490	42,882
Luxembourg	0.613	0.625	4.66	24.8	NR	2,567	72	192	1.21	7.48	14.4%	16.450	NR
Pakistan	197	0.305	0.6	NR	34,000	2,487	30	80	1.43	3.22	4.3%	NR	32,930
India	1,339	2.597	0.53	5.2	40,000	2,450	35	126	9.11	5.14	6.1%	NR	79,950
Thailand	69.04	0.4552	2.1	NR	NR	1,986	181	134	0.96	6.75	11.5%	NR	23,669
Indonesia	264	1.016	1.2	NR	NR	1,978	19	581	1.11	29.37	5.6%	NR	7,896
Saudi Arabia	32.94	0.6838	2.7	NR	NR	1,885	21	328	1.18	17.40	NR	NR	NR
Finland	5.513	0.2519	3.28	6.1	NR	1,615	19	300	3.43	18.58	20.3%	24.510	29,000
Greece	10.74	0.2003	4.24	6.0	NR	1,544	53	61	3.31	3.95	19%	34.220	15,961
South Africa [20]	56.72	0.3494	2.8	8.9	NR	1,510	50	633	2.51	41.92	6.0%	NR	50,361
Mexico	129.2	1.15	1.38	1.2	2,050	1,475	37	9	0.34	0.61	7.2%	5.83	9,481
Peru	32.17	0.2114	1.6	NR	NR	1,462	5	95	3.89	6.50	8.4%	NR	12,669
Panama	4.099	0.6184	2.3	NR	NR	1,414	55	537	4.35	37.98	NR	NR	7,333
Dominican Republic	10.77	0.7593	1.6	NR	NR	1,380	60	16	0.30	1.16	3%	NR	NR
Iceland	0.3642	0.2391	2.96	6.5	NR	1,319	4	284	2.92	21.53	14.2%	20.500	23,640
Argentina	44.27	0.6374	5.0	NR	NR	1,265	37	256	2.65	20.24	11.4%	NR	7,385
Colombia	49.07	0.3092	1.7	NR	NR	1,171	31	42	1.64	3.59	11.4%	1.300	23,760
Serbia	7.022	0.4143	5.7	NR	NR	1,161	19	55	0.45	4.74	20.2%	NR	5,008
Singapore	5.612	0.3239	2.4	NR	NR	1,114	5	266	0.78	23.88	NR	NR	39,000
World	**7,530**	**80.68**	----	-----	-----	**1,019,354**	**53,322**	**214,358**	**2.48**	**21.03**	-----	-----	

Fig. 1. Case fatality rate against the population ($R^2 = 0.09$, $P = 0.035$), the country's gross domestic product (GDP) (in trillion) ($R^2 = 0.22$, $P = 0.001$), the number of intensive care unit (ICU) beds per 100 individuals ($R^2 = 0.17$, $P = 0.016$), and the number of ventilators ($R^2 = 0.38$, $P = 0.007$), and the number of screening tests performed ($R^2 = 0.31$, $P < 0.001$). Lines represent linear regression analysis together with 95% confidence intervals around the line.



Tab. II. The result of multiple ridge regression of the association of variables of interest with CFR.

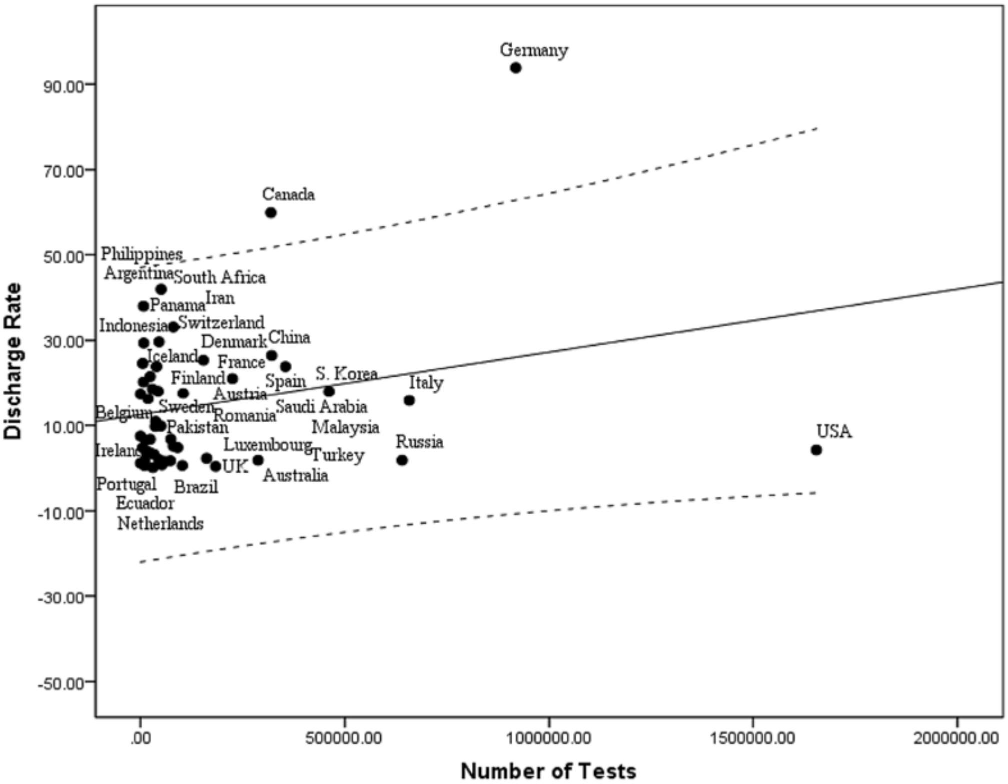
Variables	Standardized beta	SE	P-value	R^2
GPD	0.36	0.002	0.08	0.66
Population	0.38	0.46	0.51	
Number of ICU beds per 100 individuals	0.47	0.079	0.10	
Number of ventilators	0.15	< 0.0001	0.83	
Number of total COVID-19 tests	-0.24	< 0.0001	0.63	

results, these variables simultaneously were not significant, albeit the R^2 was impressive in multiple regression (Tab. II). Furthermore, based on the continents-based subgroup univariate regression analysis, the population ($R^2 = 0.37$, $P = 0.047$), GPD ($R^2 = 0.80$, $P < 0.001$), number of ICU Beds per 100,000 people ($R^2 = 0.93$, $P = 0.04$), and number of CT per one million inhabitants ($R^2 = 0.78$, $P = 0.04$) were significantly correlated with CFR in America, which means these variables could be main predictors of CFR in America. In Asia and Europe, there was no significant correlation between the CFR and most of the variables; however, the number of CT per one million inhabitants ($R^2 = 0.37$) was an important predictor when compared to other variables in Asia, and the GPD ($R^2 = 0.30$) was the main predictors of CFR in Europe (Tab. III). Moreover, the income-based subgroups analysis showed that the

Tab. III. The result of subgroup analysis of the association of variables of interest with CFR.

Continents	Variables	Standardized beta	R^2	P-value
America (n = 11)	**Population (million)**	**0.61**	**0.37**	**0.047**
	GDP (trillion)	**0.89**	**0.80**	**< 0.001**
	Number of hospital beds per 1,000 people	0.26	0.07	0.44
	Number of ICU beds per 100,000 people	**0.96**	**0.93**	**0.04**
	Number of ventilators	----	----	----
	% population ages 65 and older	0.58	0.34	0.10
	Number of CT Per 1 million inhabitants	**0.89**	**0.78**	**0.046**
	Number of COVID-19 tests	0.40	0.16	0.23
	Number of COVID-19 tests per 1 M population	0.11	0.01	0.74
Asia (n = 14)	Population (million)	0.39	0.15	0.17
	GDP (trillion)	0.07	0.005	0.81
	Number of hospital beds per 1,000 people	-0.24	0.056	0.42
	Number of ICU beds per 100,000 people	0.11	0.012	0.72
	Number of ventilators	0.32	0.11	0.59
	% population ages 65 and older	-0.39	0.15	0.22
	Number of CT Per 1 million inhabitants	-0.61	0.37	0.39
	Number of COVID-19 tests	0.21	0.044	0.47
	Number of COVID-19 tests per 1 M population	0.09	0.008	0.77
Europe (n=23)	Population (million)	0.38	0.14	0.77
	GDP (trillion)	0.55	0.30	0.27
	Number of hospital beds per 1,000 people	0.24	0.057	0.27
	Number of ICU beds per 100,000 people	0.31	0.094	0.16
	Number of ventilators	0.27	0.073	0.45
	% population ages 65 and older	0.40	0.16	0.06
	Number of CT Per 1 million inhabitants	0.29	0.088	0.25
	Number of COVID-19 tests	0.21	0.045	0.33
	Number of COVID-19 tests per 1 M population	-0.05	0.003	0.81
Africa (n = 1)	-----			
Australia (n = 1)	-----			
High income (n = 31)	Population (million)	0.19	0.036	0.31
	GDP (trillion)	**0.55**	**0.30**	**0.001**
	Number of hospital beds per 1,000 people	0.05	0.003	0.77
	Number of ICU beds per 100,000 people	**0.48**	**0.23**	**0.008**
	Number of ventilators	**0.68**	**0.46**	**0.01**
	% population ages 65 and older	0.034	0.001	0.87
	Number of CT Per 1 million inhabitants	0.04	0.002	0.86
	Number of COVID-19 tests	0.23	0.053	0.21
	Number of COVID-19 tests per 1 M population	0.01	< 0.001	0.95
Lower middle income (n = 15)	Population (million)	0.86	0.74	0.14
	GDP (trillion)	0.79	0.63	0.21
	Number of hospital beds per 1,000 people	-0.54	0.29	0.46
	Number of ICU beds per 100,000 people	0.87	0.75	0.13
	Number of ventilators	----	----	----
	% population ages 65 and older	0.67	0.45	0.33
	Number of CT Per 1 million inhabitants	----	----	----
	Number of COVID-19 tests	0.12	0.015	0.88
	Number of COVID-19 tests per 1 M population	-0.43	0.18	0.57
Upper middle income (n = 4)	Population (million)	-0.03	0.001	0.92
	GDP (trillion)	-0.22	0.047	0.44
	Number of hospital beds per 1,000 people	-0.098	0.01	0.73
	Number of ICU beds per 100,000 people	0.35	0.12	0.39
	Number of ventilators	0.23	0.054	0.85
	% population ages 65 and older	-0.24	0.055	0.42
	Number of CT Per 1 million inhabitants	0.72	0.52	0.28
	Number of COVID-19 tests	0.12	0.014	0.67
	Number of COVID-19 tests per 1 M population	-0.05	0.002	0.87

Fig. 2. Recovery rate (RR) against the number of tests. Lines represent linear regression analysis together with 95% confidence intervals around the line (R^2 = 0.06, P = 0.086).



Tab. IV. The result of subgroup analysis of the association of variables of interest with RR.

Continents	Variables	Standardized beta	R^2	P-value
America (n = 11)	Population (million)	-0.28	0.079	0.40
	GDP (trillion)	-0.11	0.012	0.75
	Number of hospital beds per 1,000 people	0.33	0.11	0.31
	Number of ICU beds per 100,000 people	0.08	0.006	0.93
	Number of ventilators	----	----	----
	% population ages 65 and older	0.63	0.38	0.07
	Number of CT Per 1 million inhabitants	-0.06	0.004	0.92
	Number of COVID-19 tests	-0.09	0.009	0.79
	Number of COVID-19 tests per 1 M population	0.15	0.02	0.66
Asia (n = 14)	Population (million)	0.031	0.001	0.91
	GDP (trillion)	0.26	0.069	0.37
	Number of hospital beds per 1,000 people	0.10	0.01	0.73
	Number of ICU beds per 100,000 people	-0.39	0.15	0.19
	Number of ventilators	-0.31	0.098	0.61
	% population ages 65 and older	0.06	0.004	0.86
	Number of CT Per 1 million inhabitants	0.76	0.58	0.24
	Number of COVID-19 tests	-0.04	0.001	0.90
	Number of COVID-19 tests per 1 M population	-0.43	0.19	0.12
Europe (n = 23)	Population (million)	0.24	0.055	0.28
	GDP (trillion)	**0.58**	**0.34**	**0.004**
	Number of hospital beds per 1,000 people	0.29	0.08	0.18
	Number of ICU beds per 100,000 people	**0.58**	**0.33**	**0.005**
	Number of ventilators	0.33	0.11	0.35
	% population ages 65 and older	0.29	0.08	0.19
	Number of CT Per 1 million inhabitants	**0.51**	**0.26**	**0.04**
	Number of COVID-19 tests	0.26	0.07	0.23
	Number of COVID-19 tests per 1 M population	-0.20	0.04	0.36

Tab. IV. The result of subgroup analysis of the association of variables of interest with RR.

Continents	Variables	Standardized beta	R^2	P-value
Africa (n = 1)	-----	-----	-----	-----
Australia (n = 1)	-----	-----	-----	-----
High income (n = 31)	Population (million)	0.097	0.009	0.61
	GDP (trillion)	0.06	0.004	0.75
	Number of hospital beds per 1,000 people	0.16	0.027	0.38
	Number of ICU beds per 100,000 people	**0.37**	**0.14**	**0.05**
	Number of ventilators	-.006	0.001	0.98
	% population ages 65 and older	0.12	0.015	0.54
	Number of CT Per 1 million inhabitants	0.036	0.001	0.87
	Number of COVID-19 tests	-0.015	0.001	0.94
	Number of COVID-19 tests per 1 M population	-0.19	0.034	0.32
Lower middle income (n = 15)	Population (million)	-0.51	0.26	0.49
	GDP (trillion)	-0.33	0.11	0.67
	Number of hospital beds per 1,000 people	**0.98**	**0.97**	**0.02**
	Number of ICU beds per 100,000 people	-0.25	0.06	0.76
	Number of ventilators	-----	-----	-----
	% population ages 65 and older	0.20	0.043	0.79
	Number of CT Per 1 million inhabitants	-----	-----	-----
	Number of COVID-19 tests	0.21	0.046	0.79
	Number of COVID-19 tests per 1 M population	-0.11	0.013	0.89
Upper middle income (n = 4)	Population (million)	-0.13	0.02	0.65
	GDP (trillion)	-0.32	0.10	0.24
	Number of hospital beds per 1,000 people	-0.035	0.001	0.90
	Number of ICU beds per 100,000 people	-0.26	0.07	0.53
	Number of ventilators	0.62	0.38	0.58
	% population ages 65 and older	-0.24	0.059	0.40
	Number of CT Per 1 million inhabitants	-0.29	0.084	0.71
	Number of COVID-19 tests	**0.71**	**0.50**	**0.003**
	Number of COVID-19 tests per 1 M population	-0.19	0.035	0.51

GPD (R^2 = 0.30, P = 0.001), number of ICU Beds per 100,000 people (R^2 = 0.23, P = 0.008), and the number of ventilators (R^2 = 0.46, P = 0.01) had a significant correlation with CFR in high-income countries. The population in low-middle income countries (R^2 = 0.74) and the number of CT per one million inhabitants (R^2 = 0.52) in upper-middle-income countries are as main predictors of CFR (Tab. III).
However, overall analysis for RR showed that there was no significant correlation between the recovery rate and GPD, population, number of ICU beds, percentage of population of aged 65 and older ages, number of ventilators, number of total COVID-19 tests, number of hospital beds, and number of CT (Fig. 2). Only RR was weakly positively related to the number of COVID-19 performed tests (R^2 = 0.06, P = 0.086) (Fig. 2). Since none of the explanatory variables was significantly correlated to recovery rate, the multiple linear regression model was not fitted. It means that these expletory variables could not be as good as predictors to the recovery rate.
Furthermore, subgroup analysis of RR based on origin continents revealed that GPD (R^2 = 0.34, P = 0.004), number of ICU Beds per 100,000 people (R^2 = 0.33, P = 0.005), and number of CT per one million inhabitants (R^2 = 0.26, P = 0.04) are the significant and main predictors of RR in Europe. In America and Asia, there is no significant correlation between the RR and expletory variables. However, the percentage of population of aged 65 and older ages (R^2 = 0.38) is the important predictor compared to other variables in America, and the number of CT per one million inhabitants is the main predictor of recovery rate in Asia (R^2 = 0.58) (Tab. IV). In addition, the result based on income subgroups showed that the number of ICU Beds per 100,000 people (R^2 = 0.14, P = 0.05) is the significant predictor of RR in high-income countries. The number of COVID-19 tests (R^2 = 0.50, P = 0.003) and the number of hospital beds per 1000 people (R^2 = 0.97, P = 0.02) are positively correlated to RR in upper-middle and lower-middle-income, respectively (Tab. IV).

Discussion

This study was aimed to measure the association of indicators of hospital capacity, age category, and the number of screening tests performed with CFR and RR using up-to-date data from around the world, showed that CFR was positively correlated to the country's GPD, population, number of ICU beds per 100 individuals, number of ventilators and number of total COVID-19 tests performed; however, RR had a weak and positive correlation to the number of COVID-19 performed tests.

In mid-February 2020, in a joint report, CDC and WHO announced that although 80% of all patients with COVID-19 had the mild form of the disease, 13.8% of all confirmed cases had serious symptoms 4.7% were in acute conditions as well [21]. This point prompted healthcare and political authorities in all countries to step up their efforts, asking whether the capacity of the hospitals, especially ICUs, was sufficient for patients with acute and severe conditions. Therefore, if the acceleration of the transmission of the disease continues in its current form, the intensive care unit in hospitals in many countries will collapse due to the high number of such patients. The United States and Germany topped the list with 34.7 and 29.2 beds per 100,000 people, while Philippines and India have 1.0 and 0.56 beds per 100,000 people at the bottom of the list [14-16]. One possible reason is that, despite bearing a good hospital and ICU capacity, the number of beds does not cover the large number of confirmed cases. The COVID-19 disease outbreak has put unprecedented pressure on hospitals, as the number of people infected in the country increases exponentially in a very short time. Thus, doctors have been forced to prioritize patients who were more likely to survive, and the rest are left to their own devices. In line with previous reports, one of the variables that positively correlated with CFR was GDP, which means CFR is associated with countries' income, so high-income countries usually have lower mortality than low-income countries [22, 23]. The possible reasons are life expectancy, health expenditure per capita, and the frequency of underlying diseases [24-26].

Especially in American countries, CFR was significantly correlated with GDP, population density, number of ICU beds, and number of CT scans. In this context, a study reported an increase in the COVID-19 test rate is associated with a decrease in the death rate [27]. Thus, to control or possibly decrease the COVID-19 associated mortality, there could be a need to increase the demand for hospital and ICU beds [28]. Our analyses also showed that COVID-19 related mortality is significantly associated with older population fraction, especially in European countries. In line with our findings, a recent study showed that COVID-19 mortality is mainly observed among older people in European countries, such as Italy [29].

Conclusions

In countries of which the average age of infected individuals is lower (Iran, Brazil, Malaysia, Pakistan, India, and Indonesia), and many of the patients are relatively young and healthy, COVID-19 related mortality is accordingly low. The level of country's preparedness and health care system capacities also are among the important predictors of both COVID-19 associated mortality and recovery. Another factor that may lead to the lower CFR and higher RR is testing far more people, which means detecting more infected people at very early stages could increase the confirmed cases, but not the mortalities. Thus, providing up-to-date information on the main predictors of COVID-19 associated mortality and recovery will hopefully improve various countries hospital resource allocation, testing capacities, and level of preparedness.

Acknowledgements

Funding sources: this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest statement

The authors declare no conflict of interest.

Authors' contributions

Conceptualization: MAK.
Methodology: ASM.
Software: ASM.
Validation: MAK.
Formal analysis: ASM.
Investigation: MAK.
Resources: FR.
Data Curation: FR.
Writing - Original Draft: FR, MAK, ASM.
Writing - Review & Editing: FR, MAK.
Visualization: ASM.
Supervision: MAK.
Project administration: FR.

References

[1] Wu Z, McGoogan JM. Characteristics of and Important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020;323:1239-42. https://doi.org/10.1001/jama.2020.2648

[2] Khafaie MA, Rahim F. Cross-country comparison of case fatality rates of COVID-19/SARS-COV-2. Osong Public Health Res Perspect 2020;11:74-80. https://doi.org/10.24171/j.phrp.2020.11.2.03

[3]Van Lancker W, Parolin Z. COVID-19, school closures, and child poverty: a social crisis in the making. Lancet Public Health 2020;5:e243-4. https://doi.org/10.1016/S2468-2667(20)30084-0

[4] Gupta S, Federman DG. Hospital preparedness for COVID-19 pandemic: experience from department of medicine at Veterans Affairs Connecticut Healthcare System. Postgrad Med 2020;132:489-94. https://doi.org/10.1080/00325481.2020.1761668

[5] Ferrua M, Sicotte C, Lalloué B, Minvielle E. Comparative quality indicators for hospital choice: do general practitioners care? PLoS One 2016;11:e0147296. https://doi.org/10.1371/journal.pone.0147296

[6] Grasselli G, Pesenti A, Cecconi M. Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response. JAMA 2020;323:1545-6. https://doi.org/10.1001/jama.2020.4031

[7] Phua J, Weng L, Ling L, Egi M, Lim CM, Divatia JV, Shrestha

BR, Arabi YM, Ng J, Gomersall CD, Nishimura M, Koh Y, Du B; Asian Critical Care Clinical Trials Group. Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations. Lancet Respir Med 2020;8:506-17. https://doi.org/10.1016/S2213-2600(20)30161-2

[8] Dai WC, Zhang HW, Yu J, Xu HJ, Chen H, Luo SP, Zhang H, Liang LH, Wu XL, Lei Y, Lin F. CT imaging and differential diagnosis of COVID-19. Can Assoc Radiol J 2020;71:195-200. https://doi.org/10.1177/0846537120913033

[9] Verity R, Okell LC, Dorigatti I, Winskill P, Whittaker C, Imai N, Cuomo-Dannenburg G, Thompson H, Walker PGT, Fu H, Dighe A, Griffin JT, Baguelin M, Bhatia S, Boonyasiri A, Cori A, Cucunubá Z, FitzJohn R, Gaythorpe K, Green W, Hamlet A, Hinsley W, Laydon D, Nedjati-Gilani G, Riley S, van Elsland S, Volz E, Wang H, Wang Y, Xi X, Donnelly CA, Ghani AC, Ferguson NM. Estimates of the severity of coronavirus disease 2019: a model-based analysis. Lancet Infect Dis 2020;20:669-77. https://doi.org/10.1016/S1473-3099(20)30243-7

[10] Worlometers 2020. Available from: https://www.worldometers.info/coronavirus

[11] World Health Organization 2020. Available from: Search Results Web results Coronavirus disease 2019 (COVID-19) - World Health...www.who.int

[12] Centers of Disease Control and Prevention 2020. Available from: https://www.cdc.gov/coronavirus/2019-ncov/cases-in-us.html

[13] (US) RMAfHRaQ. Registries for evaluating patient outcomes: a user's guide 2014. Available from: https://www.ncbi.nlm.nih.gov/books/NBK208611

[14] Halpern NA, Pastores SM. Critical care medicine beds, use, occupancy, and costs in the United States: a methodological review. Crit Care Med 2015;43:2452-9. https://doi.org/10.1097/CCM.0000000000001227

[15] Rhodes A, Ferdinande P, Flaatten H, Guidet B, Metnitz PG, Moreno RP. The variability of critical care bed numbers in Europe. Intensive Care Med 2012;38:1647-53. https://doi.org/10.1007/s00134-012-2627-8

[16] Phua J, Faruq MO, Kulkarni AP, Redjeki IS, Detleuxay K, Mendsaikhan N, Sann KK, Shrestha BR, Hashmi M, Palo JEM, Haniffa R, Wang C, Hashemian SMR, Konkayev A, Mat Nor MB, Patjanasoontorn B, Nafees KMK, Ling L, Nishimura M, Al Bahrani MJ, Arabi YM, Lim CM, Fang WF; Asian Analysis of Bed Capacity in Critical Care (ABC) Study Investigators, and the Asian Critical Care Clinical Trials Group. Critical care bed capacity in Asian countries and regions. Crit Care Med 2020;48:654-662. https://doi.org/10.1097/CCM.0000000000004222

[17] Ameryoun A, Meskarpour-Amiri M, Dezfuli-Nejad ML, Khoddami-Vishteh H, Tofighi Sh. The assessment of inequality on geographical distribution of non-cardiac intensive care beds in iran. Iran J Public Health 2011;40:25-33

[18] Adhikari NK, Fowler RA, Bhagwanjee S, Rubenfeld GD. Critical care and the global burden of critical illness in adults. Lancet 2010;376:1339-46. https://doi.org/10.1016/S0140-6736(10)60446-1

[19] Schepin VO. The structural functional analysis of beds stock of curative preventive organizations of the state public health system of the Russian Federation. Probl Sotsialnoi Gig Zdravookhranenniiai Istor Med 2014;(1):15-9

[20] Prin M, Wunsch H. International comparisons of intensive care: informing outcomes and improving standards. Curr Opin Crit Care 2012;18:700-6. https://doi.org/10.1097/MCC.0b013e32835914d5

[21] WHO-China Rot. Joint Mission on Coronavirus Disease 2019 (COVID-19). WHO 2020. Available from: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf [updated 16-24 Feb 2020].

[22] Shkolnikov VM, Andreev EM, Tursun-Zade R, Leon DA. Patterns in the relationship between life expectancy and gross domestic product in Russia in 2005-15: a cross-sectional analysis. Lancet Public Health 2019;4:e181-8. https://doi.org/10.1016/S2468-2667(19)30036-2

[23] O'Hare B, Makuta I, Chiwaula L, Bar-Zeev N. Income and child mortality in developing countries: a systematic review and meta-analysis. J R Soc Med 2013;106:408-14. https://doi.org/10.1177/0141076813489680

[24] Stewart AW, Mitchell EA, Pearce N, Strachan DP, Weiland SK; ISAAC Steering Committee. International Study for Asthma and Allergy in Childhood. The relationship of per capita gross national product to the prevalence of symptoms of asthma and other atopic diseases in children (ISAAC). Int J Epidemiol 2001;30:173-9. https://doi.org/10.1093/ije/30.1.173

[25] Li H, Feng H, Wang J, Qian Z, Gu J. Relationships among gross domestic product per capita, government health expenditure per capita and infant mortality rate in China. Biomedical Research 2017;28:2859-64.

[26] Kirigia JM, Sambo LG, Aldis W, Mwabu GM. Impact of disaster-related mortality on gross domestic product in the WHO African Region. BMC Emerg Med 2004;4:1. https://doi.org/10.1186/1471-227X-4-1

[27] Terriau A, Albertini J, Poirier A, Le Bastard Q. Impact of virus testing on COVID-19 case fatality rate: estimate using a fixed-effects model. medRxiv 2020. https://doi.org/10.1101/2020.04.26.20080531

[28] Murray CJ. Forecasting COVID-19 impact on hospital bed-days, ICU-days, ventilator-days and deaths by US state in the next 4 months. medRxiv 2020. https://doi.org/10.1101/2020.03.27.20043752

[29] Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. JAMA 2020;323:1775-6. https://doi.org/10.1001/jama.2020.4683. Erratum in: JAMA 2020;323:1619.

Received on May 9, 2020. Accepted on May 12, 2021.

Correspondence: Fakher Rahim, School of Health , Research Center of Thalassemia and Hemoglobinopathies, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran - Tel./Fax: +986133367652 -E-mail: bioinfo2003@gmail.com

How to cite this article: Khafaie MA, Malehi AS, Rahim F. The association between various indicators of hospital capacity, age category, and the number of screening tests performed with case fatality rate and recovery rate during the COVID-19 disease pandemic. J Prev Med Hyg 2021;62:E584-E269. https://doi.org/10.15167/2421-4248/jpmh2021.62.2.1569