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Estimation of novel coronavirus (COVID-19) reproduction number and case fatality rate: A systematic review and meta-analysis

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Abstract

Background and aims: Realizing the transmission potential and the magnitude of the coronavirus disease 2019 (COVID-19) aids public health monitoring, strategies, and preparation. Two fundamental parameters, the basic reproduction number (R_0) and case fatality rate (CFR) of COVID-19, help in this understanding process. The objective of this study was to estimate the R_0 and CFR of COVID-19 and assess whether the parameters vary in different regions of the world.

Methods: We carried out a systematic review to find the reported estimates of the R_0 and the CFR in articles from international databases between January 1 and August 31, 2020. Random-effect models and Forest plots were implemented to evaluate the mean effect size of R_0 and the CFR. Furthermore, R_0 and CFR of the studies were quantified based on geographic location, the tests/thousand population, and the median population age of the countries where the studies were conducted. To assess statistical heterogeneity among the selected articles, the I^2 statistic and the Cochran's Q test were used.

Results: Forty-five studies involving R_0 and 34 studies involving CFR were included. The pooled estimation of R_0 was 2.69 (95% CI: 2.40, 2.98), and that of the CFR was 2.67 (2.25, 3.13). The CFR in different regions of the world varied significantly, from 2.49 (2.08, 2.94) in Asia to 3.40 (2.81, 4.04) in North America. We observed higher mean CFR values for the countries with lower tests (3.15 vs 2.16) and greater median population age (3.13 vs 2.27). However, R_0 did not vary significantly in different regions of the world.

Conclusions: An R_0 of 2.69 and a CFR of 2.67 indicate the severity of the COVID-19. Although R_0 and CFR may vary over time, space, and demographics, we recommend considering these figures in control and prevention measures.

KEYWORDS
basic reproduction number, case fatality rate, COVID-19, meta-analysis, systematic review

1 | INTRODUCTION

Since the emergence of SARS-CoV-2, the virus causing COVID-19, in late 2019, there have been more than 35 million confirmed cases, and 950 000 confirmed deaths have been reported as of September 19, 2020.[1] The basic reproduction number (R_0) determines a disease's transmission potential and can be used to inform public health policies. In a susceptible population, the expected number of cases generated by one infected case is specified as R_0.[2,3] Outbreaks will continue to propagate until this number falls below 1.0. A timely and accurate assessment of COVID-19's R_0 notifies COVID is of great significance for assessing the spread of the virus, predicting future trends, and adjusting a series of control measures.

Another important factor to inform is the case fatality rate (CFR), which is the proportion of patients who die from a specified disease compared with the total number of patients identified with the disease within a defined population of interest and is typically presented as a percentage.[4] CFR is an indicator of disease severity and can be used to identify high-risk populations to inform targeted interventions and the overall public health response.[5]

To understand the transmissibility and severity of SARS-CoV-2 in populations, there have been several estimates of R_0 and the CFR. Estimates of R_0 and CFR have varied in different countries and different settings.[6] For example, in the Diamond Princess cruise ship, the estimated median R_0 was 2.28 (95% CI: 2.06-2.52).[7] At the early stages of the epidemic in Wuhan, the value of R_0 was estimated as 2.24 (95% CI: 1.96-2.55).[8] R_0 has also been estimated for several other countries, including Italy, 3.2 (95% CI: 2.9-3.5)[9]; USA, 5.3 (95% CI: 4.35-6.25)[10]; and, Japan, 2.6 (95% CI: 2.4-2.8).[11]

Likewise, the estimates of CFRs have varied in different countries and phases of the pandemic. A study found that, at the start of the epidemic, CFR in China was 2%, but on March 5, 2020, it increased to 3.7%. In South Korea, the same study reported the CFR as 0.6% on March 5, 2020.[12] In Europe, during March 2020, Italy, Spain, and France had a CFR of 9.26%, 6.16%, and 4.21%, respectively.[13] Given the considerable variation in estimates of both these parameters, in this current study, our aim was to perform a systematic review and meta-analysis of the published studies on the COVID-19 outbreak to provide summary statistics of R_0 and the CFR that are most applicable to other countries or regions.

2 | METHODS

We followed the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2009. The protocol of the study was registered with the International prospective register of systematic reviews (PROSPERO) (registration number ID: CRD42020182867).

2.1 | Search strategy

We systematically searched the major databases: LitCovid (a curated COVID-19 database of PubMed), PubMed, EMBASE, Scopus, and Web of Science from January 1 to August 31, 2020. We searched articles for "Basic reproduction number (R_0)" and "Case-fatality rate (CFR)" of the COVID-19 patients. For basic reproduction number, the search terms were as follows: "2019 novel coronavirus and COVID-19" AND "Basic reproduction number", OR "Basic reproduction rate" OR "R_0." For the case fatality rate, the search terms were "2019 novel coronavirus and COVID-19" AND "case fatality rate," OR "case fatality ratio," OR "CFR" according to the indices of the various databases (Table S1). We also manually scanned the reference lists of the included articles and consulted specialists in the field to ensure a thorough analysis. The records were managed by Mendeley version 1.19.4 software to exclude duplicates.

2.2 | Inclusion and exclusion criteria

Articles were selected if they reported CFR and/or R0 with a confidence interval of the patients with COVID-19. The inclusion criteria for studies were laboratory-confirmed parents with COVID-19, reported at sufficient sample size, considered all age-groups, and published in English and any counties or regions of the world. Studies were excluded if they were pre-prints, review articles, editorials and case reports, letters to the editor, short communications, and specific to children or pregnant women. However, we did not exclude some special populations representative of the general population in a particular setting (eg, Diamond Princess cruise ship). The steps followed in the literature search are illustrated in Figure 1.

2.3 | Data screening and extraction

After excluding duplicate papers, two investigators (TA and AA) independently evaluated the full-text articles for inclusion after screening the titles and abstracts using the eligibility criterion. The co-authors helped to solve any conflict in opinions. A standardized form was used to extract data from all eligible studies. For each selected article, publication details [title, first author, publication year, journal name and publisher]; design and population [country, study design, study period, and sample size]; participants' characteristics and major findings [number of deaths, case fatality rate, basic reproduction number, confidence interval, methods used, SD, and other related statistics] were extracted. Forty-five research articles[7,9-11,14-54] for R_0 and 34 research articles[13,18,50,55-85] for CFR estimation were selected.

2.4 | Critical appraisal and publication bias

The critical appraisal of each selected study was assessed by TA and AA independently using modified risk-of-bias (ROB) operational criteria (Tables S2 and S3).[86] A funnel plot was used to determine

FIGURE 1 Flow diagram for included studies in the meta-analysis. CFR, case fatality rate; R_O, basic reproduction number; Re, effective reproduction number
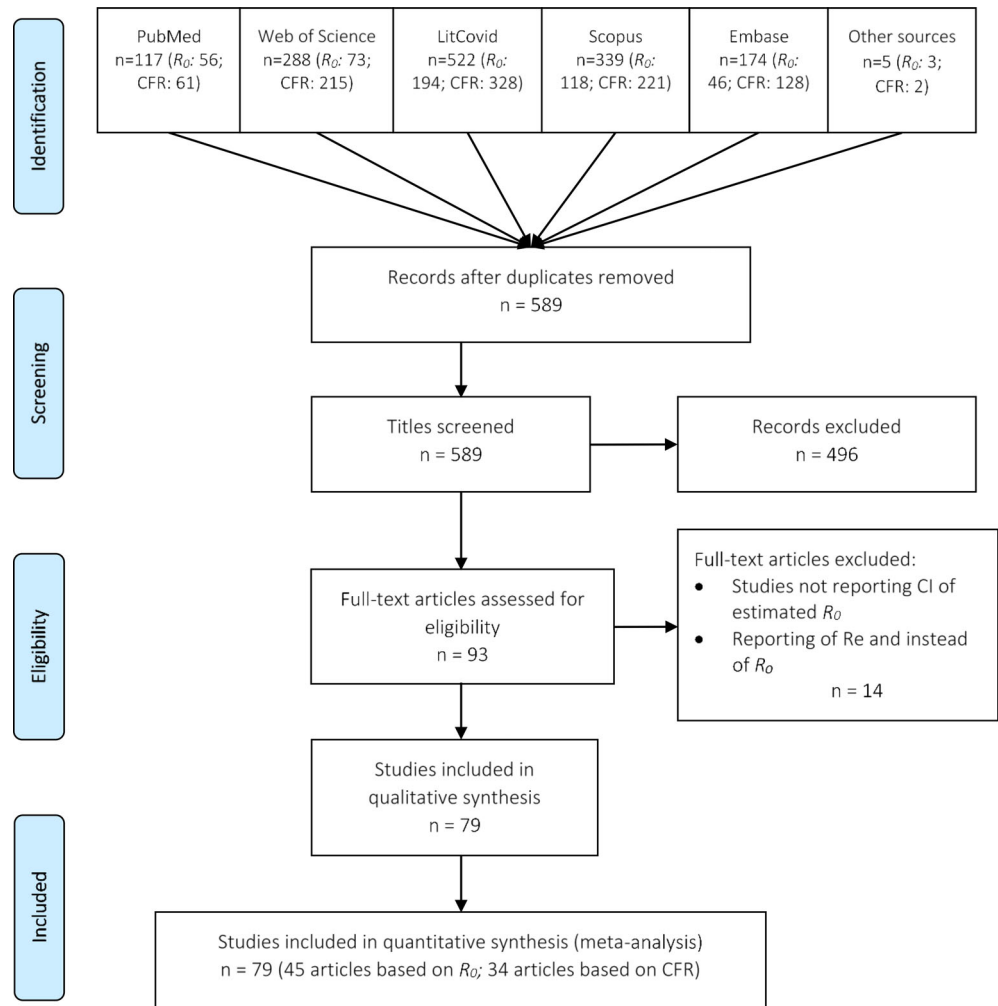
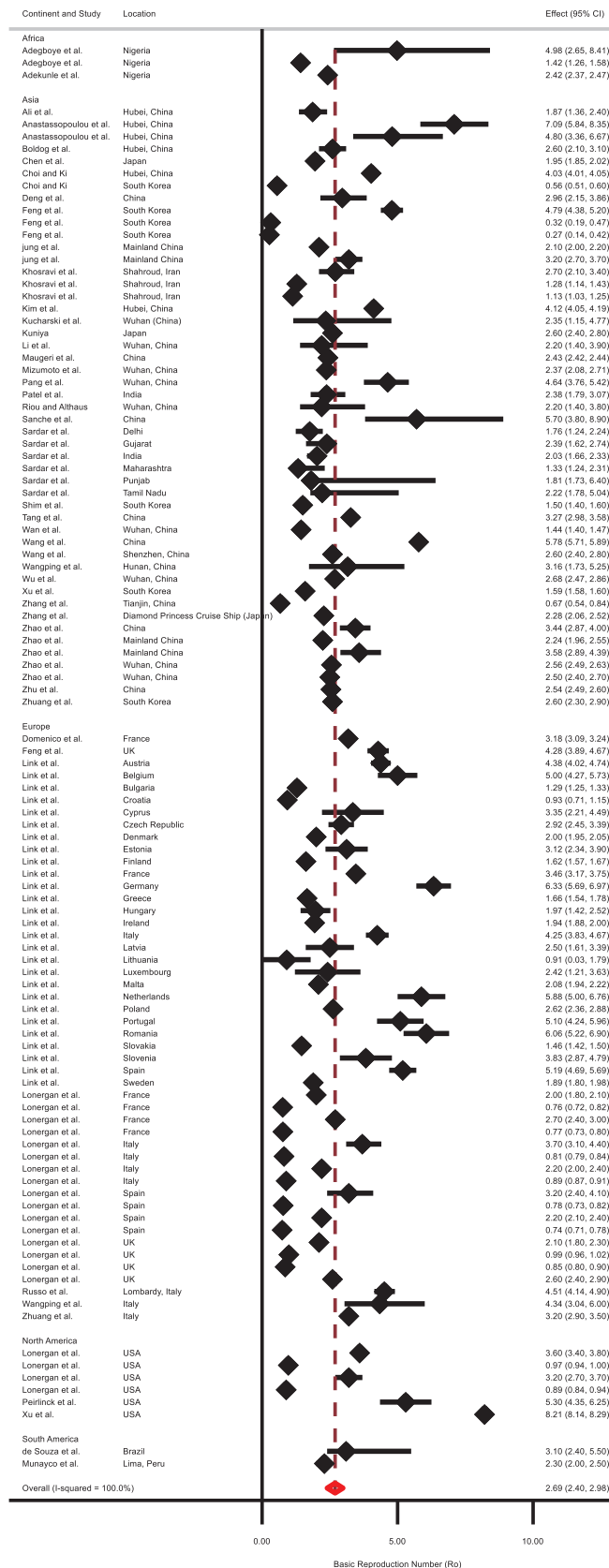**TABLE 1** Effect size and test of heterogeneity for the basic reproduction number (R_O) by region

Statistics	Region					Test for Subgroup differences	Overall
	Africa	Asia	Europe	North America	South America		
Effect Size (95% CI)	2.40 (0.96, 3.84)	2.56 (2.19, 2.94)	2.70 (2.26, 3.13)	3.69 (1.46, 5.92)	2.32 (2.07, 2.57)	3.81 (P value = .43)	2.69 (2.40, 2.98)
I^2 statistic	99.43%	99.96%	99.95%	99.98%	0.00%		99.96%
Cochran's Q statistics	-	-	-	-	-		1.6×10^5
n (sample = 108)	3	49	48	6	2		108

publication bias, and an Egger's test with $P < .05$ was an indication of small-study effects.

2.5 | Statistical analysis

We defined R_O as the number of expected cases directly generated by one infected case in a susceptible population and CFR as the percentage of COVID-19 cases that result in death. Background statistics of the COVID-19 patients were recorded through frequency distribution analysis. A random-effect model was, therefore, used to perform a meta-analysis. The geo-location variations for R_O and geo-location, tests per thousand population, and population median age variations for CRF were examined using subgroup analysis. However, R_O estimations for Africa and South America and CFR estimations for Africa and Oceania might not reflect the actual situations of these continents because of the inadequate data used for these estimates. The median values of the frequency distributions were used as cutoff values of the subgroups. Heterogeneity was assessed among the selected studies using Higgin's and Thompson's I^2 statistic and Cochran's Q test. Stata SE version 16.1 (Stata Corporation, College Station, TX, USA 5) was used for all statistical analyses.

Continent and Study	Location		Effect (95% CI)
Africa			
Adegboye et al.	Nigeria		4.98 (2.65, 8.41)
Adegboye et al.	Nigeria		1.42 (1.26, 1.58)
Adekunle et al.	Nigeria		2.42 (2.37, 2.47)
Asia			
Ali et al.	Hubei, China		1.87 (1.36, 2.40)
Anastassopoulou et al.	Hubei, China		7.09 (5.84, 8.35)
Anastassopoulou et al.	Hubei, China		4.80 (3.36, 6.67)
Boldog et al.	Hubei, China		2.60 (2.10, 3.10)
Chen et al.	Japan		1.95 (1.85, 2.02)
Choi and Ki	Hubei, China		4.03 (4.01, 4.05)
Choi and Ki	South Korea		0.56 (0.51, 0.60)
Deng et al.	China		2.96 (2.15, 3.86)
Feng et al.	South Korea		4.79 (4.38, 5.20)
Feng et al.	South Korea		0.32 (0.19, 0.47)
Feng et al.	South Korea		0.27 (0.14, 0.42)
jung et al.	Mainland China		2.10 (2.00, 2.20)
jung et al.	Mainland China		3.20 (2.70, 3.70)
Khosravi et al.	Shahroud, Iran		2.70 (2.10, 3.40)
Khosravi et al.	Shahroud, Iran		1.28 (1.14, 1.43)
Khosravi et al.	Shahroud, Iran		1.13 (1.03, 1.25)
Kim et al.	Hubei, China		4.12 (4.05, 4.19)
Kucharski et al.	Wuhan (China)		2.35 (1.15, 4.77)
Kuniya	Japan		2.60 (2.40, 2.80)
Li et al.	Wuhan, China		2.20 (1.40, 3.90)
Maugeri et al.	China		2.43 (2.42, 2.44)
Mizumoto et al.	Wuhan, China		2.37 (2.08, 2.71)
Pang et al.	Wuhan, China		4.64 (3.76, 5.42)
Patel et al.	India		2.38 (1.79, 3.07)
Riou and Althaus	Wuhan, China		2.20 (1.40, 3.80)
Sanche et al.	China		5.70 (3.80, 8.90)
Sardar et al.	Delhi		1.76 (1.24, 2.24)
Sardar et al.	Gujarat		2.39 (1.62, 2.74)
Sardar et al.	India		2.03 (1.66, 2.33)
Sardar et al.	Maharashtra		1.33 (1.24, 2.31)
Sardar et al.	Punjab		1.81 (1.73, 6.40)
Sardar et al.	Tamil Nadu		2.22 (1.78, 5.04)
Shim et al.	South Korea		1.50 (1.40, 1.60)
Tang et al.	China		3.27 (2.98, 3.58)
Wan et al.	Wuhan, China		1.44 (1.40, 1.47)
Wang et al.	China		5.78 (5.71, 5.89)
Wang et al.	Shenzhen, China		2.60 (2.40, 2.80)
Wangping et al.	Hunan, China		3.16 (1.73, 5.25)
Wu et al.	Wuhan, China		2.68 (2.47, 2.86)
Xu et al.	South Korea		1.59 (1.58, 1.60)
Zhang et al.	Tianjin, China		0.67 (0.54, 0.84)
Zhang et al.	Diamond Princess Cruise Ship (Japan)		2.28 (2.06, 2.52)
Zhao et al.	China		3.44 (2.87, 4.00)
Zhao et al.	Mainland China		2.24 (1.96, 2.55)
Zhao et al.	Mainland China		3.58 (2.89, 4.39)
Zhao et al.	Wuhan, China		2.56 (2.49, 2.63)
Zhao et al.	Wuhan, China		2.50 (2.40, 2.70)
Zhu et al.	China		2.54 (2.49, 2.60)
Zhuang et al.	South Korea		2.60 (2.30, 2.90)
Europe			
Domenico et al.	France		3.18 (3.09, 3.24)
Feng et al.	UK		4.28 (3.89, 4.67)
Link et al.	Austria		4.38 (4.02, 4.74)
Link et al.	Belgium		5.00 (4.27, 5.73)
Link et al.	Bulgaria		1.29 (1.25, 1.33)
Link et al.	Croatia		0.93 (0.71, 1.15)
Link et al.	Cyprus		3.35 (2.21, 4.49)
Link et al.	Czech Republic		2.92 (2.45, 3.39)
Link et al.	Denmark		2.00 (1.95, 2.05)
Link et al.	Estonia		3.12 (2.34, 3.90)
Link et al.	Finland		1.62 (1.57, 1.67)
Link et al.	France		3.46 (3.17, 3.75)
Link et al.	Germany		6.33 (5.69, 6.97)
Link et al.	Greece		1.66 (1.54, 1.78)
Link et al.	Hungary		1.97 (1.42, 2.52)
Link et al.	Ireland		1.94 (1.88, 2.00)
Link et al.	Italy		4.25 (3.83, 4.67)
Link et al.	Latvia		2.50 (1.61, 3.39)
Link et al.	Lithuania		0.91 (0.03, 1.79)
Link et al.	Luxembourg		2.42 (1.21, 3.63)
Link et al.	Malta		2.08 (1.94, 2.22)
Link et al.	Netherlands		5.88 (5.00, 6.76)
Link et al.	Poland		2.62 (2.36, 2.88)
Link et al.	Portugal		5.10 (4.24, 5.96)
Link et al.	Romania		6.06 (5.22, 6.90)
Link et al.	Slovakia		1.46 (1.42, 1.50)
Link et al.	Slovenia		3.83 (2.87, 4.79)
Link et al.	Spain		5.19 (4.69, 5.69)
Link et al.	Sweden		1.89 (1.80, 1.98)
Lonergan et al.	France		2.00 (1.80, 2.10)
Lonergan et al.	France		0.76 (0.72, 0.82)
Lonergan et al.	France		2.70 (2.40, 3.00)
Lonergan et al.	France		0.77 (0.73, 0.80)
Lonergan et al.	Italy		3.70 (3.10, 4.40)
Lonergan et al.	Italy		0.81 (0.79, 0.84)
Lonergan et al.	Italy		2.20 (2.00, 2.40)
Lonergan et al.	Italy		0.89 (0.87, 0.91)
Lonergan et al.	Spain		3.20 (2.40, 4.10)
Lonergan et al.	Spain		0.78 (0.73, 0.82)
Lonergan et al.	Spain		2.20 (2.10, 2.40)
Lonergan et al.	Spain		0.74 (0.71, 0.78)
Lonergan et al.	UK		2.10 (1.80, 2.30)
Lonergan et al.	UK		0.99 (0.96, 1.02)
Lonergan et al.	UK		0.85 (0.80, 0.90)
Lonergan et al.	UK		2.60 (2.40, 2.90)
Russo et al.	Lombardy, Italy		4.51 (4.14, 4.90)
Wangping et al.	Italy		4.34 (3.04, 6.00)
Zhuang et al.	Italy		3.20 (2.90, 3.50)
North America			
Lonergan et al.	USA		3.60 (3.40, 3.80)
Lonergan et al.	USA		0.97 (0.94, 1.00)
Lonergan et al.	USA		3.20 (2.70, 3.70)
Lonergan et al.	USA		0.89 (0.84, 0.94)
Peirlinck et al.	USA		5.30 (4.35, 6.25)
Xu et al.	USA		8.21 (8.14, 8.29)
South America			
de Souza et al.	Brazil		3.10 (2.40, 5.50)
Munayco et al.	Lima, Peru		2.30 (2.00, 2.50)
Overall (I-squared = 100.0%)			2.69 (2.40, 2.98)

Basic Reproduction Number (Ro)

FIGURE 2 Forest plot of the basic reproduction number (R_0) values based on the random-effects model

Funnel plot with pseudo 95% confidence limits

FIGURE 3 Funnel plot for the basic reproduction number (R_0) values based on the random-effects model

3 | RESULTS

We identified a total of 490 articles estimating R_0. After considering the duplicates, inclusion, and exclusion criteria, we reviewed these research articles. We searched for titles, abstracts and keywords, methodology, and references and found 59 articles to investigate further (Figure 1). Out of these 59 articles, we found 45 research articles that reported 108 R_0 estimates ranging from 0.27 to 8.21 with related statistics for a meta-analysis (Table S4). Similarly, for the CFR, after considering filtering criteria, only 34 research articles of 955 articles qualified for quantifying parameter values of CFR (Figure 1), and these 34 articles provided 158 estimates of CFR ranging from 0.00 to 25.9 for use in the meta-analysis (Table S5). No studies were excluded.

3.1 | Pooled estimation of the basic reproduction number (R_0)

The pooled R_0 for COVID-19, in the random-effects model, was found to be 2.69 (2.40, 2.98), indicating that an infected person with COVID-19 can transmit the infection to, on average, three susceptible people (Table 1, and Figure 2). There was significant heterogeneity between studies (I^2: 99.96; Table 1).

The outcome of the subgroup analysis showed that the R_0 value for Asia was 2.56 (2.19, 2.94), for "Europe" was 2.70 (2.26, 3.13), and for North America was 3.69 (1.46, 5.92; Table 1). There were inadequate studies for Africa (n = 3) and South America (n = 2), and it might not reflect the actual R_0 for these two continents. Moreover, the test of geographic subgroup variations shows that the calculated mean R_0 values across these regions are not significantly different (P = .43). Figure 3 illustrates a funnel plot for assessing publishing bias in R_0 values. The presence of asymmetry and publication bias is indicated

TABLE 2 Effect size and test of heterogeneity for the case fatality rate (CFR) by region, population median age (median value), and tests per thousand population (median value)

Statistics	Region						Test for Subgroup differences	Overall
	Africa	Asia	Europe	North America	Oceania	South America		
Effect Size (95% CI)	7.11 (6.38, 7.91)	2.49 (2.08, 2.94)	2.82 (1.98, 3.81)	3.40 (2.81, 4.04)	0.20 (0.02, 0.51)	2.89 (2.03, 3.89)	254.44 (P-value = .00)	2.67 (2.25, 3.13)
I^2 statistic	-	99.66%	99.98%	99.84%	32.87%	99.69%		99.95%
Cochran's Q statistics	-	-	-	-	-	-		315 324.53
n (sample = 158)	1	69	60	15	4	9		158
	Total tests per thousand population							
	Less than or equal to 111.16 tests			Greater than 111.16 tests				Overall
Effect size (95% CI)	3.15 (2.57, 3.79)			2.16 (1.57, 2.83)			5.14 (P value = .02)	2.68 (2.25, 3.14)
I^2 statistic	99.90%			99.97%				99.95%
Cochran's Q statistics	-			-				315 324.53
n (sample = 157)	87			70				157
	Population Median Age Category							
	Less than or equal to 38.7 years		Greater than 38.7 years					Overall
Effect size (95% CI)	2.27 (1.85, 2.74)		3.13 (2.44, 3.91)				4.30 (P value = .04)	2.67 (2.25, 3.13)
I^2 statistic	99.80%		99.97%					99.95%
Cochran's Q statistics	-		-					315 324.53
n (sample = 158)	82		76					158

by this funnel plot. Additionally, the existence of small-study effects was indicated by Egger's test ($P < .001$).

3.2 | Pooled estimation of the case fatality rate

The pooled estimation of the CFR from the random-effects model was 2.67 (2.25, 3.13). There was significant heterogeneity between studies (I^2: 99.95, Q = 315 324.53 with $P = .00$; Table 2, and Figure 4). The high value of the I^2 statistic (99.95%) confirms a high level of between-study heterogeneity.

The outcome of the subgroup analyses stratified by region showed that the CFR for Asia was 2.49 (2.08, 2.94), for Europe was 2.82 (1.98, 3.81), for North America was 3.40 (2.81, 4.04), and for South America was 2.89 (2.03, 3.89; Table 2). Our estimated CFR might not reflect the actual CFR for Africa and Oceania as there were only one study included for Africa and four studies for Oceania. We observed higher mean CFR values for the countries with lower tests (3.15 vs 2.16) and greater median population age (3.13 vs 2.27). The subgroup difference tests were significant (Table 2), indicating that the calculated mean CFR values for these subgroups were significantly different. The funnel plot for CFR values is shown in Figure 5. Though the funnel plot indicates asymmetry, the Egger test ($P = .182$) suggests that there was no significant evidence of small-study effects.

However, if we exclude the extreme CFR values (reported in the included articles), the pooled CFR estimation became 2.63 (2.24, 3.05). Furthermore, if we exclude the cases where naïve CFR (estimated as the ratio of the deaths to the confirmed cases mentioned in the article) >4, the pooled CFR estimation became 1.23 (0.97, 1.53).

4 | DISCUSSION

According to our estimation of the R_0 statistic, in the absence of any control measures, one infected individual can transmit the infection to more than two and a half susceptible persons in a naïve population. However, R_0 did not significantly differ across the continents. Among these regions, the highest R_0 was estimated for "North America" (3.69) and the lowest for "Asia" (2.56). We estimated a CFR of above two and a half, and the CFR varied in different continents (highest 3.40 in North America, lowest 2.49 in Asia). We further observed lower CFR values of COVID-19 in the countries where a higher number of samples (per thousand population) were tested and higher CFR values where the median age of the national population was higher (>38.7 years).

Our estimated overall R_0 is slightly greater than WHO estimates of 1.4 to 2.5[87] but smaller than the results of the other studies, that is, He et al. and Alimohamadi et al. estimated R_0 as 3.15 (95% CI: 2.41-3.90) and 3.32 (95% CI: 2.81-3.82), respectively.[88,89] Our estimated R_0 value is close to the R_0 values for the severe acute respiratory syndrome epidemic ($R_0 = 2-3$) but greater than the Middle East
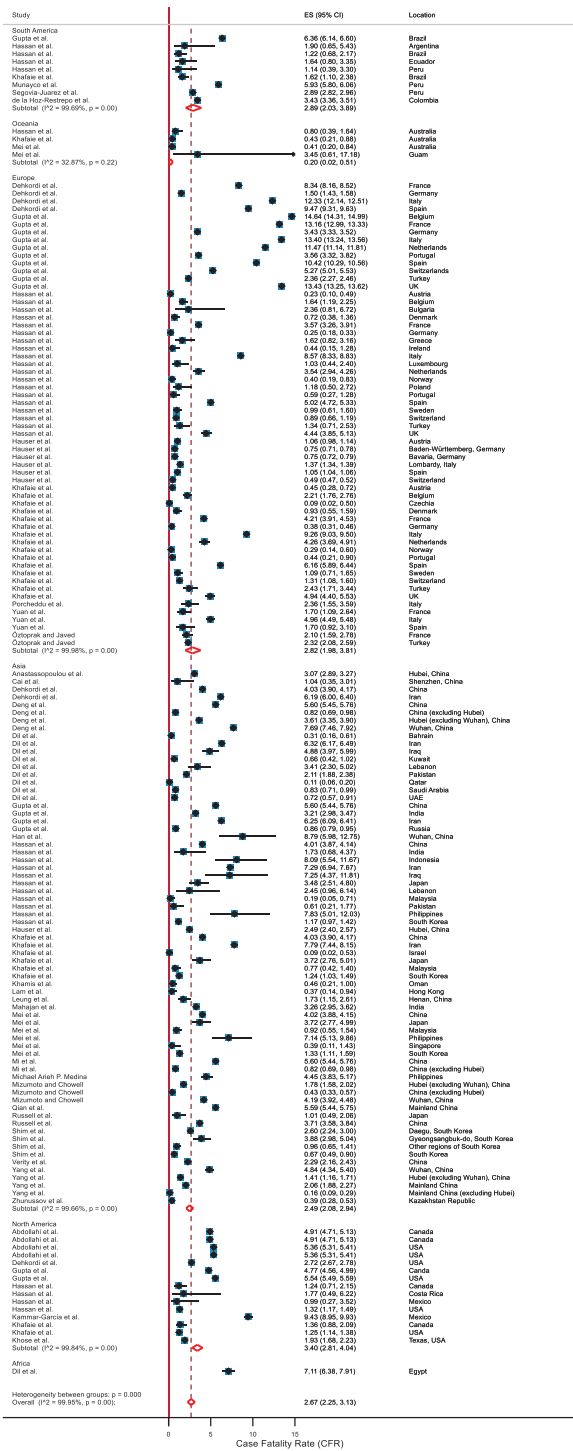
FIGURE 4 Forest plot of the case fatality rate (CFR) values based on the random-effects model

FIGURE 5 Funnel plot for the case fatality rate (CFR) values based on the random-effects model

respiratory syndrome in the Middle East ($R_0 < 1$).[90] However, high R_0 values tend to be estimated in the early stages of epidemics and pandemics due to small sample sizes and incomplete information. However, the total value of R_0 in a population is the average of the R_0 subtypes of that community. Therefore, the probability of transmission in specific subgroups of a population can still be high, even if its overall R_0 value is low.
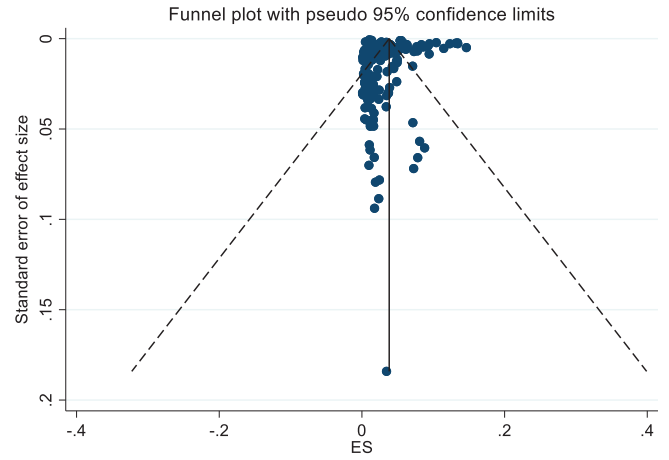
Our estimated value for CFR is similar to the estimates of the Chinese Center for Disease Control and Prevention (China CDC; 2.3%)[91] and He et al. (2.72% with 95% CI:1.29%-4.16%)[88] but less than the WHO reported estimate of 3.4%.[92] Additionally, our estimated CFR is lower than the CFR values estimated for the other severe coronavirus, severe acute respiratory syndrome epidemic (9.6%), and the Middle East respiratory syndrome (40%),[90] but higher than that of influenza (0.1%).[93,94] Although several researchers found higher case fatality rates than ours, usually those are not the actual case fatality rates, as mild, atypical, and asymptomatic cases may not be identified (contrary to deaths), particularly in countries where access to testing is limited.[95] For example, before March 11, 2020 in United States, there was insufficient state-funded testing.[96] According to a study of 565 Wuhan evacuated Japanese citizens, the CFR would then only be around one-tenth of what it is now if we consider the underreporting.[97] Our included studies may suffer from underreporting bias, which could increase the pooled CFR estimation. Thus, we further estimated the CFR by excluding the extreme values and the naive CFR greater than four. These gave us lower CFR values close to one.

In our estimation, the CFR varied among different regions, but R_0 did not vary significantly. We found lower CFR in the countries with a higher number of sample testing per thousand population. A higher number of testing allowed the detection of more pre-/a-symptomatic and mild cases, which reduced the rate of fatal outcomes.[98] We further found that countries with higher median age had higher CFR values. Older age has been recognized as one of the most common risk factors for a severe outcome of COVID-19.[99-101] A study conducted with 5484 patients in Italy found the CFR of COVID-19 was 0.43% for people below 70 years and 10.5% for people aged 70 years and above.[101] Another study showed that an increase of 1% population that is aged 65 years and above increased the risk of death due to COVID-19 by 10%.[100]

An estimate of R_0 is affected by several factors, including the proportion of the susceptible population, population density, and

awareness among people. Because SARS-COV-2 is a novel virus, we believe the proportion of the susceptible population remains the same across the world; however, other factors (density and awareness) vary. The density of the population is lower in European and North American countries compared with Asian counterparts. Thus, our estimation of R_0 for nonsignificant variation came as a surprise. However, the early phase of the pandemic produces incomplete data. Further studies on R_0 are essential to understand how different lockdown measures, especially face covering, social distancing, and demographic (population density), and environmental factors (temperature, humidity, UV light), affect the transmission dynamic of SARS-CoV-2.[102-105]

For developing and populated countries, the R_0 value of 2.69 indicates the rapid spread of the COVID-19, and the CFR value of 2.67 is an indication of a relatively poor outcome of the treatments. Necessary precautions and strategies such as restricting mass gatherings, limiting the transportation system, and closing educational institutions should continue to prevent the outbreak of this disease until a successful vaccine arrives.

5 | LIMITATIONS

An important limitation of our study was that very few studies on Africa (one article on CFR and three articles on R_0), South America (two articles on R_0), and Oceania (four articles on CFR) were available in peer-reviewed journals. Therefore, our estimated R_0 and CFR estimates for these regions might not be representative. Thus, we were unable to draw any conclusion on CFR or R_0 of these geographical regions. Furthermore, we did not include any preprint articles, although a number of those were published as peer-reviewed articles and included in this review (those published up until August 31, 2020).

Future research on R_0 and CFR should include more studies of these regions. Moreover, some of the selected studies had limitations because of sample size, missing information on the onset of COVID-19, and data availability. As a result, the findings, as mentioned earlier, should be interpreted with caution in that regard. Furthermore, future systematic reviews should include Chinese literature since our article was limited to the publications written in English language only. Another important limitation is the case detection and testing heterogeneity. Countries' responses varied, and some countries are facing difficulties in testing enough samples. Furthermore, the quality of the testing samples also varies in different countries. All these have affected the case detection and thus impacted R_0 and CFR. However, we believe the effects are minimum, and data across the world are still comparable.

6 | CONCLUSION

The estimated R_0 of SARS-CoV-2 was 2.69 (95% CI: 2.40, 2.98) and the CFR of COVID-19 was 2.67 (95% CI: 2.25, 3.13) based on published literature from January to August 2020. The analysis by subgroups of regions confirmed a significant CFR variation, but the same was not found for R_0. Considering the estimated COVID-19's R_0 and CFR values, implementing the social distancing program and other non-pharmaceutical interventions are necessary steps to control the epidemic until an effective vaccine reaches all susceptible populations.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

AUTHOR CONTRIBUTIONS

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All authors have read and approved the final version of the manuscript.

Md. Jamal Uddin had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

Tanvir Ahammed affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA AVAILABILITY STATEMENT

The complete list of data and the data entries for all included studies are provided in the paper (Tables S4 and S5). No additional supporting data are available.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.