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A ratio and formula for transmission dynamics of COVID-19

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Abstract:	A basic reproductive number Ro is an important in dynamics of a newly emerged and rapidly growing infectious disease outbreak, such as COVID-19. However, the current researches indicated that Ro for COVID-19 is quite affected by many other factors or parameters. To find the alternative index for the reality of spread of the COVID-19, a study based on the population of 2,067.14 millions from seven countries, USA, UK, Brazil, India, South Africa, Canada and Sweden, was conducted and the weekly new case ratio as index for mathematical method or anticipatable formula for application was introduced. In addition, it could be used for evaluating Ro value and setting a methodological formula or index for other contagious disease in the future.

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Abstract

A basic reproductive number Ro is an important in dynamics of a newly emerged and rapidly growing infectious disease outbreak, such as COVID-19. However, the current researches indicated that Ro for COVID-19 is quite affected by many other factors or parameters.

To find the alternative index for the reality of spread of the COVID-19, a study based on the population of 2,067.14 millions from seven countries, USA, UK, Brazil, India, South Africa, Canada and Sweden, was conducted and the weekly new case ratio as index for mathematical method or anticipatable formula for application was introduced. In addition, it could be used for evaluating Ro value and setting a methodological formula or index for other contagious disease in the future.

Introduction

The transmission dynamics or epidemiological transmission model of COVID-19 is critical to develop effective public health and infection prevention measures to break chains transmission. To obtain and select the index for the transmission dynamics are key factors to be success in application of the model.

Ro, pronounced “R naught”, is a mathematical term that indicates how contagious an infectious disease is. It’s also referred to as the reproduction number Ro; defined as the average number of secondary cases attributable to infection by an index case after that case is introduced into a susceptible population. Ro is an important in dynamics of COVID-19 outbreak.

However, the current researches indicated that Ro for COVID-19 is quite affected by many other factors or parameters. The R0 for COVID-19 is a median of 5.7, according to a study published online in Emerging Infectious Diseases [*1*]. That’s about double an earlier R0 estimate of 2.2 to 2.7 [*2*]. A early serials of studies estimates of R0 for COVID-19 shows that the estimates ranged from 1.4 to 6.49, with a mean of 3.28, a median of 2.79 and inter quartilerange (IQR) of 1.16 [*3*].

As the range of R0 for COVID-19 varied, the estimation from their transmission dynamics or epidemiological transmission model of COVID-19 varied as well. How to find an indication as a useful calculation for predicting and controlling the transmission of COVID-19 disease is important and urgent for the public health in the world. Instated of Ro for COVID-19, a new ratio and formula for transmission dynamics of COVID-19 was introduced to anticipate and measure COVID-19 disease that may spread in a susceptible population in this study.

The study was based on the large set of data from the population of 2,067.14 millions in seven counties, USA, UK, Brazil, India, South Africa, Canada and Sweden, with varieties of geographic, culture, medical and health resources, and so on [*4*]. By comparing and analyzing the data in this large scale and taking account of other possible of varieties by country, a ratio as an coefficient used to a formula calculation was found for predicting and controlling the transmission of COVID-19.

Methods

Overview

The Ro for a contagious disease, such as COVID-19, is quite affected by many other factors or parameters and those factors or parameters are often mixed in their role in the reality, therefore we could take the account of those factors or parameters in the realty of transmission modules for study. Based on a large scale of data, large numbers of new cases with wide range of population, geographic and cultural differences and varieties of other factors, it could bring the actual index to set the experiencing model to estimate the trend of the transmission spread. In other word, the importance of those factors or parameters affecting the Ro for COVID-19 would be diluted and their role would be mixed in reflection on a large-scale base for the reality of transmission model of a contagious disease, COVID-19.

In this study, a new calculation method was adopted for a ratio, as an indication of transmitting speed of the COVID-19. The definition of the ratio: the number of weekly new cases divided by the number of previous weekly new cases. The ratio is expressed as A to B, A divided by B, or A: B; where the A and B is the number of new case based on daily reports and accumulated in a whole week. The new case is a tested and confirmed case and a week is a seven consecutive day counted. The main reason to select a period of week is diluting the daily reports by possible incidence or errors.

Steps:

1.Calcuating the number of the weekly new cases from each country. The number of weekly new cases in the seven countries between the early of March 2020 and July 10, 2020 showed in Table 1 (see the Tables attached).

2.Using each country's weekly number to divide the previous one and getting the respective ratio for each country in a week. The Table 2 (see the Tables attached) showed the ratio for the weekly changes in the seven countries between the early of March 2020 and July 10, 2020.

3.Selecting the outbreak starting point that the new cases were reported and accumulated to be close to 100 (range between 80-110) of the new case number, as of date of outbreak happened and then making an adjustment for the starting point for data computation in this study. The reason for doing so is that the new cases have to be reported to a significant level as an indication of the outbreak in the each country and it might happen in different points of timing (week). According to this starting point, a chronological (weekly) adjustment was set. For example, the outbreak in USA, from the reports and records of this study, happened two weeks early than it happened in India; therefore, the starting point of outbreak for India would be set as the same as the first week with USA's outbreak for data comparing purpose. This kind of adjustment was showed in Table 3 (see the Tables attached), the ratio by chronological order adjustment for the changes in the seven countries between the early of March 2020 and July 10, 2020.

4.Based on the adjustment of data in the Table 3, a chart for the weekly new case ratio in the seven countries is computed for analyzing and comparing (Chart 1). Finally, a formula or a model used to estimate the transmissibility of the COVID-19 virus was established (Formula 1) and a respective sensitivity analysis for the formula was conducted and the results were showed in Table 4.

Data:

1.The numbers of the new cases (data sources) are based on the reports and records of World Health Organization (WHO) [*5*]. Those reports are also available online published by Google News and Wikipedia [*6.7*]. The numbers of the new cases, daily confirmed and updated, from United States, Canada, United Kingdom, Sweden, Brazil and India, between early of March of 2020 and July 10, 2020, were collected for this study.

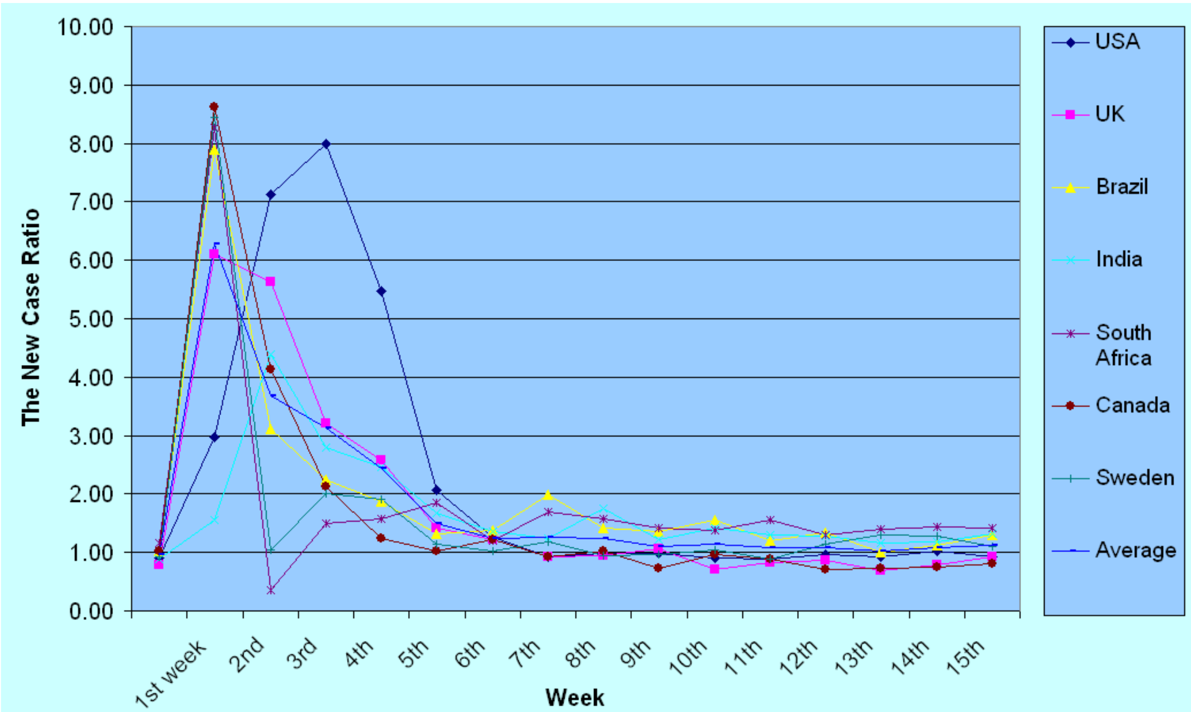
2. The new cases only included people who were tested and confirmed positive. The number of the new cases recorded by World Health Organization (WHO) was considered reliable though it may changes due to not reflecting some cases still being reported.

3. The population of seven countries are from the data published online by World Bank, European Union Institutions, Worldometer and Statistics South Africa [*4*]

Result

A serial set of the ratio for this study was consisted of 16 consecutive weeks as the first week of outbreak for all seven counties was adjusted to the same point for comparing and analyzing purpose. The weekly new case ratio and their trends of changes in seven countries between March 2020 and July of 2020 were showed in Chart 1.

Chart 1: The New Case Ratio for the Seven Countries Between March 2020 and July 2020.



1. The Chart 1 indicated that there was the similar ratio curve pattern in seven countries, even the varieties of other factors existing among the countries.

2. If the ratio higher than 2 was considered as the period of higher speed of transmission or the outbreak, it indicated the period would be between the first 2-5 weeks in seven countries.

3. Then, the ratios dropped down and most likely remain between 0.8-1.45 in the seven countries.

4. According to the ratio curve pattern, the ratio between 0.8-1.45, except the early outbreak period of 2-5 weeks, as a coefficient to formulate the estimation of the number of the new cases in next coming week becomes possible.

The ratio as a coefficient to formulate the estimation model, Formula 1, is described as follows:

$$X = nC$$

where, X: the extra number estimated in coming interval, a week;
C: the case number confirmed in previous interval, a week;
n: the coefficient of the new-case ratio, the previous interval, a week.

For example, based on the Table 1 and Table 2, the ratio for USA in 7th week was n=0.93, the number of weekly new case, C=203,054; then, the number of the weekly new case estimated would be: X=nC=0.93x203,054=201,023. While the actual the number of weekly new cases was reported in total of 200,860, the difference was 163, or the difference in percentage, 1.17%.

Sensitivity Analysis for the Formula:

Sensitivity is generally the ability to appreciate and respond to complex influences. Assumed that the ratio was available in the 6^{th} week, and then the ratio could be used for anticipating the number of new cases in 7th week. By using the number of the weekly new cases that actually counted in 7^{th} week to check the number anticipated by the formula model, a sensitivity analysis could be conducted. The sensitivity in the study was expressed as a percentage, the lower percentage, the better sensitivity. The methods for sensitivity analysis was based on the following calculations:

$$\frac{A-(B \times R)}{B} \times 100\%$$

where, A, the actual number of the weekly new cases;
B, the number of the weekly new cases before the test;
R, the ratio of the weekly new cases before the test;
(BxR, the new case number estimated by the Formula 1)

The testing numbers for a total of 11 consecutive weeks, starting at 6^{th} week, were calculated for the each country and the results of the sensitivity analysis were showed in Table 4 as follows:

Table 4: The sensitivity analysis for the weekly new case ratio

Week	USA	UK	Brazil	India	South Africa	Canada	Sweden
	%	%	%	%	%	%	%
1. (6th)	4.66	29.19	54.94	31.92	27.60	20.44	14.84
2. (7th)	1.17	2.80	4.80	12.07	63.77	28.90	22.63
3. (8th)	6.74	12.07	60.81	52.21	49.62	8.38	1.29
4. (9th)	1.39	35.17	57.28	53.91	12.84	29.87	7.99
5. (10th)	6.97	11.00	6.13	20.16	14.63	24.27	15.44
6. (11th)	4.14	3.86	19.64	12.52	4.52	8.01	24.96
7. (12th)	8.41	17.79	35.38	1.05	17.64	17.28	16.00
8. (13th)	9.34	8.98	15.32	12.70	25.43	2.51	1.47
9. (14th)	29.88	15.17	33.16	1.22	9.16	0.95	18.15
10. (15th)	22.11	10.04	10.16	15.09	3.55	6.31	13.95
11. (16th)	6.36	2.82	17.89	9.37	0.53	25.39	26.02
Average (%)	9.20	13.53	28.68	20.20	20.84	15.66	14.79
Range (%)	1.17 - 29.88	2.82 - 35.17	4.80 - 60.81	1.05 - 53.91	0.53 - 63.77	0.95 - 29.87	1.29 - 26.02

Discussion

1. The result of this study showed that, as the outbreak occurred, there was always a quite sharp peak of higher increase of the weekly new cases. It indicated that a rapid growth spread of COVID-19 in the early stage in a reality, showing the potential and/or natural value of its Ro.

2. However, this study, based on a large scale of population, didn't find that the number of weekly new cases would keep the same growth rate as its Ro might be referred in a reality of world, even considering the value of its Ro 2, as an exponent growth rate, the number of the weekly new cases would increase at very significant higher level.

3. The most interesting finding was the ratio that all seven countries showed the similar ratio after its outbreak though the absolute number varied among the countries. As the ratio was generated from the large scale of population, or an actual indexation from the reality of the pandemic of COVID-19, it should be reliable and valuable for estimation its trends of spread. It could be also used as the index in transmission dynamics, epidemiological surveillance and evaluation of the prevention measures.

4. The weekly new case ratio introduced in this study also indicated the prevalence of COVID-19 might remain a long epidemic period among the population or could be long-run challenge in public health field since the ratio would not dramatically drop in seven countries.

5. The weekly new case ratio intruded in this study was expressed by the percentage, not the exponent number; therefore, it could tolerate the range of changes and not bring an exponent power to the estimation or anticipation in an application of dynamics transmission of COVID-19. Though the sensitivity analysis for ratio showed that there were quite range by countries, but the average of sensitivity still acceptable and its estimation, by the Formula 1, marched quite well in some countries. The further studies for the reasons of its sensitivity varied by countries may need.

6. The factor why the growth ratio not so high after outbreak may be due to the treatment for the new cases confirmed, as it reduced the chance for infecting the population; or due to people to adopt other prevention measures, such as social distancing efforts, washing hands, and/or other relevant factors.

About author
Cheng Xia has his MD and MPH degree. His primary research interest lies in epidemiology, health economics and complex disease dynamics inferred from data science and mathematical modeling.
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Tables

Table 1: Number of the weekly new cases in the seven counties

Date (weekly)	USA	UK	Brazil	India	South Africa	Canada	Sweden
	new cases	new cases	new cases	new cases	new cases	new cases	new cases
Mar. 5, 2020	90	...	...	...	...	...	...
03/06/2020	167	78	...	...	...	...	92
03/13/2020	1, 911	476	...	89	...	103	777
03/20/2020	15, 276	2, 683	102	139	117	889	810
03/27/2020	83, 573	8, 585	806	611	968	3, 670	1, 630
04/03/2020	173, 139	22, 160	2, 513	1, 713	335	7, 792	3, 113
04/10/2020	219, 416	31, 362	5, 639	4, 214	498	9, 599	3, 578
04/17/2020	203, 054	38, 016	10, 582	7, 074	780	9, 779	3, 690
04/24/2020	200, 860	34, 985	14, 044	9, 617	1, 437	11, 961	4, 353
05/01/2020	196, 493	33, 175	19, 313	11, 913	1, 731	11, 173	4, 150
05/08/2020	178, 831	35, 462	38, 304	20, 977	2, 944	11, 373	4, 010
05/15/2020	160, 076	25, 436	54, 029	25, 628	4, 629	8, 179	4, 195
05/22/2020	154, 631	21, 042	72, 895	36, 477	6, 601	7, 867	3, 741
05/29/2020	143, 433	18, 219	112, 667	47, 352	9, 115	6, 937	4, 270
06/05/2020	145, 608	12, 534	134, 276	60, 971	14, 194	4, 918	5, 557
06/12/2020	135, 395	9, 748	180, 605	70, 765	18, 493	3, 610	7, 150
06/19/2020	170, 069	9, 060	183, 039	82, 997	25, 788	2, 684	7, 902
06/26/2020	241, 455	7, 511	204, 103	109, 869	36, 875	2, 165	7, 631
07/03/2020	329, 214	6, 015	264, 107	135, 143	52, 534	2, 296	5, 384
07/10/2020	377, 767	3, 864	261, 740	168, 256	73, 563	2, 035	2, 800

Table 2: The ratio for the number of the weekly new cases in seven countries

Date (weekly)	USA	UK	Brazil	India	South Africa	Canada	Sweden
	ratio	ratio	ratio	ratio	ratio	ratio	ratio
Mar. 5, 2020	0. 90	--	--	--	--	--	--
03/06/2020	1. 86	0. 78	--	--	--	--	0. 92
03/13/2020	11. 44	6. 10	--	0. 89	--	1. 03	8. 45
03/20/2020	7. 99	5. 64	1. 02	1. 56	1. 17	8. 63	1. 04
03/27/2020	5. 47	3. 20	7. 90	4. 40	8. 27	4. 13	2. 01
04/03/2020	2. 07	2. 58	3. 12	2. 80	0. 35	2. 12	1. 91
04/10/2020	1. 27	1. 42	2. 24	2. 46	1. 49	1. 23	1. 15
04/17/2020	0. 93	1. 21	1. 88	1. 68	1. 57	1. 02	1. 03
04/24/2020	0. 99	0. 92	1. 33	1. 36	1. 84	1. 22	1. 18
05/01/2020	0. 98	0. 95	1. 38	1. 24	1. 20	0. 93	0. 95
05/08/2020	0. 91	1. 07	1. 98	1. 76	1. 70	1. 02	0. 97
05/15/2020	0. 90	0. 72	1. 41	1. 22	1. 57	0. 72	1. 05
05/22/2020	0. 97	0. 83	1. 35	1. 42	1. 43	0. 96	0. 89
05/29/2020	0. 93	0. 87	1. 55	1. 30	1. 38	0. 88	1. 14
06/05/2020	1. 02	0. 69	1. 19	1. 29	1. 56	0. 71	1. 30
06/12/2020	0. 93	0. 78	1. 35	1. 16	1. 30	0. 73	1. 29
06/19/2020	1. 26	0. 93	1. 01	1. 17	1. 39	0. 74	1. 11
06/26/2020	1. 42	0. 83	1. 12	1. 32	1. 43	0. 81	0. 97
07/03/2020	1. 36	0. 80	1. 29	1. 23	1. 42	1. 06	0. 71
07/10/2020	1. 15	0. 64	0. 99	1. 25	1. 40	0. 89	0. 52

Table 3: The weekly new case ratio adjusted by chronological order

Week	USA	UK	Brazil	India	South Africa	Canada	Sweden	Average
	ratio	ratio	ratio	ratio	ratio	ratio	ratio	Ratio
Base Pts.	0. 90	0. 78	1. 02	0. 89	1. 17	1. 03	0. 92	0. 96
1st	1. 86	6. 10	7. 90	1. 56	8. 27	8. 63	8. 45	6. 27
2nd	11. 44	5. 64	3. 12	4. 40	0. 35	4. 13	1. 04	3. 69
3rd	7. 99	3. 20	2. 24	2. 80	1. 49	2. 12	2. 01	3. 12
4th	5. 47	2. 58	1. 88	2. 46	1. 57	1. 23	1. 91	2. 44
5th	2. 07	1. 42	1. 33	1. 68	1. 84	1. 02	1. 15	1. 50
6th	1. 27	1. 21	1. 38	1. 36	1. 20	1. 22	1. 03	1. 24
7th	0. 93	0. 92	1. 98	1. 24	1. 70	0. 93	1. 18	1. 27
8th	0. 99	0. 95	1. 41	1. 76	1. 57	1. 02	0. 95	1. 24
9th	0. 98	1. 07	1. 35	1. 22	1. 43	0. 72	0. 97	1. 10
10th	0. 91	0. 72	1. 55	1. 42	1. 38	0. 96	1. 05	1. 14
11th	0. 90	0. 83	1. 19	1. 30	1. 56	0. 88	0. 89	1. 08
12th	0. 97	0. 87	1. 35	1. 29	1. 30	0. 71	1. 14	1. 09
13th	0. 93	0. 69	1. 01	1. 16	1. 39	0. 73	1. 30	1. 03
14th	1. 02	0. 78	1. 12	1. 17	1. 43	0. 74	1. 29	1. 08
15th	0. 93	0. 93	1. 29	1. 32	1. 42	0. 81	1. 11	1. 12
16th	1. 26	0. 83	0. 99	1. 23	1. 40	1. 06	0. 97	1. 11