

Cyclical Behavior and Connection between Recovered and Sick COVID-19 Patients Worldwide

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Abstract

The article presents an approximation of the dynamic parabola of the ratio of serious and critical cases to the total number of patients with COVID-19 in the world with short-term prognosis. The purpose of the article is to study the statistical material and to search for patterns and relationships of indicators, which will help us understand the global trend of fight against the COVID-19. Gradual reduction of the number of critical cases is proven due to the development of new methods and implementation of strategies to defeat COVID-19 worldwide. The analysis clearly shows structure and correlation between the number of recovered patients and total COVID-19 patients in relative terms to the number of all infected by COVID-19 in the world, and this relationship is shown to be close and inverted. The cyclical nature of the behavior of such interconnections is proved, which testifies both to the natural and objective regularity. The proposed study results will help medics and government in all countries to better cope with the problem and prepare in advance for the outbreak of disease.

Keywords: critical cases, number of patients, number of recovered patients, number of infected, correlation coefficient, approximation, cycle

JEL Classification: I110, I180, I190, J110, M200

1. Introduction

COVID-19 continues to expand around the world and captures new countries. The main danger of COVID-19 is that it affects the lungs and can cause severe pneumonia. A well-known prediction by scientists at the Harvard University is that 40-70% of the Earth's population will fall ill with COVID-19 at some point. It should be noted that some countries do not have a disease surveillance system comparable to that of China, and therefore the risks of the virus spreading within these countries are higher. COVID-19 already caused a serious damage to economies and healthcare systems of the world, and disrupted modern society on a large scale. Under these conditions, there are three possible scenarios: unlikely (countries simultaneously defeat the virus), dangerous (scenario of many becoming infected simultaneously with dire consequences) and continual (gradual elimination of disease outbreaks and invention of vaccine).

According to experts, the imperfection of the tests, limitations of their number and overload on the medical system lead to the fact that the official statistics on COVID-19 markedly diverge from the real situation; mathematical models help improve this.

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Diagnosis and coronavirus infection cases make it possible to adequately assess the pandemic situation and understand the goals of preparedness.

The purpose of the article is to study the statistical material and to search for patterns and relationships of indicators, which will help understand the global trends in the fight against COVID-19. The research is based on methods of approximation of statistical dynamic series of dimensionless quantities with the further possibility of using extrapolation as a short-term prediction for the development of studied statistical series.

Thus, in our opinion, the development of new strategies follows careful study of statistical material, and is based on the search for patterns and interrelations of indicators, which will contribute to our understanding of global trends.

2. Literature review

In the world practices of pandemic control, the aspect of cancellation of certain types of medicines, which were routinely used to treat similar symptoms before, presented in the scientific work (“Topische Steroide trotz COVID-19 nicht absetzen!”, 2020) is considered important. In the publication of Chinese experts (Tao et al., 2020) the authors recommend Background Chest CTs, which may be considered a major tool for detection of COVID-19 symptoms in epidemic areas. Japanese scientists (Shirato et al., 2020) analyzed the beginnings and spread of COVID-19 between China and Japan, and focus on the specialized medical tests that have identified cases of infection in Japan.

The authors of the scientific paper (Maxwell, Perl & Cutrell, 2020) emphasize the new requirements for changing the primary strategy of the fight against COVID-19 in China. They emphasize the need to focus on mitigation of effects of globalization. The authors emphasize that, today, the primary goal of health care systems is the global involvement of international medical community, governments, and society in general.

The Chinese authors (Qin et al., 2020) highlight the potential clinical utility of proposed imaging technique in the differential diagnosis of complex cases, which is an achievement of the worldwide pandemic practice. The study of Global Health Governance Working Group for COVID-19 Outbreak, Institute for Global Health and School of Public Health (Guo, Huang et al., 2020) analyzed the global epidemiological trends of COVID-19, as well as the impact of the pandemic on global health security, diplomacy and the social environment in China. The paper provides strategic recommendations for China's response to the spread of the pandemic.

In the publication of Chinese analytics (Liu, Xu, Yuan et al., 2020), a map of the spatial-temporal changes in cases is presented. The authors constructed a population growth curve that shows the hypotheses of the epidemic picture. A statistical description and analysis of the epidemic situation in Anhui province was also conducted. The importance of urgent analysis of effective and specific methods of prevention and treatment of COVID-19 is presented in the scientific paper of Yan C-X., Li J., Shen X. (Yan, Li, Shen et al., 2020). The authors considered the potential use of biologic agents and presented a report that will undoubtedly be useful for COVID-19 treatment worldwide. Figure 1 presents the dynamics of cases in China and other countries cited by the authors Klaus-Jürgen Gern & Philipp Hauber (Gern & Hauber, 2020).

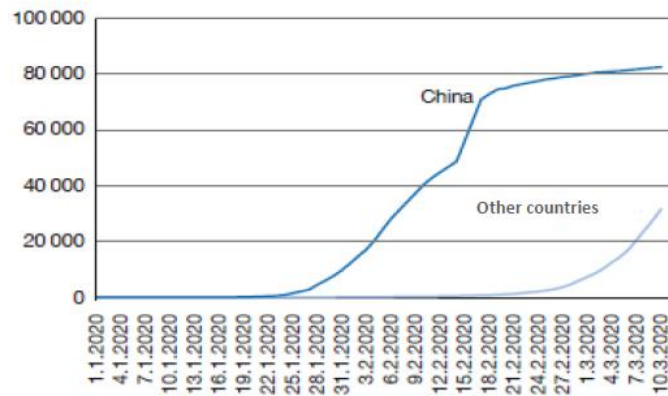


Figure 1. Dynamics of cases in China and other countries

Notes: based on data of World Health Organization (Gern & Hauber, 2020)

Figure 1 shows that the second curve characterizing other countries is delayed but with similar growth rates. Issues of consequences for the economy and changes in consumer behavior are also considered. It is emphasized that quarantine measures can also prevent the production of goods and production processes.

In scientific paper Wang M. (Wang, 2020) the authors show that prevention and control measures have achieved remarkable results. It is suggested that a pandemic strategy in the future should have a clear system of measures that includes not only disease control but also laboratory testing capabilities.

Scientists are quick to respond to COVID-19 events. In 2020, a number of scientific studies have emerged that are substantiated by mathematical models. In an article by a group of scientists at the Centre for Mathematical Modelling of Infectious Diseases, London School of Hygiene & Tropical Medicine (Kucharski et al., 2020), the mathematical model is based on the assumption that symptomatic cases are distributed by the Poisson law and the incubation period is assumed to be distributed by the Erlang law. The probability was laid for the cases that were removed from Wuhan during the height of the epidemic. The Monte Carlo simulation model was used to determine the rate of transmission of infection over time. The target function was to determine the baseline reproduction over time (R_t), which is the average of secondary cases of infection. To evaluate the occurrence of new outbreaks outside Wuhan, there were used the R_t estimates to simulate new outbreaks, taking into account the individual difference in transmission of infection. The authors concluded that the probability of a single outbreak of SARS-CoV-2 with SARS-like or syndrome (MERS) is equal to 0.17-0.25 (Figure 2).

The results of mathematical models widely presented in the scientific work of Jomar F. Rabajante (Rabajante, 2020) are consistent with recommendations of the World Health Organization (World Health Organization, 08/02/2020) to halt the spread of viruses if countries respond to early detection. Therefore, modeling of processes related to prediction of infection spread is important, and constitutes a pressing research problem.

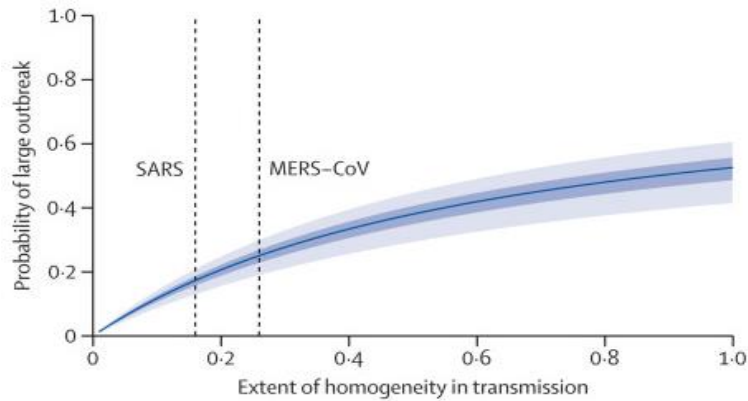


Figure 2. The probability of a single outbreak of SARS-CoV-2, SARS and MERS
Notes: based on data of World Health Organization (Kucharski et al., 2020)

3. The research methodology

The study is based on the methods of approximation of statistical dynamic series of dimensionless quantities. We review the ratio of serious and critical cases to the total number of infected, the ratio of the number of recovered to the total number of infected, and the ratio of the number of the sick to the total number of infected ones. This made possible the use of extrapolation as a means of short-term prediction of development of statistical series.

4. Results

Table 1 presents the dynamics of the ratio of serious and critical cases to the total number of the sick with COVID-19 (K1) in the world for the period 02/02/2020–08/04/2020.

Table 1. Dynamics of the ratio of serious and critical cases to the total number of patients (K1) in the world for the period 02/02/2020–08/04/2020

Date	02/02/2020	03/02/2020	04/02/2020	05/02/2020	06/02/2020	07/02/2020	08/02/2020
K1	0,1440481	0,1481521	0,1429395	0,1452911	0,168136	0,1928495	0,183863
Date	09/02/2020	10/02/2020	11/02/2020	12/02/2020	13/02/2020	14/02/2020	15/02/2020
K1	0,1803839	0,1942652	0,2106289	0,1929152	0,194065	0,1933829	0,1949078
Date	16/02/2020	17/02/2020	18/02/2020	19/02/2020	20/02/2020	21/02/2020	22/02/2020
K1	0,1821099	0,20056454	0,2051243	0,2075159	0,2094307	0,2096622	0,2169374
Date	23/02/2020	24/02/2020	25/02/2020	26/02/2020	27/02/2020	28/02/2020	29/02/2020
K1	0,1884664	0,1801446	0,1774828	0,1755488	0,1817148	0,18225	0,1817972
Date	01/03/2020	02/03/2020	03/03/2020	04/03/2020	05/03/2020	06/03/2020	07/03/2020
K1	0,1784717	0,1782049	0,1737211	0,1699763	0,1597032	0,1513239	0,1430334
Date	08/03/2020	09/03/2020	10/03/2020	11/03/2020	12/03/2020	13/03/2020	14/03/2020
K1	0,1360608	0,1275114	0,1226913	0,1093014	0,0991481	0,0870817	0,0781388

Date	15/03/2020	16/03/2020	17/03/2020	18/03/2020	19/03/2020	20/03/2020	21/03/2020
K1	0,068727	0,0640434	0,0651067	0,0553759	0,0493804	0,0458189	0,0476897
Date	22/03/2020	23/03/2020	24/03/2020	25/03/2020	26/03/2020	27/03/2020	28/03/2020
K1	0,0475845	0,0475441	0,0446923	0,0437508	0,0513654	0,0512584	0,0519439
Date	29/03/2020	30/03/2020	31/03/2020	01/04/2020	02/04/2020	03/04/2020	04/04/2020
K1	0,049945	0,0512487	0,0506491	0,0511471	0,0503112	0,0486742	0,0476761
Date	05/04/2020	06/04/2020	07/04/2020	08/04/2020			
K1	0,0487316	0,0475155	0,0474652	0,0457232			

Notes: developed by the authors based on data of Worldometers ("COVID-19 Coronavirus Pandemic — Worldometer", 2020)

According to Table 1 we create a graph, shown on Figure 3. After 01/03/2020, the decline of K1 began with some stabilization. New techniques have been developed rapidly in the world within a month and implementation of important strategies started on 01 March 2020, and K1 begun to decline.

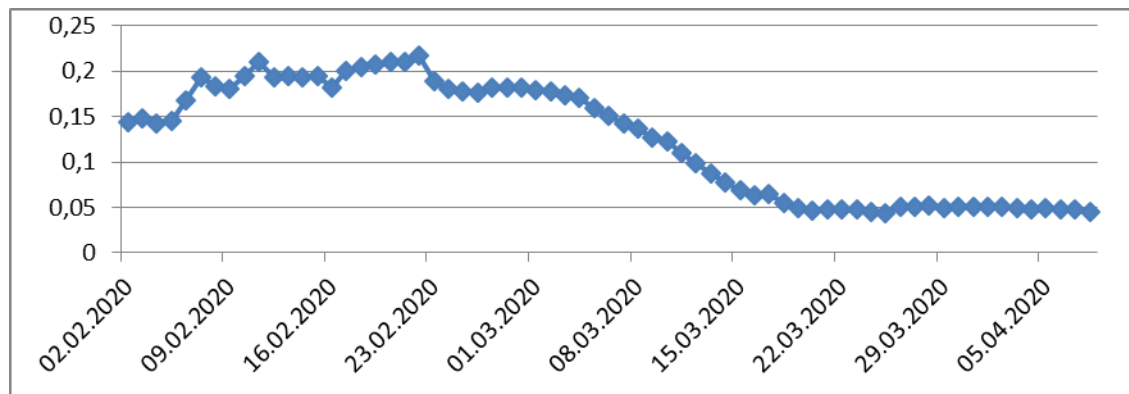


Figure 3. Dynamics of the ratio of serious and critical cases to the total number of the sick with COVID-19 (K1) in the world for the period 02/02/2020–08/04/2020

Notes: developed by the authors based on data of Worldometers ("COVID-19 Coronavirus Pandemic — Worldometer", 2020)

Figure 4 presents the approximation of K1 for the period 26/03/2020–08/04/2020 parabola with a coefficient of determination of 0.8831 and with a 5-day forecast. This makes it possible to assert that the number of critical cases is on the decline with the tendency of gradual decrease. Thus, the short-term prognosis has positive dynamics.

Table 2 presents the dynamics of the number of recovered and the sick to total the number of infected in the world for the period 19/01/2020–08/04/2020. The matter of interest here is the statistical analysis with the goal of identification of qualitative patterns of absolute growth of indicators.

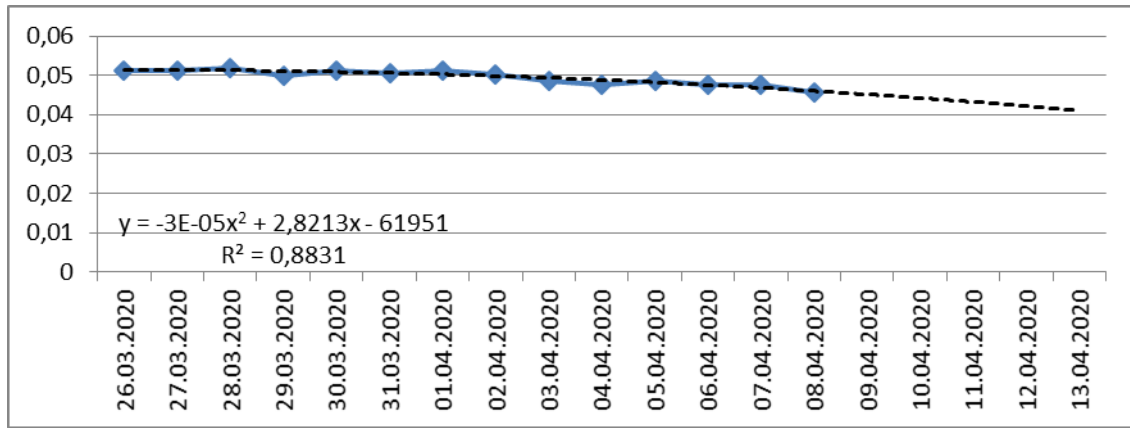


Figure 4. Approximation of K1 parabola with short-term prognosis.

Notes: developed by the authors based on data of Worldometers ("COVID-19 Coronavirus Pandemic — Worldometer", 2020).

Table 2. The dynamics of the number of recovered and the sick from the number of infected in the world for the period 19/01/2020–08/04/2020

Date	19/01/2020	20/01/2020	21/01/2020	22/01/2020	23/01/2020	24/01/2020	25/01/2020
Infected	198	291	440	555	654	941	1438
Recovered	25	25	25	28	30	36	39
Sick	170	260	406	510	606	879	1357
Date	26/01/2020	27/01/2020	28/01/2020	29/01/2020	30/01/2020	31/01/2020	01/02/2020
Infected	2118	2927	5578	6165	8235	11302	13950
Recovered	52	61	107	126	143	222	284
Sick	2010	2784	5340	5906	7921	10867	13407
Date	02/02/2020	03/02/2020	04/02/2020	05/02/2020	06/02/2020	07/02/2020	08/02/2020
Infected	16787	19881	23892	28276	30818	34392	37121
Recovered	472	623	852	1124	1487	2011	2616
Sick	15953	18832	22548	26588	28697	31662	33699
Date	09/02/2020	10/02/2020	11/02/2020	12/02/2020	13/02/2020	14/02/2020	15/02/2020
Infected	40151	42763	44803	48076	60370	66887	69032
Recovered	3244	3946	4683	5150	6295	8058	9395
Sick	36001	37804	39007	41723	52704	57306	57971
Date	16/02/2020	17/02/2020	18/02/2020	19/02/2020	20/02/2020	21/02/2020	22/02/2020
Infected	71226	73260	75138	75641	76199	77277	78599
Recovered	10865	12583	14352	16121	18177	19919	22886
Sick	58591	58809	58779	57398	55775	54998	53255

Date	23/02/2020	24/02/2020	25/02/2020	26/02/2020	27/02/2020	28/02/2020	29/02/2020
Infected	78985	79570	80415	81397	82784	84173	86022
Recovered	23419	25227	27905	30384	33350	36880	39801
Sick	53097	51714	49802	48243	46617	44417	43279
Date	01/03/2020	02/03/2020	03/03/2020	04/03/2020	05/03/2020	06/03/2020	07/03/2020
Infected	88352	90306	92864	95177	98050	101888	105956
Recovered	42728	45705	48469	51435	54125	56123	58628
Sick	42623	41514	41227	40488	40569	42300	43759
Date	08/03/2020	09/03/2020	10/03/2020	11/03/2020	12/03/2020	13/03/2020	14/03/2020
Infected	109786	114223	118644	125811	134322	145114	155862
Recovered	60960	62834	65105	67051	68898	70920	74438
Sick	45024	47384	49270	54153	60455	68786	75609
Date	15/03/2020	16/03/2020	17/03/2020	18/03/2020	19/03/2020	20/03/2020	21/03/2020
Infected	169126	181686	197467	217325	242209	272068	304327
Recovered	76598	78339	81691	84383	86714	90618	94677
Sick	86036	96216	107823	124025	145503	170148	196667
Date	22/03/2020	23/03/2020	24/03/2020	25/03/2020	26/03/2020	27/03/2020	28/03/2020
Infected	335366	374708	417348	463371	525300	590287	657915
Recovered	97594	101523	108300	113802	123329	132447	141419
Sick	223161	256835	290453	328657	378270	430895	486063
Date	29/03/2020	30/03/2020	31/03/2020	01/04/2020	02/04/2020	03/04/2020	04/04/2020
Infected	721330	772226	856910	934825	1014296	1097810	1192619
Recovered	151004	160243	177141	193989	212018	228405	246063
Sick	536370	574961	637662	693647	749296	810265	882329
Date	05/04/2020	06/04/2020	07/04/2020	08/04/2020			
Infected	1262320	1331104	1380345	1431706			
Recovered	260338	277737	295764	302150			
Sick	933480	979427	1006337	1047476			

Let us consider the ratio of the number recovered to the total number of infected (coefficient K2), and the ratio of the number of the sick to infected (K3) for the period 19/01/2020–08/04/2020 (Figure 5). The correlation coefficient is -0.998539, which indicates a close inverse relationship between K2 and K3.

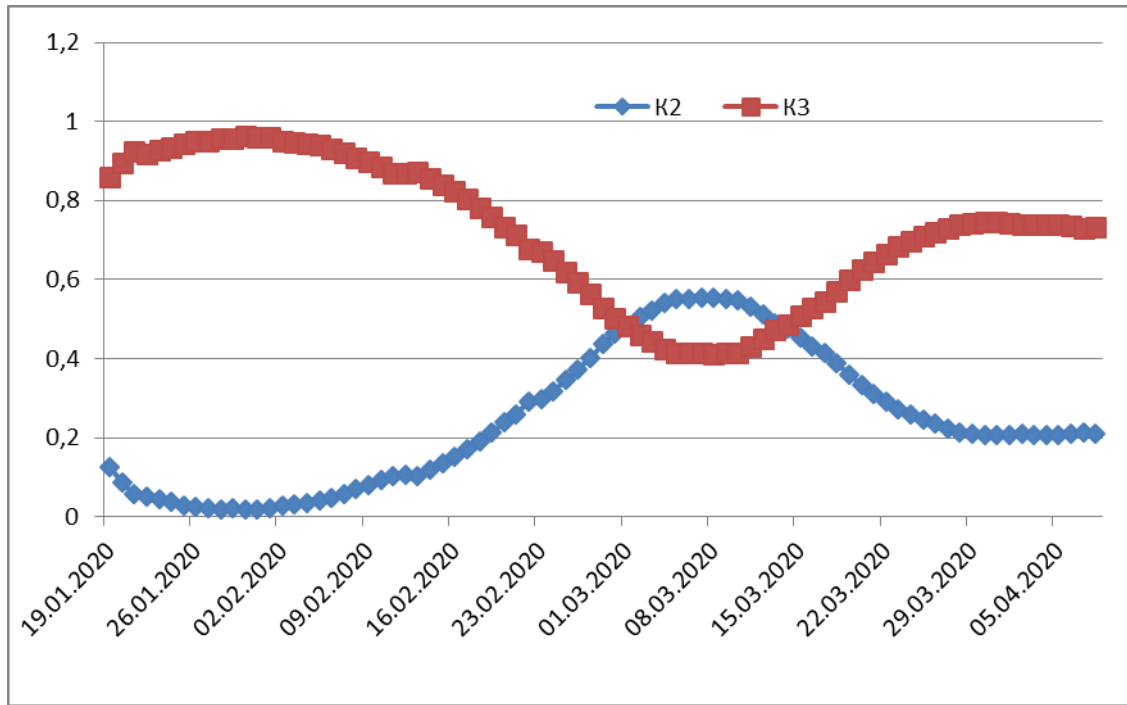


Figure 5. Dynamics of K2 and K3 coefficients for the period 19/01/2020–08/04/2020

Notes: developed by the authors based on data of Table 2.

As we can see from Figure 5, there are 2 points of intersection of two graphs corresponding to two dates 01/03/2020 and 14/03/2020. Therefore, it is of interest to examine the next interval from 14/03/2020.

Figure 6 presents an approximation of the dynamic series of the coefficients K2 and K3 for the period 14/03/2020–08/04/2020 with a 15-day forecast.

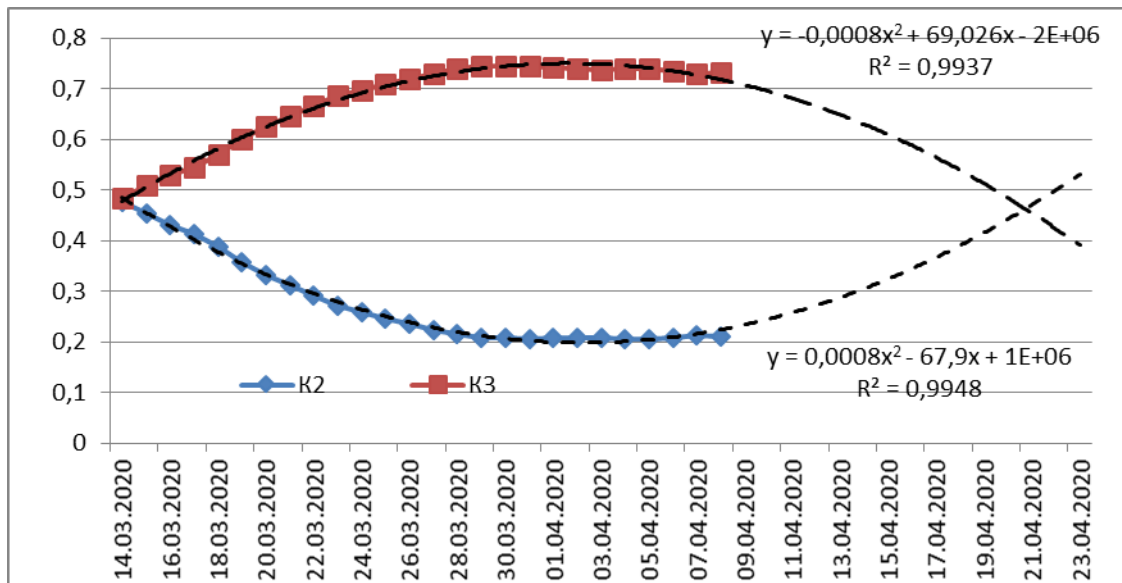


Figure 6. Approximation of the dynamic series K2 and K3 for the period 14/03/2020–08/04/2020 with a forecast up to 23/04/2020

Notes: developed by the authors based on data of Worldometers ("COVID-19 Coronavirus Pandemic — Worldometer", 2020), Figure 5.

As can be seen from Figure 6, the point of the predicted intersection falls on 21.04.2020 and again the cyclical nature of the behavior of K2 and K3 continues.

Therefore, by analyzing Fig. 3, 4, we can state the cyclic nature of the behavior of the two coefficients K2 and K3 with close coupling. The first cycle ended on 01/03/2020 (equality $K2 = K3$), the second cycle ended on 14/03/2020. In the second cycle, the values of the coefficients relative to each other changed. According to the forecast, the third cycle will end on April 21 with the expected divergence of schedules.

4. Conclusions

We constructed a statistical dynamic series of the ratio of serious and critical cases to the total number of COVID-19 sick in the world for the period from 02/02/2020 to 08/04/2020, based on statistics. We conclude that due to the efforts of medics and scientists to establish treatment protocols, find new techniques, involve mass security tools, and implementation of important strategies after 01/03/2020 we see beginning of decline of K1 with some stabilization today. We presented the statistical dynamic series of the ratio of the number of recovered to the total number of infected, and the ratio of the number of the sick to infected for the period 19/01/2020–08/04.2020 are presented.

Therefore, our analysis shows a clear structure and relationship between given indicators of number of recovered patients to total infected (K2), and currently infected to total infected (K3). This relationship is close, with correlation coefficient of -0.998539, and inverted, demonstrating very strong negative correlation. We carried out an approximation of time series, making extrapolation of K2 and K3 possible from 14/03/2020–8.04.2020 data with prognosis to 23/04/2020, where we see the third cycle, with the beginning of the fourth cycle likely on 21/04/2020.

In our opinion, this analysis demonstrates the natural regularity and objective normality of cyclical behavior of the coefficients K2 and K3, which will likely affect future behavior.

References

- [1] COVID-19 Coronavirus Pandemic - Worldometer. (2020). Retrieved 8 April 2020, from <https://www.worldometers.info/coronavirus>.
- [2] Gern, K.J., Hauber, P. (2020). Business cycle highlight: Coronavirus keeps the global economy in suspense. Wirtschaftsdienst, Springer; ZBW - Leibniz Information Centre for Economics, 100(3), 223-224. <https://doi.org/10.1007/s10273-020-2607-5>.
- [3] Guo, Y., Huang, Y.M., Huang, J. et al. (2020). COVID-19 Pandemic: global epidemiological trends and China's subsequent preparedness and responses. Zhonghua Liuxingbingxue Zazhi. 41(5), 643-648. DOI: <https://doi.org/10.3760/cma.j.cn112338-20200301-00222>.
- [4] Kucharski, A., Russell, T., Diamond, C., Liu, Y., Edmunds, J., & Funk, S. et al. (2020). Early dynamics of transmission and control of COVID-19: a mathematical modelling study. The Lancet Infectious Diseases. [https://doi.org/10.1016/s1473-3099\(20\)30144-4](https://doi.org/10.1016/s1473-3099(20)30144-4).
- [5] Liu, M., Xu, H. L., Yuan, M., Liu, Z. R., Wu, X. Y., Zhang, Y., Ma, L. Y., Gong, L., Gan, H., Zong, W. W., Tao, S. M., Liu, Q., Du, Y. N., & Tao, F. B. (2020). Analysis on epidemic situation and spatiotemporal changes of COVID-19 in Anhui. Zhonghua Yu Fang Yi Xue Za Zhi [Chinese Journal of Preventive Medicine], 54(0), E019. <https://doi.org/10.3760/cma.j.cn112150-20200221-00150>.
- [6] Maxwell, D., Perl, T., & Cutrell, J. (2020). "The Art of War" in the Era of Coronavirus Disease 2019 (COVID-19). Clinical Infectious Diseases. <https://doi.org/10.1093/cid/ciaa229>.
- [7] Qin, C., Liu, F., Yen, T., & Lan, X. (2020). 18F-FDG PET/CT findings of COVID-19: a series of four highly suspected cases. European Journal of Nuclear Medicine and Molecular Imaging, 47(5), 1281-1286. <https://doi.org/10.1007/s00259-020-04734-w>.

- [8] Rabajante, J. F. **(2020)**. Insights from early mathematical models of 2019-nCoV acute respiratory disease (COVID-19) dynamics. arXiv preprint arXiv:2002.05296. <https://arxiv.org/ftp/arxiv/papers/2002/2002.05296.pdf>.
- [9] Shirato, K., Nao, N., Katano, H., Takayama, I., Saito, S., & Kato, F. et al. **(2020)**. Development of Genetic Diagnostic Methods for Novel Coronavirus 2019 (nCoV-2019) in Japan. Japanese Journal Of Infectious Diseases. 10.7883/yoken.jjid.2020.061.
- [10] Tao, A., Zhenlu, Y., Hongyan, H., Chenao, Z., Chong, C., & Wenzhi, L. et al. **(2020)**. Correlation of Chest CT and RT-PCR Testing in Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases. Radiology. Retrieved 26 February 2020, from <https://pubs.rsna.org/doi/10.1148/radiol.2020200642>.
<https://doi.org/10.3760/cma.j.issn.0253-2727.2020.0001>.
- [11] Topische Steroide trotz COVID-19 nicht absetzen!. **(2020)**. MMW - Fortschritte Der Medizin, 162(6), 3-3. <https://doi.org/10.1007/s15006-020-0308-z>.
- [12] Wang, M. **(2020)**. The importance of strengthening the ability of fundamental disease prevention and control system from the perspective of the epidemic situation of COVID-19. Chinese Journal of Preventive Medicine, 54(0), E020. <https://doi.org/10.3760/cma.j.cn112150-20200220-00149>.
- [13] World Health Organization. **(2020)**. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). Geneva, Switzerland. Retrieved 08 February 2020, from [https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-\(2019-ncov\)](https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)).
- [14] Yan, C. X., Li, J., Shen, X., Luo, L., Li, Y., Li, MY. **(2020)**. Biological Product Development Strategies for Prevention and Treatment of Coronavirus Disease 2019. Journal of Sichuan University (Medical Science Edition), 51(2), 139-145. I: <https://doi.org/10.12182/20200360506>.

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