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Original Article

How to Reduce Misinterpretation of Quantitative Infection Risk by Assessment Parameters Associated with the COVID-19 Pandemic

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ABSTRACT

Introduction: The quantitative information on the risk of infection in the COVID-19 pandemic is calculated currently exclusively on the base of new infections per day, which only contribute 6.60%±1.34% to the 100% contagious acute infections and are, therefore, not proportional to the risk of infection. All methods and results presented here are shown for data in Germany, but can be transferred to any other region worldwide.
Methods: More precise parameters as are used at present, are based on acute infections: stress index with information about the distance to the stress limit of the health system, the density of the sources of infection and the change in acute infections during the last 5 days are suggested here.
Results: The comparison of the results of the current and the new assessment parameters shows that large daily fluctuations in new infections of up to ±22% lead to unnecessary uncertainties. The new assessment parameters are correspondingly more precise. The 7-days incidence warning thresholds introduced by German law in November 2020 and April 2021 are defined on the base of new infections. As a result, the real infection risks can be incorrectly assessed due to the large fluctuations of the 7-days incidence values up to ±23%, so that legal conflicts can arise if legally prescribed protective measures are objectively unjustified or introduced too late.
Conclusion: By moving from new infections to acute infections as a base for calculation, infection risks can be described more precisely and even unjustified, expensive protective measures can be avoided.

Introduction

The risk of being infected by the COVID-19 virus primarily depends on the number of sources of infection in the region in question, i.e. the number of acute infections F. Depending on the virus variant present, the risk of infection from a single virus patient can be higher than with the original virus. This additional risk can only be taken into account by specifying the spread of the infected variant, which varies greatly over time, and should not be dealt with here.

The number of acute infections F can easily be

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calculated according {Equ.3} from the three daily published basic parameters "Cumulative Infections A, Recovered B and Deaths C".[1] The risk of infection can be determined more precisely from a risk-proportional parameter such as acute infections F, but can be estimated with great uncertainty from only one of the three base parameters (cumulative infections A).

From this one base parameter A and its daily change E, all risk-assessing parameters are calculated at present, i.e. based on variables that are not risk-proportional. Attempts are undertaken to reduce the resulting major uncertainties in assessing the risk of infection by averaging over longer periods of time (4 to 7 days).

It is proposed here to start from the risk-proportional, contagious acute infections F. Then the uncertainties mentioned above of the determined risk-proportional assessment parameters do not apply and can in some cases be determined more easily and more precisely.

After the explanation of the previous set of assessment parameters and the introduction of the new set proposed here, a tabular comparison of these two parameter sets is presented for the first year of the pandemic as evidence of the advantages of the new parameters.

All quantitative results are valid for the region "Germany", but can be applied also in the same way to any smaller region or any other country worldwide.

In the following, all results (except for 7-days incidence values) are cited on the base of new infections E from the literature.[1, 3] All results in the text and in the tables based on the acute infections F including all incidence values (based on E and F) are calculated according to the formula in the text or in the column heading.

In order to shorten the article, only a small part of all relevant data is presented in Tables 1, 2 and 3, so that the complete overview of the pandemic data since its inception and some less important evidence are not presented here.

Base parameters

All quantitative statements on the risk of infection from COVID-19 are based on the following three base parameters e. g.[1] (which are used here):

A: Cumulative infections (contagious infected people)

B: Cumulative recoveries

B is known very precisely with an uncertainty range of approx. ±0.1%. (Uncertainty of the recovered are 50 to 100 people per day compared to the number of cumulative recoveries of currently over 1 million)

C: Cumulative deaths

Current assessment parameters

D: The doubling time D_E indicates in how many days the number E of new infections doubles. This parameter is only relevant in the case of a rapid increase in the number A of acute infections, i.e. in the initial phase of the COVID-19 pandemic (March - April 2020) and the second wave (September - December 2020). As soon as exponential growth is not feared longer, the doubling times lengthen and become infinite if the number of sick remains constant.

R: Robert May and Roy Anderson[2] analyzed the HIV/AIDS epidemic in 1987 and successfully used the assessment parameter "reproductive number R" for various applications. For COVID-19 pandemic

Table 1. COVID-19-data for Germany for the period between first and second wave
Data for A up to E according[1], F_0 is estimated provisionally as 80.000 people. H_0 = 83,020,000 inha-bitants in Germany 2019, R-values up to May 15, 2020 (RKI graph, later digital statements of RKI[3])

Date	Basis Parameters			Actual assessment parameters on the base of parameter E			New (here presented) assessment parameters on the base of parameter F				E/F share of parameter E in F [%]
Year 2020	A: Cumulative infections	BEstimated cumulative recoveries	C: Cumulative deaths with COVID-19 infection	E:New infections [average within 7 days]	R_4 | R_7 Reproduction numbers [within 4 respectively 7 days]		F =A-B-C: Acute contagious infections	G = F/F_0: Stress index	H = H_0/F: Infection-source density: 1 of	K = F_x/F_{x-5}: Relative change of acute infections within 5 days	E/F: share of parameter E in F [%]
05.03.	564	0	2	143	-	-	562	0.007	147,722	5.62	25.44
10.03.	1,799	0	8	307	3.4	3.1	1,791	0.022	46,251	3,19	17.00
15.03.	6,865	50	23	1,187	2.1	2.1	6,792	0.085	12,223	3.79	17.48
20.03.	20,091	200	69	2,667	1.0	1.1	19,822	0.373	4,188	2.92	13.45
25.03.	37,856	5,900	210	3,958	1.0	0.9	31,746	0.397	2,615	1.60	12.47
30.03.	66,125	16,100	616	4,226	0.9	1.0	59,409	0.743	1,397	1.87	8.80
05.04.	100,024	30,600	1,576	6,074	0.9	0.9	67,848	0.848	1,224	1.14	8.97
10.04.	120,157	55,980	2,688	5,403	0.9	0.8	61,489	0.769	1,350	0.91	8.79
15.04.	133,456	71,995	3,592	2,078	0.8	0.7	57,869	0.723	1,435	0.94	3.59
20.04.	146,653	91,500	4,706	1,809	0.7	0.8	50,447	0.631	1,646	0.87	3.59
25.04.	155,755	109,800	5,.834	2,146	0.8	0.8	40,121	0.502	2,069	0.80	5.35
30.04.	161,994	123,500	6,535	1,478	0.7	0.8	31,959	0.399	2,598	0.80	4.62
05.05.	166,706	135,278	6,993	738	1.0	0.9	24,435	0.305	3,398	0.76	3.02
10.05.	171,324	144,400	7,549	771	0.7	0.8	22,375	0.280	3,710	0.92	3.45
15.05.	174,478	151,537	7,884	868	0.8	0.8	15,057	0.188	5,514	0.67	5.76
20.05.	178,150	156,966	8,136	760	0.88	0.87	13,048	0.160	6,363	0.87	5.19
25.05.	180,338	160,881	8,287	301	0.84	0.83	11,170	0.140	7,432	0.86	5.07
30.05.	182,922	164,245	8,504	587	1.03	0.95	10,173	0.130	8,161	0.91	4.51
05.06.	184,924	167,909	8,635	477	0.72	0.84	8,380	0.100	9,907	0.88	3.88
10.06.	186,522	170,529	8,748	327	0.86	0.86	7,245	0.091	11,459	0.86	5.18
15.06.	187,518	172,089	8,801	317	1.02	0.93	6,628	0.083	12,526	0.91	4.95
20.06.	190,670	174,567	8,895	459	1.79	1.55	7,208	0.090	11,518	1.09	6.37
24.06.	192,786	176,325	8,924	583	0.72	1.17	7,537	0.094	11,015	1.01	7.87
25.06.	193,257	176,422	8,933	601	0.59	1.11	7,902	0.099	10,506	1.03	7.61
30.06.	195,398	177,770	8,979	489	0.83	0.67	8,649	0.108	9,599	1.09	5.65
05.07.	197,423	181,680	9,012	412	0.96	0.94	6,731	0.084	12,334	0.78	6.27
10.07.	199,254	183,960	9,062	367	0.80	0.90	6,232	0.078	13,322	0.93	5.89
15.07.	200,700	186,000	9,079	346	1.02	0.95	5,621	0.070	14,770	0.90	6.16
20.07.	203,325	188,070	9,094	402	1.15	1.13	6,287	0.079	13,205	1.12	6.39
25.07.	205,976	18,908	9,124	489	1.08	1.16	6,944	0.087	11,956	1.10	7.04
30.07.	208,819	191,279	9,137	603	1.02	1.17	8,403	0.105	9,880	1.21	7.18
05.08.	213,090	194,435	9,166	709	0.90	0.97	9,489	0.119	8,749	1.05	7.47
10.08.	217,300	197,083	9,203	856	1.09	1.05	11,014	0.138	7,538	1.16	7.77
15.08.	224,488	200,756	9,235	1,044	1.14	1.13	14,517	0.181	5,719	1.32	7.20
20.08.	229,706	205,000	9,257	1,228	1.04	1.14	15,449	0.193	5,374	1.06	7.95
25.08.	237,570	210,350	9,281	1,361	0.90	0.92	17,948	0.224	4,626	1.16	7.58
30.08.	242,835	215,250	9,300	1,291	1.04	0.95	18,285	0.229	4,540	1.02	7.06
05.09.	251,058	223,550	9,329	1,144	1.00	0.97	18,179	0.227	4,567	0.97	6.29
10.09.	257,376	229,800	9,345	1,844	0.99	1.04	18,231	0.228	4.554	1.00	10.11

Average E/F=6.60%±1.34% (variation±22%) with data from each day in the period May 20-September 10, 2020

R indicates the number of newly infected people, who, on average, are infected by one acute infected person. R is defined generally by May and Anderson with four factors:
R=duration [days of infection] × chances [average contacts per day] × probability of transmission [of infection through contact] × susceptibility [of people] {Equ. 1}
Due to the similar mode of action, this parameter R was useful for various types of applications in medicine, finance, physics and chemistry, which is probable why the Robert Koch Institute (RKI) in Germany also use and recommend this parameter for the Covid-19 pandemic.
R for COVID-19 cannot be determined directly using the four-factor formula above, as quantitative data are not available for these factors. Therefore, R can be estimated only using the Newcasting Method in complex calculations with a very large range of uncertainty, specified by RKI.[3] Averaging over 4 days (R_4) leads to an uncertainty range of ±21.2%. In order to reduce the large random fluctuations, the RKI also introduced a second parameter that is an average over 7 days (R_7) with an uncertainty range of ±11.7%. However, the results are often inadequate and sometimes even misleading: It can happen that the uncertainty ranges of R_4 and R_7 do not even partially overlap (Table 1, June 25, 2020: R_4=0.59, uncertainty range ΔR_4=0.48-0.73 and R_7=1.11, ΔR_7=1.03-1.19). The reproduction number R has for this day an uncertainty range between (minimum) R_4=0.48 to (maximum) R_7=1.19, i. e. the total uncertainty range of R, taken from R_4 and R_7 is R=0.84±42%).
Sometimes misleading cases even occur in which R_4 is clearly in the "green area" (below 1.00, i.e. a reduced risk of infection) and R_7 is clearly in the "red area" (above 1.00, i. e. increased risk of infection: Table1: June 24, 2020: R_4=0.72 and R_7=1.17). In this case and equally on June 25, 2020, the confused reader can choose to be in the green or red area. Reliable and meaningful information about the existing risk of infection can be expected hardly with such characteristics of the reproductive numbers for COVID-19.

E: The number E of new infections has been the most frequently used assessment parameter since summer 2020. It is defined as difference between A_x on the day x and A_{x-1} on the day before:

$E=A_x - A_{x-1}$ {Equ. 2}

The new infections E constitute in average only 6.60% of all contagious, acute infections F, calculated for the daily base parameters A, B and C. The fluctuation of E between two days by a sudden hot spot of ±50% would change the acute infections F by only 50% × 0.066=3.3%. The new infections E are only proportional to the infection risk with an uncertainty of ±22%, taken from E/F in the columns in Table 1 and 2. However, the proportionality to the infection risk is correct for the total number F of acute infections, since only these represent all existing sources of infection.

New, easy to calculate and at the same time more precise assessment parameters

F: The base of all the assessment parameters listed below is the number F of all acute infections in the region under consideration. This number is easy to obtain:

F=A-B-C {Equ. 3}

Accidental larger fluctuations in F generally do not occur, and even on the days discussed under R with the most unreliable reproduction numbers (June 24 and 25, 2020), the numbers F are in a trustworthy order (Table 1).

G: The stress index G provides specific information about the current risk difference between the acute infections F and the limit value F_0 at which the health system is overloaded and the patients cannot longer receive the help they need:

- Required vaccine servings
- Required hospital beds
- Required intensive care beds
- Required (private) medical capacity
- Required size of diagnostic stations and number of test drugs
- Required number of oxygen ventilation systems and other facilities
- Required capacity of the health authorities to follow up an confirmed infection by looking for other people at risk of infection
- Required personal for all of the above topics

This limit value is to be determined by experts for each region and corresponds to the case that at least one of the essential requirements such as intensive care beds can no longer be met. The regular determination of the current limit value F_0 on the base of the latest data from the health system is certainly complex, but in view of the enormous consequences of the pandemic an inevitable obligation of the responsible state authorities. The stress index can be calculated easily as:

$$G=F/F_0 \qquad \text{\{Equ. 4\}}$$

H: An easily understandable parameter is the infection source density H, based on the population H_0 in the region under consideration (for Germany: H_0=83,020,000 inhabitants 2019) divided by the acute infections. represented as 1 of H (as example 1 of 2,000 persons). This way to describe a risk for side effects is used in common practice in the health system to explain the risk of unwanted effects of medicaments outside the aiming point or function. H is to be calculated as

$$H=H_0/F \qquad \text{\{Equ. 5\}}$$

K: The relative change in acute infections F can serve as an indicator of the tendency towards a change in the risk of infection. If F_x is the value of F on day x and F_{x-5} is this value five days earlier, then K can be calculated from:

$$K=F_x/F_{x-5} \qquad \text{\{Equ. 6\}}$$

This parameter is undoubtedly a better indicator for showing the tendency for a change in the risk of infection than the reproduction numbers R. The decisive advantage of K is its small uncertainty range of less than ±0.1%, while that for R_4 with the average range of uncertainty ±21.2 % and for R_7 with ±11.7% can only be estimated much less reliable.

Comparison of the current and the new quantitative assessment parameters of the COVID-19 infection risk in the first year after the start of the pandemic

In Tables 1 and 2 the actual values of the current and the proposed assessment parameters are shown for demonstration with the following interpretations:

D: The doubling time D_E was given in the first 3 months of the pandemic on the base of new infections E and changed from 2 days at the beginning to almost half a year (165 days) until the information was discontinued on May 15. The doubling time D_F calculated on the base of the acute infections F is similar to D_E and has changed for the second wave from 30 days to 9 days since September 2020 and has increased again to over 46 days since November 1, 2020.

E and F: The quotient E/F shows quantitatively the deviations of E from the proportionality to the risk of infection. The percentage of E in acute infections F in the period from April 15 to September 5, 2020 is 6.60%±1.34%, which is a variation of E by ±22%. This average value E/F in the period between the first two waves of COVID-19 (April to September) is smaller than the value 8.0%±5% during the second wave (September – December 2020). The fluctuation is more than±50% (Table 2). This uncertainty can be explained best by the overestimation of hot spots due to a sudden increase in E. A hot spot like the one in the Tönnies meat factory in Rheda-Wiedenbrück/Germany in mid-June 2020 (1,500 newly infected people within 7,000 employees) does not increase the risk of infection at a greater distance in another federal state, but can be localized and combated in a very confined space. Thus E grows drastically and do not represent the real infection risk, what is done by F, which remains nearly constant.

G: In the practical application of this parameter, the main difficulty is that the current exposure limit value F_0 has to be determined by experts based on the latest knowledge about the conditions in the health system. It is pointed out expressly that, in contrast to all other parameters, the presented numerical values for G in Tables 1 and 2 cannot precisely describe reality, since the limit value F_0 is only roughly estimated and experts have not adjusted the changes in the health system during the observed period.

H: The risk of infection can also be demonstrated clearly by specifying the density of the sources of infection H, as is known from the instructions for use for medical products on the risk of side effects. For example, knowing that an average of one in H = 2,000 people is acutely infected, it is easy to understand the extent of the risk by this side effect.

R and K: The parameters R (based on E) and K (based on F) only provide information about the tendency of the infection risk change. The confusing information of some occurring R_4 and R_7 values was already discussed under R above: The sharp increase in R during the hot spot in the Tönnies factory in mid-June 2020 contrasts with an only slight credible change in F (Table 1).

7-days incidence warning limits J

Due to the rapid, alarming increase in acute infections F since September 2020, the German federal law officially introduced two (later five) important 7-days incidence warning limits.[4,5]

If the number of 35 or 50 (later 100, 150 and 165[5]) new infections per 100,000 inhabitants per week in a region is exceeded, gradually higher protective measures should be taken (e.g. maximum group size in the public and private areas, wearing masks under certain conditions, restriction of travel and contact between people, curfew, closure of shops, schools and daycare centers, alcohol ban). In order to avoid the effects of excessive daily fluctuations in the case of new infections, the specified warning limits for protective measures must be exceeded continuously for three days or undercut for five days.

The hitherto assessment parameters could lead to quantitative uncertainties when

Table 2. COVID-19-data for Germany during the period of the second wave
Data for A up to E according[1], Data for reproduction numbers according.[3] F_0 is estimated provisionally as 80.000 people. R_7-numbers are valid for 8 until 13 days before. H_0 = 83.020.000 inhabitants of Germany 2019

Date	Basis Parameter			Actual assessment parameters on the base of parameters A and E				New (here presented) assessment parameters on the base of parameter F					
	A:	B:	C:	D_E:	E:	R_4	R_7:	D_F:	E/F:	F=A-B-C:	G= F/F_0	H = H_0/F	K=F_x/F_{x-5}:
Year 2020	Cumulative infections	Estimated cumulative recoveries	Cumulative deaths with COVID-19 infection	Doubling time on the base of parameter E [d]	New infections	Reproduction numbers [within 4 respectively 7 days]		Doubling time on the base of parameter F [d]	Share of parameter E in F [%]	Acute contagious infections	Stress index	Infection source density:1 of	Relative change of acute infections in 5 days
08.09.	254,561	227,300	9,336	29	1,508	1.10	0.98	30	8.41	17,925	0.224	4,631	0.998
11.09.	258,851	231,150	9,346	27	1,427	1.00	1.11	27	7.78	18,355	0.229	4,523	1.009
14.09.	262,558	233,950	9,356	24	999	1.18	1.04	26	5.19	19,252	0.241	4,312	1.057
17.09.	268,085	237,650	9,375	22	2,170	1.07	1.15	24	10.30	21,060	0.263	3,942	1.079
20.09.	273,831	241,150	9,390	21	1,283	1.22	1.17	23	5.49	23,391	0.293	3,549	1.172
23.09.	278,296	245,900	9,413	19	1,882	0.95	0.95	20	8.62	22,983	0.287	3,612	1.092
26.09.	285,026	250,100	9,459	16	2,645	1.08	1.05	19	9.99	25,467	0.318	3,260	1.109
29.09.	290,471	255,200	9,492	13	2,065	1.12	1.03	16	8.01	25,779	0.323	3,220	1.142
01.10.	295,539	258,200	9,513	12	2,475	0.90	1.05	15	8.89	27,826	0.348	2,984	1.093
04.10.	301,572	262,000	9,538	10	2,045	1.23	1.14	13	6.81	30,034	0.375	2,764	1.165
07.10.	311,085	267,950	9,582	9	2,836	1.10	1.11	13	8.45	33,553	0.419	2,474	1.151
10.10.	323,460	273,800	9,620	10	4,818	1.42	1.43	11	12.03	40,040	0.501	2,073	1.281
13.10.	335,713	279,700	9,682	9	3,965	1.18	1.20	10	8.56	46,331	0.579	1,792	1.289
16.10.	356,814	288,050	9,773	9	7,388	1.22	1.30	10	12.52	58,991	0.737	1,407	1.415
19.10.	373,825	295,250	9,842	9	4,382	1.35	1.25	10	6.38	68,693	0.859	1,209	0.378
22.10.	403,874	306,700	9,960	8	11,265	1.09	1.17	9	12.92	87,214	1.090	952	1.407
25.10.	438,383	317,650	10,062	15	11,136	1.36	1.38	12	10.06	110,671	1.383	750	1.528
28.10.	481,613	333,850	10,281	49	14,798	1.17	1.21	16	10.76	137,482	1.719	604	1.414
30.10.	519,712	346,950	10,462	-	18,745	0.97	1.17	28	11.55	162,300	2.029	512	1.467
01.11.	545,703	356,500	10,541	-	13,971	1.13	1.13	46	7.82	178,662	2.233	465	1.408
04.11.	598,462	303,600	10,949	-	17,763	0.94	0.89	-	8.71	203,913	2.549	407	1.256
07.11.	659,603	413,150	11,306	-	23,279	0.99	0.99	-	9.53	235,147	2.939	353	1.267
10.11.	706,720	445,250	11,781	-	15,192	0.88	0.92	-	4.68	249,539	3.119	333	1.162
13.11.	774,711	487,200	12,404	-	23,556	0.92	0.99	-	8.89	265,107	3.314	313	1.099
16.11.	817,526	521,800	12,833	-	11,118	1.12	0.97	-	3.93	282,893	3.536	293	1.100
19.11.	880,579	570.450	13.667	-	22,617	0.88	0.95	-	7.63	296,464	3.706	280	1.055
22.11.	932,111	610,400	14,159	-	16,007	1.08	1.03	-	5.20	307,562	3.845	270	1.081
25.11.	984,941	664,450	15,210	-	17,690	0.76	0.87	-	5.79	305,281	3.816	272	1.010
28.11.	1,044,349	717,650	16,181	-	21,613	0.94	0.96	-	6.96	310,528	3.882	267	1.017
01.12.	1,086,063	767,600	17,177	-	13,189	0.94	0.89	-	3.93	335,640	4.196	247	1.090
04.12.	1,157,514	828,800	18,581	-	23,542	1.00	1.04	-	7.62	310,133	3.887	268	0.998
07.12.	1,200,102	872,300	19,437	-	12,712	1.20	1.06	-	4.14	308,364	3.855	265	1.019
10.12.	1,273,800	932,200	21,064	-	24,051	0.90	1.03	-	7.50	320,543	4.007	259	1.030
13.12.	1,339,406	976,800	22,109	-	20,731	1.16	1.12	-	6.09	340,497	4.256	244	1.102
16.12.	1,412,095	1,036,700	24,274	-	25,666	0.88	0.98	-	7.31	350,921	4.387	253	1.100
19.12.	1,497,689	1,096,500	26,173	-	31,537	1.05	1.06	-	8.41	375,016	4.688	221	1.108
22.12.	1,558,698	1,151,000	28,102	-	19,031	0.93	0.95	-	5.01	379,595	4.744	219	1.061
25.12.	1,632,730	221,200	29,581	-	25,892	-	-	-	6.78	381,955	4.770	217	1.003
28.12.	1,661,394	1,272,050	30,300	-	10,959	0.71	0.74	-	3.00	365,048	4.563	227	0.947
31.12.	1,746,920	1,350,700	33,791	-	32,401	0.74	0.80	-	8.94	362,438	4.530	229	0.944

Table 3. Uncertainty of ±23% for 7-days incidence values J_E based on new infections E compared to 7-days incidence values J_F based on acute infections F, January 1 to March 6, 2021[1]

Date 2021	E New infections	E_7 7 days new infections	F= A-B-C Acute infections	F_7 7 days acute infections	F/E Acute infections per new infections	F_7/ E_7 7 days acute per new infections	J_E = 100,000× E_7/H_0 7-days incidence based on E	J_F = 100,000× F_7/H_0 7-days inidence based on F	J_{E0} = 100,00× F_7/H_0×18.3 corrected 7-days inci-dence based on E_0	J_E/J_{E0} Correction factor for 7-days incidence based on E
01.01.	23,323	132,317	354,054	2.581,676	15.2	19.5	159.4	3,110	169,0	0.944
02.01.	13,473	129,748	349,453	2,553,775	25.9	19.7	156.3	3,076	167.1	0.935
03.01.	10,655	128,179	342,303	2,529,187	32.1	19.7	154.4	3,047	165.6	0.932
04.01,	10,122	124,912	333,466	2,499,053	32.9	20.0	150.5	3,011	163.6	0.920
05.01.	11,931	124,075	326,205	2,467,471	27.3	19.9	149.5	2,973	161.6	0.925
06.01.	20,611	123,376	325,640	2,433,734	15.8	19.7	148.6	2,932	159.3	0.933
07.01.	26,587	122,516	331,438	2,393,559	12.4	19.5	147.6	2,884	156.8	0.941
08.01.	30,568	116,702	335,988	2,362,559	11.0	20.2	140.6	2,846	154.7	0.909
09.01.	25,066	123,947	338,896	2,344,493	13.5	18.9	149.3	2,836	154.1	0.969
10.01.	19,004	135,540	337,221	2,333,936	17,7	17.2	163.3	2,812	152.8	1.071
11.01.	11,754	143,889	328,110	2,328,854	27.9	16.1	154.7	2,806	152.5	1.014
12.01.	11,789	145,521	319,384	2,323,498	27.1	14.9	175.3	2,799	152.1	1.152
13.01.	19,585	145,379	316,313	2,316,677	16.1	15.9	175.2	2,791	151.7	1.154
14.01.	24,720	144,353	314,630	2,307,350	12.7	16.0	173.9	2,780	151.1	1.151
15.01.	21,445	142,486	313,355	2,290,542	14.6	16.1	171.7	2,760	150.0	1.144
16.01.	19,385	133,343	311,472	2,267,909	16.1	17.3	160.7	2,732	148.5	1.082
17.01.	13,971	127,662	309,722	2,240,485	22.2	17.6	153.8	2,699	146.7	1.048
18.01.	8,036	122,649	298,,349	2,212,986	37.1	18.0	147.8	2,666	144.9	1.020
19.01.	9,671	118,931	285,717	2,183,225	29.5	18.4	143.3	2,630	142.9	1.003
20.01.	15,839	116,813	279,210	2,149,558	17.6	19.3	140.7	2,590	1.408	0.999
21.01.	19,837	113,067	275,475	2,112,455	16.4	18.7	136.2	2,545	1,383	0.985
22.01.	17,903	108,184	272,024	2,073,300	15.8	19.2	130.3	2,498	1,358	0.959
23.01.	15,987	104,642	269,042	2,031,969	16.8	19.4	126.1	2,448	133.0	0.948
24.01.	12,706	101,244	267,418	1,989,539	21.0	19.7	122.0	130.3	130.3	0.936
25.01.	6,731	99,963	257,274	1,947,235	38.2	19.5	120.4	2,346	127.5	0.944
26.01.	6,025	98,674	246,006	1,906,160	40.8	19.3	118.9	2,297	124.8	0.953
27.01.	12,556	95,028	239,228	1,866,449	19.1	19.6	114.4	2,249	122.2	0.936
28.01.	16,884	91,745	135,577	1,826,467	19.9	19.9	110.5	2,201	119.6	0.924
29.01.	14,111	88,792	233,265	1,786,569	16.5	20.1	107.0	2,152	117.0	0.915
30.01.	12,508	85,000	229,473	1,747,810	18.3	20.6	102.4	2,106	114.4	0.895
31.01.	10,945	81,521	228,300	1,608,241	20.9	19.7	98.2	1,937	105.3	0.933
01.02,	6,259	79,760	221,416	1,669,123	35.4	20.9	96.1	2,011	109.3	0.879
02.02.	5,117	79,288	210,262	1,633,265	41.1	20.6	95.5	1,968	107.0	0.893
03.02	8,886	78,380	203,469	1,597,521	22.9	20.4	94.4	1,925	104.6	0.902
04.02.	13,982	74,710	198,482	1,461,762	14.2	19.6	90.0	1,761	95.7	0.940
05.02.	13,054	71,808	192,404	1,524,667	14.7	21.2	86.5	1,837	99.8	0.867
06.02.	10,694	70,751	188,241	1,483,806	29.5	21.0	85.2	1,788	97.2	0.877
07.02.	8,530	69,994	187,002	1,442,574	21.9	20.6	84.3	1,738	94.5	0.892
08.02.	4,817	66,522	179,779	1,401,276	16.4	21.1	80.1	1,688	91.7	0.874
09.02.	3,424	65,080	169,643	1,359,639	49.5	20.9	78.4	1,638	89.0	0.881
10.02.	8,321	63,387	162,621	1,135,920	16.8	17.9	76.4	1,369	74.4	0.995

Date 2021	E New infections	E_7 7 days new infections	$F = A-B-C$ Acute infections	F_7 7 days acute infections	F/E Acute infections per new infections	F_7 / E_7 7 days acute per new infections	$J_E =$ 100,000× E_7/H_0 7-days incidence based on E	$J_F =$ 100,000× F_7/H_0 7-days inidence based on F	$J_{E0} =$ 100,00× F_7/H_0×18.3 corrected 7-days incidence based on E_0	J_E/J_{E0} Correction factor for 7-days incidence based on E
11.02.	10,117	62,822	158,541	1,095,072	15.7	17.4	75.7	1,319	71.7	1.056
12.02.	9,842	58,957	154,592	1,238,231	38.2	22.7	71.0	1,492	81.1	0.875
13.02.	8,277	55,745	149,965	1,012,178	18.1	18.2	67.2	1,219	66.3	1.014
14.02.	6,062	53,328	147,337	1,162,143	19.1	21.8	64.3	1,400	76.1	0.845
15.02.	4,428	50,850	143,237	1,121,860	32.3	22.1	61.3	1,352	73.5	0.834
16.02.	3,957	50,471	137,464	1,085,936	16.5	21.5	60-8	1,308	71.1	0.855
17.02.	7,595	51,004	132,776	1,053,757	17.5	20.7	61.5	1,270	69.0	0.891
18.02.	10,185	50,278	131,611	1,023,912	20.9	20.4	60.6	1,234	67.1	0.903
19.02.	9,148	50,346	129,849	996,982	14.2	19.8	60.7	1,201	65.3	0.930
20.02.	9,094	40,485	128,439	972,239	14.1	24.3	48.8	1,171	63.6	0.767
21.02.	7,851	41,302	128,569	950,713	16.4	18.5	49.8	1,145	62.2	0.801
22.02.	4,337	43,091	126,534	931,945	29.2	21.6	52.0	1,123	61.0	0.852
23.02.	3,768	43,000	122,823	915,242	31.8	21.3	51.8	1,103	59.9	0.865
24.02.	7,958	51,978	123,417	900601	15.5	17.3	62.6	1,085	59.0	1.061
25.02.	11,733	52,341	125,191	891242	10.7	17.0	63.1	1,074	58.4	1.080
26.02.	10,335	53,889	125,945	884,822	12.2	16.4	64.9	1,066	57.9	1.121
27.02.	9,558	55,076	115,695	880,918	12.1	16.0	66.4	1,061	57.7	1.151
28.02.	7,891	56,004	126,593	868,174	16.0	15.5	67.5	1,046	56.8	1.189
01.03.	4,700	56,044	124,354	866,198	26.5	15.5	67.5	1,044	56.7	1.190
02.03.	4,029	55,973	121,935	864,198	30.3	15.4	67.4	1,041	56.6	1.191
03.03.	8,972	56,234	122,747	863,130	13.7	15.3	67.8	1,007	54.7	1.239
04.03.	11,871	57,248	125,198	862,407	10.5	15.1	69.0	1,039	56.5	1.221
05.03.	10,596	57,356	125,685	862,467	11.9	15.0	69.1	1,039	56.5	1.223
06.03.	9,568	57,617	126,362	862,207	13.2	15.0	69.4	1,039	56.5	1.228
				Average	15.4	18.3				1.000±23%

describing the risk of infection, but had no legal consequences. This is changed fundamentally by the protection laws,[4, 5] in which quantitative warning limits are set for legally required far-reaching and expensive protective measures. These warning limits must describe certain risks of infection and not values of parameters that are proportional to the risk of infection only with great uncertainty.

To describe this problem, Table 3 shows the 7-days incidence values J_E based on the new infections E and J_F based on the acute infections F in detail. Starting with E (column 2) and the 7-days total sum E_7 for the previous week (column 3), the same is done for F and F_7 in the next columns 4 and 5. The next two columns 6 and 7 show that the average of F/E is 15.4, the average of F_7/E_7 is j=18.3. This agrees well with F/E=1/0.066 = 15.2 in Table 1 for another period.

In order to remove the uncertainty of E regarding its proportionality to the risk of infection, the value J_F must be used for the definition of the 7-days incidence warning limit. These numbers of J_F are larger than the corrected value J_{E0} by the average correction factor j =18.3. This means that the civil protection law has to be changed in this respect. The conversion is carried out as follows:

For 7 days per 100,000 inhabitants in the affected region {Equ. 7}

new infections E (current regulation)	35	50	100	150	165
correspond with	↓	↓	↓	↓	↓
acute infections F (possibly future regulation)	640	915	1,830	2,745	3,020

Alternatively, there is a sufficient indirect route without changing the law: Instead of the 7-days incidence value J_E specified in the current wording of the law, the corrected value J_{E0} is to be used, calculated from:

$$J_{E0} = 100{,}000 \times F_7 / (H_0 \times j) = 100{,}000 \times F_7 / (H_0 \times 18.3) = J_F / 18.3 \qquad \text{\{Equ. 8\}}$$

The same result is obtained, if for calculation of J_{E0} the corrected value E_0 is taken instead of E:

$$E_0 = E \times J_{E0} / J_E \qquad \text{\{Equ. 9\}}$$

In order to make the result of the method described above more visible, correction factors J_E/J_{E0} are given in the last column of Table 3. These correction factors indicate by how much the uncorrected 7-days incidence values J_E deviate from the desired corrected actual incidence values J_{E0}. In the period of 65 days in Table 3, an extreme deviation is found (20.02.2021: J_E/J_{E0} = 0.767 and 03.03.2021: J_E/J_{E0} = 1.239). This corresponds to an uncertainty range for the 7-days incidence of ±23%.

Three days of continuously exceeding an incidence warning limit are necessary to initiate the next step of measures, five days are needed until an abolition is allowed. In three periods, overestimations or underestimations of the 7-days incidence values occur continuously for more than three respectively five days with the conversion factor <1 (01.01.2021 – 09.01.2021 and 20.01.2021 – 10.02.2021) or >1 (24.02.2021 – 06.03.2021).

For example, if a 7-days incidence above 165.1 is given instead of values J_{E0} < 165 for continuously three days face-to-face teaching must be prohibited in schools. The same risk of infection can also be present for J_E=127 to 203 by its uncertainty range of ±23%.

Should new infections E continue to define legal warning thresholds? If J_{E0}=165 is exceeded by J_E for three days - according to the current wording of the law - objectively unjustified protective measures must be ordered. In such cases there is a risk of expensive claims for damages and if in contrary underestimated, the protection goal of civil protection will be missed.

Conclusion

In the context of the COVID-19 pandemic, using the number of contagious acute infections F instead of the new infections E currently in use will result in more accurate and meaningful information for decision-makers and the public and avoid errors in the legislative design of protective measures.

Supplement

With the formation of the fourth wave of the COVID-19 pandemic in August 2021, the federal government in Germany does not consider the 7-days incidence alone to be sufficient for demanding or abolishing protective measures. The numbers of Covid-19 infected people who need hospital beds or even intensive beds are expected to be used for decisions. A suitable quantitative assessment variable can be the "stress index" G introduced above, which quantifies the current distance up to the stress limit F_0 of the health system e. g. according to hospital beds and/or intensive care beds.

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