Secrets of *The Diamond Princess*

Dr. Michael Levitt's Analysis March 2020

accurately assessed the impact of Covid-19

March 2020 the increasing presence of SARS-CoV-2 around the world and news of Italy's outbreak and strict lockdown response were causing alarm; Neil Ferguson and the Imperial College of London's predictions of high amounts of deaths [18] and the intention of policymakers to also employ lockdown restrictions were widely circulated [27].

Dr. Michael Levitt of Stanford University had been doing continuous real-time data analysis of the Covid-19 epidemic in China since it's start [9], then the rest of the world as it spread [28], and recognized that the estimates of deaths being publicized were far too high.

As governments made decisions about how to respond, he combined his China analysis with contemporary scholarship and the impact of the Covid outbreak and quarantine on the cruise ship the *Diamond Princess* to try to accurately ascertain the true burden of the pandemic.
Its possible for the analysis to be so definitive because circumstances on a cruise ship are defined and mimic an intensified version of normal life, with:

- **100% exposure** and...
- **high reproduction numbers** among a ...
- **vulnerable population**.

Many sound studies and data were available that when carefully analyzed, together provided everything necessary to accurately predict the scope of outcomes.

Covid-19 was allowed to run rampant on the Princess, yet high amounts of immunity was established without high amounts of death.

Dr.Levitt's analysis quickly revealed:

- *Covid deaths would be around* ***1 month's worth of normal death***
- ***a model that over-projected deaths by 9 times is being used to justify decisions***

The Diamond Princess compared to a normal community

Cruise ships are ideal for studying characteristics of infectious disease, both in terms of population and environment. There are many features similar to a community taking place in small spaces with close contact: gambling rooms, theaters, performances, pools, and shared daily facilities like buffets, toilets, spas, elevators, and narrow hallways.

"... the quarantine on the DP cruise ship, the enclosed circumstances revealed how SARS-CoV-2 can be spread in the community". [11]

On the Diamond Princess the percent of people over 65 was almost 2.5 times higher than the UK. [33][35]. That was especially relevant for Covid-19 since, as Dr. Levitt knew from following the latest research from China, the age demographics of cases and deaths released on 14 February 2020 [17][42] which was backed up by other studies clearly showing younger age groups were not as affected by Covid-19. [51][63][65]

Contemporary data from Italy also corroborated the fact that, unlike certain flus, deaths were occurring mainly in the higher age groups [37][38]

"... outbreaks on cruise ships can resemble outbreaks in long-term care facilities - in both settings, outbreaks can be extensive and involve high-risk populations. Similar to LTCFs, cruise ships often carry passengers at increased risk for influenza complications - persons aged ≥ 65 and with medical comorbidities" *[29]*

While there where not people on board the Diamond Princess who would've been in the same poor health as those in hospitals, we can trust that there were many on the level of those unable to live alone, a number of them were not able to walk on their own [14].

Many places, including a study published in the Journal of the American Geriatrics Society [3], even suggest cruise ships as a viable, inexpensive option instead of an assisted living facility for people who find it difficult to care for themselves, giving them access to meals, cleaning service, on-board pharmacies, and medical service [2].

The epidemic began when one passenger began having symptoms on 19 January 2020, and boarded the Diamond Princess the next day [19]; all passengers had potential repeated exposures for 5 days before that person disembarked on 25 January. Another passenger, possibly a second primary case, became symptomatic 23 January, and a food worker 2 February [20]. On 4 February, one day before quarantine was announced, it was confirmed that 10 people out of the 31 (33.3%) tested onboard were positive [10][14],

Before quarantine everyone had 16 days of potential repeated exposures to at least one primary case and multiple secondary cases that existed in the small confines of a ship with high reproduction numbers.

Ship Environment HOUSEHOLD ATTACK RATES

Even before quarantine was implemented and passengers spent more time in their cabins, conditions on the Diamond Princess would be akin to a household. With a population density of 24400/sq. km. [1], the general environment onboard the Diamond Princess would be equivalent to 2 people continuously living together in a small 900 sq. ft. home.

The environment on the Diamond Princess cruise ship was similar to that of a home, so exposure was the same as household secondary attack rates, near 100%

That means infections should be regarded in terms of ranges of household attack rates, secondary attack rates such as you would find in smaller locations like homes and barracks, where exposure level is 100% because people share meals, facilities, and spend long periods of time in close proximity. [22].

Like other respiratory illness, Covid is more likely to be contagious in small spaces [41]. SARS-CoV-2 showed a high attack rate in household environments, one study finding that 4 out of 13 who were exposed in a home and 5 out of 11 in a chalet (31% and 45% respectively) became infected [6], and the CDC found a lower end of the range at 12% [7]. The Diamond Princess was in the middle, with about 19% of the population testing positive over a 3 week period, about half that being symptomatic [33]

QUARANTINE was INEFFECTIVE

After quarantine was implemented it was not as effective as hoped. Many officials stated the inadequacy of the quarantine, including Russia's Foreign Ministry, the US Centers for Disease Control and Prevention, and Nathalie MacDermott of King's College London who said:

"Obviously the quarantine hasn't worked, and this ship has now become a source of infection." [26]. The CDC's statement on 18 February 2020, 12 days after quarantine started: "the rate of new reports of positives new on board, especially among those without symptoms, highlights the high burden of infection on the ship & the potential for ongoing risk" [4].

Dr. Anthony Fauci: "Something went awry in the process of the quarantining on that ship"

A Japanese infectious disease expert described the situation post-quarantine as "violating all infection control principles" and "completely chaotic" [34], and Dr. Anthony Fauci, head of the White House Coronavirus Task Force: "The quarantine process failed ... I'd like to sugarcoat it and try to be diplomatic about it but it failed. People were getting infected on that ship. Something went awry in the process of the quarantining on that ship" [5]

"A day after the quarantine began, hundreds of passengers continued regular cruise activities and ate together at large buffets" [43]

Due to the nature and layout of a ship and the needs of the many elderly passengers, quarantine was difficult; for example, infected and non-infected passengers shared an elevator: "There were many difficulties in implementing quarantine, such as creating a dividing traffic line between infectious and noninfectious passengers, finding hospitals and transportation providers willing to accept these patients, transporting individuals, language barriers, and supporting daily life"[14].

Conditions during quarantine also caused some of the same uncertainty and prolonged stress that could be found under lockdown conditions. "Diamond Princess had already reported a shortage of medicines on Day 2 of the quarantine ...The MHLW responded quickly and supplied the medications needed by patients with diabetes and heart disease by Day 7 of the quarantine ... however, there was still a shortage" [26]

Reproduction Numbers

Another strong assurance that the circumstances on the Princess were much more extreme than would be found in normal settings is the high estimates of R on the ship that would continue to influence the amount of infections even after quarantine.

One study estimated R on the Diamond Princess had been 12, peaking after quarantine and not reaching R 2.5 until 4 days after quarantine, and staying above an R of 1 until about 8 days after, with the crew peaking after the passengers [31]. Another estimated R0 was 14.8 before quarantine [1]. This means ***R was 4 to 5 times higher*** than the highest estimates of ICL's for normal UK communities [18], and at least 6 to 7 times higher than R0 estimates from China [40] and hard-hit Italy [39]

R and Transmission After Quarantine

Considering the high R values, small corridors and cabins and the difficulty in carrying out effective quarantine, its no surprise that Covid still circulated and infections didn't stop. Some infections that occurred on the Princess after quarantine were not factored in to the previous calculations of R, so its possible that calculated R values were a conservative estimate [31].

(after quarantine) "... the infection risk continued to be significant inside the Diamond Princess Ship" [31] see again

The fact that more of the crew, who were mostly in the younger adult age groups, became infected last [31] shows that there was a group of them exposed last, meaning that the passengers, who were composed mostly of older people, many in poor health, were bearing the brunt of the early transmission from the first cases.

The fact that Covid was still spreading after quarantine yet few of the passengers got sick later could indicate that large amounts of immunity had been established in that population.

Asymptomatic Infections

There is a lot of controversy about how relevant asymptomatic transmission is, but putting that aside, the high number of asymptomatic infections that have been discovered via testing is important. It is a big factor in how high infection, case and population fatalities appear to be, and so consequently, Covid death rates.

Asymptomatic Covid-positive cases or infections are people who had been exposed to Covid, but for whatever reason didn't become ill, so could represent pre-existing immunity, and thus also an important and significant amount of pre-existing herd immunity.

Majority of Infections are Asymptomatic

A case [23] in Hong Kong referenced in this previously cited study [6] on household attack rates showed that in a home environment with shared meals 9 out of 19 (47%) became infected, at least 2 out of 19 being symptomatic (11% of all exposed, 22% of the positives), meaning ***78% were asymptomatic***, ***4 times*** the number of symptomatics. In another Chinese home all were infected with 70% being asymptomatic [44], in hard-hit Wuhan it may have been 60% [51], and even a nursing home in Washington State USA had around 50% asymptomatic [45]. Considering some might not recognize a brief, mild symptom, mildly symptomatics could also be important. A study found among PCR-positives with known exposure asymptomatic and mild symptomatics together accounted for almost 72% of all positves [65]

Ferguson himself stated that “Analyses of data from China as well as data from those returning on repatriation flights suggest that *40-50% of infections were not identified as cases*” [18].

That could raise the number of infections on the Princess from 700 to 1400, which would result in 38% of the population infected, (about half of what would be needed to reach Ferguson’s HIT of the equivalent of 2997 infected) or 55% of passengers, very close to a lower HIT estimate of 61% that Dr. Levitt found with his scaling (see Behind the Princess), and also close to 1692, the amount of people on the Princess over age 65.

Key points when it may be that herd immunity was developed first among the passengers.

The timing and duration of the testing period, testing protocol, and the optimal time frame to detect Covid may have hampered the ability to discover all infections.

Asymptomatic Infections Are Often Missed:

Testing Period and Viral Shedding Time

Considering testing protocol and criteria [14] onboard the Diamond Princess of testing symptomatics first, and the long testing period over 3 weeks instead of all being tested soon after exposure like in the other case studies, it would've made it likely that asymptomatic or mildly symptomatic infections may have been missed and explain why reported infections were so low.

While in some individuals viral shedding can continue for over a month, it was found to generally be much shorter, declining significantly over 11 days, and after that continuing to become harder to detect [49][50].

It was over a week from the time of exposure to the symptomatic passengers til testing started, plenty of time to be infected and clear the virus, and even after testing started, capacity was low and slowly scaled up [21], many could have been missed over that long time span due to:

- short time that virus can be detectected
- limited testing over a span of time
- lack of any sign of infection

How there could be so few severe infections

Pre-Existing Immunity

Pre-existing immunity may have come from a person already being exposed to Covid or another coronavirus or pathogen that provided an ammount of immune response that reduced severity, even to the point of a Covid infection being unnoticed.

Later it would be discovered that Covid had T-cell cross immunity with other coronaviruses, but previous to that it was well known that cross immunity even among very different pathogens can provide at least some amount of immunity.[57]

If there is cross-immunity between SARS-CoV-2 and other coronaviruses, they'd have to be prevalent enough to have any noticible benefit. The most obvious place to look for cross immunity would be with other coronaviruses and how common they are throughout the world.

Prevalence of Cornavirus

The few serological studies available show a very high prevalence of asymptomatic people seropositive for the 4 common coronaviruses that have been in continuous circulation, from 58%-98% in the general population [54][52]

In children it is high also; a study of under 2 years olds found they were born with high levels of antibodies inherited from their mothers, and had high levels of seroconversion by the end, at least 76%.[60]

"Estimates for exposure to non-SARS coronaviruses are high, particularly for 229E and OC43" [52]

Showing that immunity, presense of asymptomatics, and spread of these types of viruses is not well understood, the Norweigian study found slightly higher prevalence among healthy individuals that patients with respiratory illness. And alarmingly, in Israel a study found 78% of camels infected with another coronavirus that caused world-wide concern, MERS, even though there have been no reported human cases in Israel. [56]

In the chart below, the large difference in the amount of people found positive using serological tests and those using PCR show how a PCR test is like a snapshot of a short period of time, while serological studies can give a broader perspective of how many have been infected.

PREVALENCE of COMMON CORONAVIRUSES				"all"= OC43, NL63, 229E, & HKU1		
Country	StudyYears	Virus	%	Location	Test Type	REF
GERMANY	1974-76	OC43	58.2	general population	serological hemagglutintion inhibition	54
USA	2008	229E	91.3	general population age 18-65	Sero: immunoassay based on	52
USA	2008	HKU1	59.2	general population age 18-65	amino- and carboxy-terminally tagged	52
USA	2008	NL63	98.1	general population age 18-65	recombinant coronavirus nucleocapsid	52
USA	2008	OC43	90.8	general population age 18-65	antigens.	52
Netherlands	late 90s-	229E	20	Healthy children 0-2yrs	serological	60
Netherlands	early	HKU1	36	Healthy children 0-2yrs	serological	60
Netherlands	2000s	NL63	68	Healthy children 0-2yrs	serological	60
Netherlands		OC43	76	Healthy children 0-2yrs	serological	60
Netherlands, Scotland	2006-2011	(all)	14	Hospitalized RTI children 0-2 yrs	PCR	60
Seattle Washington USA	Nov 2019 -	(all)	6	Patients, Children Hospitals	PCR	59
Seoul SOUTH KOREA	Jan2020	(all)	9.4	Patients, Children Hospitals	PCR	59
NORWAY	2006-2015	(all)	10.2	Control	PCR	53
NORWAY	2006-2015	(all)	9.1	RTI patients	PCR	53
ISRAEL	2015-16	(all)	10.36	community surveillance	RT-PCR	55
ISRAEL	2018	MERS	71.8	CAMELS	(Mnt) assay confirmed by MERS-specific (IFA)	56
SE Asia, Australia,	Feb 2010-	(all)	5.6	children under 10	PCR; nasal ,throat	58
Latin America	Aug2011	(all)	5.6	children under 10	PCR; nasal ,throat	58

With overall a ***very high prevalnce of 58% to 98%*** in the general population, it would make it easy to see how symptomatic case and total infection saturation occured on the Diamond Princess at about 9% and 19% respectively if there is indeed those levels of cross-immunity.

What About the Children: Kids and Covid

One of the shortcomings of the Diamond Princess scenario was that there were few children onboard, so one might wonder whether the presence of children would increase the likelyhood of deaths, but the consensus at the time was that children weren't significant drivers of transmission, were largely asymptomatic, and generally less affected by Covid. [65][63]

There is some controversy about a few newer studies that showed viral load in children might be higher than some adults, but evidence and observation can refute that; if the outcomes are the same, viral load and transmission are not relevant.

> *"no data showed that the infected children could serve as the sources of transmitting viruses to adults"* *[63]*

The fact that the Chinese population has more normal age distribution and mixing of age groups than existed on the Princess, and the Chinese case fatality rates align well with the Princess shows that children cannot be transmitting disease more than adults; If children were increasing disease severity more than adults would, fatalies on the Princess would've been less.

the presense of children does not worsen outcomes

SUMMARY

The Diamond Princess had:

- a population particulary susceptable to Covid
- the most susceptable part of the population exposed first
- high contact rate, exposure and R due to the envirinment on the ship

Outcomes show:

- the amount of extra risk or death that Covid generally causes is about a month
- children do not significantly negatively affect outcomes

Behind the Princess: Step by Step

In their paper of 16 March 2020, [18] an Imperial College of London (ICL) team, headed by epidemiologist Neil Ferguson, further adjusted the age-banded Infection Fatality Ratios (IFR) calculated by Ferguson and Verity et al [36] and used them in their models to make projections of Covid-19 deaths and hospitalizations for the UK and US, and also the effects various Non Pharmaceutical Interventions (NPI) would have on outcomes.

Believing their projections to be too high, Dr. Michael Levitt of Stanford University used that same IFR to try to replicate their results, applying it to 81% of the populations, since ICL assumed that is the herd immunity threshold of SARS-CoV-2.

The results were higher than the projections, so using published data of fatalities and infections from the Covid outbreak on the Diamond Princess [33] he made his own scaling factors, which represent all the variables and parameters ICL used in their models except the IFR, to match the results first to ICL's population fatality projections, then another to lower ICL's projections to reconcile them with reality.

ICL's model and Dr. Levitt's methods are all ways of using the data from IFRs to find Population Fatalitiy Ratios (PFR) and determine the risk to an entire country.

Dr. Levitt's scaling factors could then be used to make more accurate estimates of deaths that would occur in the US, UK and Wuhan, China (post-evacuation).

The amount of deaths that ICL had predicted that would occur were found to be almost 9 times too high.

Dr. Levitt immediately brought this significant discrepancy between reality and the models to the attention of the authors of the ICL paper, to Sir David Spiegelhalter, an advisor to SAGE, of which Ferguson was also a member, in a response to Sir David's Medium article in support of the ICL's predictions that reiterated their incorrect conclusions, and attempted to circulate his analyses among fellow scientists, but was ignored by all.

Here now is a step by step exposition of Dr. Levitt's work on the Diamond Princess ....

ORIGINAL DOCUMENT CIRCULATED MARCH 2020 BY DR.LEVITT IN ATTEMPT TO AVOID THE UNNECESSARY DISASTER OF LOCKDOWNS

How Accurate are the Number of UK and US Deaths Predicted by Ferguson et al. (2020)?

The preprint (https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf) by the renowned team at Imperial College received international attention by claiming that left untreated coronavirus would infect 81% of the population and lead to 510,000 deaths in the UK and 2,200,000 deaths in the US. Although the Medium post by Sir David Spiegelhalter (https://medium.com/wintoncentre/how-much-normal-risk-does-covid-represent-4539118e1196) at the Winton Center in Cambridge converted these numbers to being no more than one year of normal risk of death in each country, they still seemed high to me as pointed out in my reply to Sir David (https://medium.com/@michael.levitt/the-medium-post-by-david-spiegelhalter-from-the-winton-center-at-cambridge-university-is-well-7b1e157ba876). This lead me to a common-sense test: Apply the Ferguson et al. 2020 method of converting population numbers to fatalities with the Infection Fatality Rates pre-printed in Verity et al. 2020 (Ferguson is senior author). The two situations are the Diamond Princess Cruise ship and the City of Wuhan in China; both were more infected than anywhere else. See the Table below, with each column explained to make it easy to follow.

A	B	C	D	E	F	G	H	I	J	K	L
Age-group (years)	% symptomatic cases requiring hospitalisation	% hospitalised cases requiring critical care	Infection Fatality Ratio from Verity et al 2020	United Kingdom Population	United Kingdom: Number of Deaths Expected	United States Population	United States Number of Deaths Expected	Diamond Princess: Population from Russell et al 2020 Table 2	Diamond Princess: Number of Deaths Expected	China Population	Wuhan with 6,000,000 people Number of Deaths Expected
0 to 9	0.1%	5.0%	0.002%	8,065,283	97	39,891,845	491	16	0	171,585,833	9
10 to 19	0.3%	5.0%	0.006%	7,569,160	274	42,398,071	1,565	23	0	166,513,709	25
20 to 29	1.2%	5.0%	0.030%	8,630,614	1,564	46,179,065	8,525	347	0	192,891,037	148
30 to 39	3.2%	5.0%	0.080%	9,203,569	4,448	43,980,069	21,650	428	0	223,506,345	456
40 to 49	4.9%	6.3%	0.150%	8,624,679	7,816	40,288,440	37,186	334	0	223,201,182	854
50 to 59	10.2%	12.2%	0.600%	9,138,365	33,126	42,557,686	157,120	398	1	214,623,812	3,286
60 to 69	16.6%	27.4%	2.200%	7,206,475	95,785	37,845,098	512,314	923	12	148,420,591	8,332
70 to 79	24.3%	43.2%	5.100%	5,673,457	174,811	23,009,234	722,064	1,015	32	66,894,771	8,705
80+	27.3%	70.9%	9.300%	3,418,559	192,078	12,915,409	739,085	216	12	26,146,412	6,205

Total Number of Population and Predicted Deaths		67,530,161	510,000	329,064,917	2,200,000	3,700	58	1,433,783,692	28,020
Predicted Deaths from Ferguson et al 2020			510,000		2,200,000				
Predicted Deaths after correction to Diamond Princess			61,311		264,478		7		3,368
Assumed Percent Infected from Ferguson et al. 2020	81%								
UK Fudge factor to match Ferguson et al 2020	0.74587								
US Fudge factor to match Ferguson et al 2021	0.75966								
Mean Ferguson Fudge factor for DP & Wuhan	0.75277								
Fraction China Population in Wuhan (pop 6,000,000)	0.00418	6,000,000							
Correction Factor to Match Diamond Princess Deaths	0.120	8.32							

A Conventional Ten-Year Age stratification.

B to D Exactly as given in Verity et al (2020) (see (A)) below. I use their Infection Fatality Ratio (IFR) values in column D; IFR is the death rate as a percentage of the infected population.

E UK population by age group from https://www.populationpyramid.net/united-kingdom/2019/

F UK deaths calculated from population age groups using the 81% infection rate (Ferguson et al. 2020) (see (B) below) and the IFR values (Verity et al. 2020). A fudge factor (0.74587) is needed to get the 510,000 UK deaths they find.

G & H Same sanity test is applied to the US population from same site reproduces the Ferguson et al (2020) value of 2.2 million with a very similar fudge factor value of 0.75966. Using a fudge factor is equivalent to a 61% infection rate.

I & J The same calculation (with Mean US/UK fudge factor of 0.75277) is applied to the Diamond Princess using the population per age group from Russell et al. at University College London (See (C) below). https://www.medrxiv.org/content/10.1101/2020.03.05.20031773v2. The number of deaths predicted by Ferguson et al (2020) is 59, more than eight times the actual number of 7 from (C). The older passengers may die from old age: if we wait long enough, the Ferguson value will be accurate. These people will be dying **WITH** coronavirus and not **BECAUSE OF** coronavirus, an important distinction that needs to be widely understood. As the Diamond Princess is the only case of high levels of infection and testing (Russell et al. 2020), I feel it may be valid to normalize the Ferguson values, dividing them by a factor of 7/59 = 0.120 (or 1/8.32) to give 7 deaths (Russell et al 2020, see (C)). We note that the effective value of percent infected of 61% is more than the reported 618 infected. We believe our higher number is justified by the number of 'uninfected' passengers who carried coronavirus back home.

K China population by age group from https://www.populationpyramid.net/china/2019/

L COVID fatalities in Wuhan assuming a population of 6,000,000 with the same age distribution as in China. This value is less than the normal population of 11 million and assumes that the 5 million people said to have left Hubei (SCMP https://www.scmp.com/news/china/society/article/3047720/chinese-premier-li-keqiang-head-coronavirus-crisis-team-outbreak) were mainly from Wuhan. The number of deaths predicted by Ferguson et al (2020) for Wuhan is 28,020, much higher than the actual number as of about 2,550. When corrected by the Diamond Princess correction factor of 0.120, we get 3,850 deaths, which is much closer. This suggests that about 3,000,000 people in Wuhan were infected by coronavirus, something that could and should be tested serologically.

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5/29/2020

Step by Step

To match ICL's predictions Dr. Levitt experimented with 2 different methods; one was finding a scaling factor, the second was lowering their herd immunity threshold.

The first column involving calculations is column F. Since ICL believed 81% of a population must be infected to reach herd immunity, to arrive at the numbers in F, first find 81% of the population by multiplying column E by (0.81). Next the IFR is converted from percents to decimals by dividing by 100 (coral column). They are then multiplied: 81% of the population times the IFR in decimal form.

The results (red box) for the UK and US don't match ICL's estimates, and don't match any of the estimates for any of the other R values for the UK in their paper, being 134,000 over the highest.

So Dr. Levitt found scaling factors, what he calls the “fudge factor”, needed to match ICL's predictions. The fudge factor is what the red box column has to be multiplied by in order to equal Ferguson’s predictions for the US and UK.

The fudge factor (brown column) may represent errors of variables vaguely referred to in the ICL paper that they used in their models, their miscalculation of herd immunity threshold, or both. Multiplying the red-box column by the fudge factor gives a result close to Ferguson’s prediction (column F, yellow box).

Another way of arriving at Ferguson ICL’s predictions is to not use the fudge factor at all, but rather to change the Herd Immunity Threshold they used, taking 61% of the population instead of 81%, which gives very similar results. (yellow box, far right).

UK

	Ferguson assumes 81% infected to reach herd immunity					Multiply by “Fudge Factor”		OR	Match prediction by changing Herd Immunity Threshold to 61%				
	E						F				61% of	multiply by	Equals
AGE	UK population	so Multiply	81% of UK POP	multiply by VERITY IFR in decimal	Verity IFR x 81% of POP	of 0.74587	# of Deaths Expected		UK POP	multiply by	UK POP	VERITY IFR in decimal	Ferguson's Prediction
0-9	8065283	by	6532879	2.00E-05	131	to match	97		8065283		4919823	2.00E-05	98
10-19	7569160		6131020	6.00E-05	368	Ferguson's	274		7569160	0.61	4617188	6.00E-05	277
20-29	8630614	0.81	6990797	0.0003	2097	Prediction	1564		8630614		5264675	0.0003	1579
30-39	9203569		7454891	0.0008	5964	of	4448		9203569	to get	5614177	0.0008	4491
40-49	8624679	to get	6985990	0.0015	10479	510000	7816		8624679	61% of	5261054	0.0015	7892
50-59	9138365	81% of	7402076	0.006	44412	UK Deaths	33126		9138365	UK POP	5574403	0.006	33446
60-69	7206475	UK POP	5837245	0.022	128419		95784		7206475		4395950	0.022	96711
70-79	5673457		4595500	0.051	234371		174810		5673457		3460809	0.051	176501
80 over	3418559		2769033	0.093	257520		192076		3418559		2085321	0.093	193935
TOTAL	67530161		54699430	0.17468	683761		509997		67530161		41193398	0.17468	514931
					Doesn't match 510000		close match						close match

USA

Ferguson assumes 81% infected to reach herd immunity so Multiply by 0.81 to get 81% of US POP					Multiply by "Fudge Factor" of 0.74587 to match Ferguson's Prediction of 220000000 US Deaths		OR	Match prediction by changing Herd Immunity Threshold to 61%				
	G					H						
AGE	US population		81% of US POP	multiply by VERITY IFR in decimal	Verity IFR x 81% of POP	# of Deaths Expected		US POP	multiply by	61% of US POP	multiply by VERITY IFR in decimal	Equals Ferguson's Prediction
0-9	39891845		32312394	2.00E-05	646	491		39891845		24334025	2.00E-05	487
10-19	42398071		34342438	6.00E-05	2061	1565		42398071	0.61	25862823	6.00E-05	1552
20-29	46179065		37405043	0.0003	11222	8525		46179065		28169230	0.0003	8451
30-39	43980069		35623856	0.0008	28499	21650		43980069	to get	26827842	0.0008	21462
40-49	40288440		32633636	0.0015	48950	37186		40288440	61% of	24575948	0.0015	36864
50-59	42557686		34471726	0.006	206830	157121		42557686	US POP	25960188	0.006	155761
60-69	37845098		30654529	0.022	674400	512314		37845098		23085510	0.022	507881
70-79	23009234		18637480	0.051	950511	722066		23009234		14035633	0.051	715817
80 over	12915409		10461481	0.093	972918	739087		12915409		7878399	0.093	732691
TOTAL	329064917		266542583	0.17468	2896037	2200004		329064917		200729599	0.17468	2180966
					Doesn't match 22000000	close match						close match

The Diamond Princess

Here is where we see **ICL was *over 8 times off***

(58 projected deaths divided by the actual 7)

Fudge Factors are averaged & applied to Wuhan & the Diamond Princess 0.75966 plus 0.74587 divided by 2 equals 0.75277							OR	Match Expected Deaths by changing Herd Immunity Threshold to 61%				
	I					J						
AGE	DP population	Multiply by 0.81 to get 81% of DP POP	81% of DP POP	multiply by VERITY IFR in decimal	Verity IFR x 81% of POP	# of Deaths Expected		DP POP	multiply by 0.61 to get 61% of DP POP	61% of DP POP	multiply by VERITY IFR in decimal	Ferguson Deaths Expected
0-9	16		12.96	2.00E-05	0.0002592	0.000195118	Multiply by "Fudge Factor" of 0.75277	16		9.76	2.00E-05	0.0001952
10-19	23		18.63	6.00E-05	0.0011178	0.0008414463		23		14.03	6.00E-05	0.0008418
20-29	347		281.07	0.0003	0.084321	0.0634743192		347		211.67	0.0003	0.063501
30-39	428		346.68	0.0008	0.277344	0.2087762429		428		261.08	0.0008	0.208864
40-49	334		270.54	0.0015	0.40581	0.3054815937		334		203.74	0.0015	0.30561
50-59	398		322.38	0.006	1.93428	1.4560679556		398		242.78	0.006	1.45668
60-69	923		747.63	0.022	16.44786	12.381455572		923		563.03	0.022	12.38666
70-79	1015		822.15	0.051	41.92965	31.563382631		1015		619.15	0.051	31.57665
80 over	216		174.96	0.093	16.27128	12.248531446		216		131.76	0.093	12.25368
TOTAL	3700		2997	0.17468	77.351922	58.228206324		3700		2257	0.17468	58.252682

Wuhan

The population was reduced to post-lockdown levels [46] then scaled by age to the entire Chinese population to get a Wuhan age-banded population. The rest of the process was as it was for the above locations.

To scale Wuhan to age groups divide China pop 1433783692 by Wuhan pop 6000000 = 0.00418								OR	Match Expected Deaths by changing Herd Immunity Threshold to 61%					
	K								L					
AGE	CHINA Population	Multiply by 0.00418 to get Age stratified Wuhan post-evacuation Lockdown population	Lockdown WUHAN POP	81% of WUHAN POP	multiply by VERITY IFR in decimal	Verity IFR x 81% of POP		Multiply by "Fudge Factor" of 0.75277	# of Deaths Expected	Lockdown WUHAN POP	Multiply by 0.61 to get 61% of Wuhan POP	61% of Wuhan POP	multiply by VERITY IFR in decimal	Ferguson Expected Deaths
0-9	171585833		717229	580955	2.00E-05	12			9	717229		437510	2.00E-05	9
10-19	166513709		696027	563782	6.00E-05	34			25	696027		424577	6.00E-05	25
20-29	192891037		806285	653090	0.0003	196			148	806285		491834	0.0003	148
30-39	223506345		934257	756748	0.0008	605			456	934257		569896	0.0008	456
40-49	223201182		932981	755715	0.0015	1134			853	932981		569118	0.0015	854
50-59	214623812		897128	726673	0.006	4360			3286	897128		547248	0.006	3283
60-69	148420591		620398	502522	0.022	11055			8332	620398		378443	0.022	8326
70-79	66894771		279620	226492	0.051	11551			8705	279620		170568	0.051	8699
80 over	26146412		109292	88527	0.093	8233			6205	109292		66668	0.093	6200
TOTAL	1433783692		5993216	4854505	0.17468	37180			28019	5993216		3655862	0.17468	28000

Projections for the UK, USA and Wuhan, China

The amount of deaths that the Ferguson's model would predict for the Diamond Princess population was then used to find a second scaling factor to project more accurate deaths for the UK, US and Wuhan, China. This scaling factor is the actual number of deaths divided by ICL projected deaths for the Princess.

To determine actual # of deaths Dr. Levitt used a scaling factor derived by dividing actual deaths on the DP by Ferguson's (incorrect) expected deaths				7 / 58.228206 =		Predicted Deaths Based on Dr. Levitt's Scaling to Diamond Princess Death		
AGE	Ferguson's Expected DP	Ferguson's Expected UK	Ferguson's Expected US	Ferguson's Expected WUHAN	0.120216652 multiply by scaling factor	UK	US	WUHAN
0-9	0.00	97.45	490.93	9	0.120216652	11.72	59.02	1.08
10-19	0.00	274.38	1565.31	25	to	32.98	188.18	3.01
20-29	0.06	1564.27	8524.53	148	correct	188.05	1024.79	17.79
30-39	0.21	4448.30	21649.61	456	to	534.76	2602.64	54.82
40-49	0.31	7815.96	37185.70	853	Diamond	939.61	4470.34	102.54
50-59	1.46	33125.92	157120.75	3286	Princess	3982.29	18888.53	395.03
60-69	12.38	95784.17	512314.44	8332	deaths	11514.85	61588.73	1001.65
70-79	31.56	174809.93	722065.53	8705		21015.06	86804.30	1046.49
80 over	12.25	192076.48	739086.71	6205		23090.79	88850.53	745.94
TOTAL	58.23	509996.86	2200003.52	28019		61310.11	264477.06	3368.35

Equivalent Months of Death

Deaths occuring during a Covid epidemic can be put in perspective of deaths that would normally occur by dividing the normal amount of deaths per year by 12 to get normal deaths per month, and then dividing Covid deaths by that, allowing them to be compared as extra months of death or risk. Using equivalent months of death is quick way to extrapolate population fatalies that works well for the Princess since there was 100% exposure.

NORMAL DEATHS				Projected Deaths		Equivalent Deaths per Month
	Per year		Per month		divide by	
UK	600000	divide by 12	50000	61310	50000	1.24

From the above charts, Covid deaths on the Princess were 1.24 month's worth, **a bit over a month**, or almost ***5 weeks worth*** of normal deaths in the UK.

Dr. Levitt's scaling of deaths to population is a good match with the relative risk method using infection fatlities (see next section), showing that it was accurately scaled and so could be safely used to find Population Fatality Ratios (PFR).

Sir David Spiegelhalter and Relative Risk

Dr. Levitt brought these errors of calculation and inference to the attention of the public and Sir David Spiegelhalter 22 March 2020 in response to Sir David's Medium article published the day before in support of ICL and Neil Ferguson's work [25] [24]. Sir David has advised SAGE, of whom Ferguson was also an advisor, regarding Covid and is Winton Professor of the Public Understanding of Risk in the Statistical Laboratory at the University of Cambridge.

Sir David used normal background mortality rates for the UK [47] and the Verity-ICL IFR to compare the risk of dying from Covid after becoming infected to normal risk of a year of living. He then showed that extra months of risk translates to equivalent amounts of months of death and used that as proof that ICL predictions were correct, that becoming infected with Covid poses an extra year's worth of risk of dying.

Since the Ferguson predictions were wrong, *so too were Sir David's estimates*, which **are *almost 10 times too high.***

Despite Sir David's claims that Dr. Levitt was wrong, its very clear and easy to see that when applied to those infected on the Diamond Princess the results are irrefutable, Covid-19 poses only ***about 1 month of additional risk to those who become infected***.

Comparing the extra risk of being infected with Covid-19 to the risk of living, there's a bit over a month's worth

Risk For ALL INFECTED									
	From Russell et al Diamond Princess cases & death			From Spiegelhalter Medium article BACKGROUND MORTALITY			Relative Risk (IFR divided by Mortality)	multiply by 12 to get months	MONTHS of additional RISK for ALL INFECTED
AGE	CASES	Deaths	IFR %	Female	Male	ALL			
0-9	1	0	0	0.01	0.01	0.01	0	0	
10-19	5	0	0	0.02	0.03	0.025	0	0	
20-29	28	0	0	0.03	0.06	0.045	0	0	
30-39	34	0	0	0.07	0.12	0.095	0	0	
40-49	27	0	0	0.19	0.27	0.23	0	0	
50-59	59	0	0	0.39	0.59	0.49	0	0	
60-69	177	0	0	0.95	1.45	1.2	0	0	
70-79	234	6	2.56	2.78	3.98	3.38	0.76	9.1	
80 over	54	1	1.85	9.53	12.05	10.79	0.17	2.06	1.24

Comparing the extra risk of being 100% exposed to Covid-19 to the risk of living, there's a bit over **1 week**'s worth of risk to a population

Risk For ALL EXPOSED

From Russell et al Diamond Princess population & death				ALL Background	RelativeRisk Ratio % PFR divided by	multiply by 12 to get	Averaged
AGE	DP POP	Deaths	PFR %	Mortality %	Background Mortality	months of Risk	
0-9	16	0	0	0.01	0		Equivalent Months of Normal Death
10-19	23	0	0	0.025	0		
20-29	347	0	0	0.045	0		
30-39	428	0	0	0.095	0		
40-49	334	0	0	0.23	0		
50-59	398	0	0	0.49	0		
60-69	923	0	0	1.2	0		0.29
70-79	1015	6	0.59	3.38	0.17	2.10	
80 over	216	1	0.46	10.79	0.04	0.51	8 days

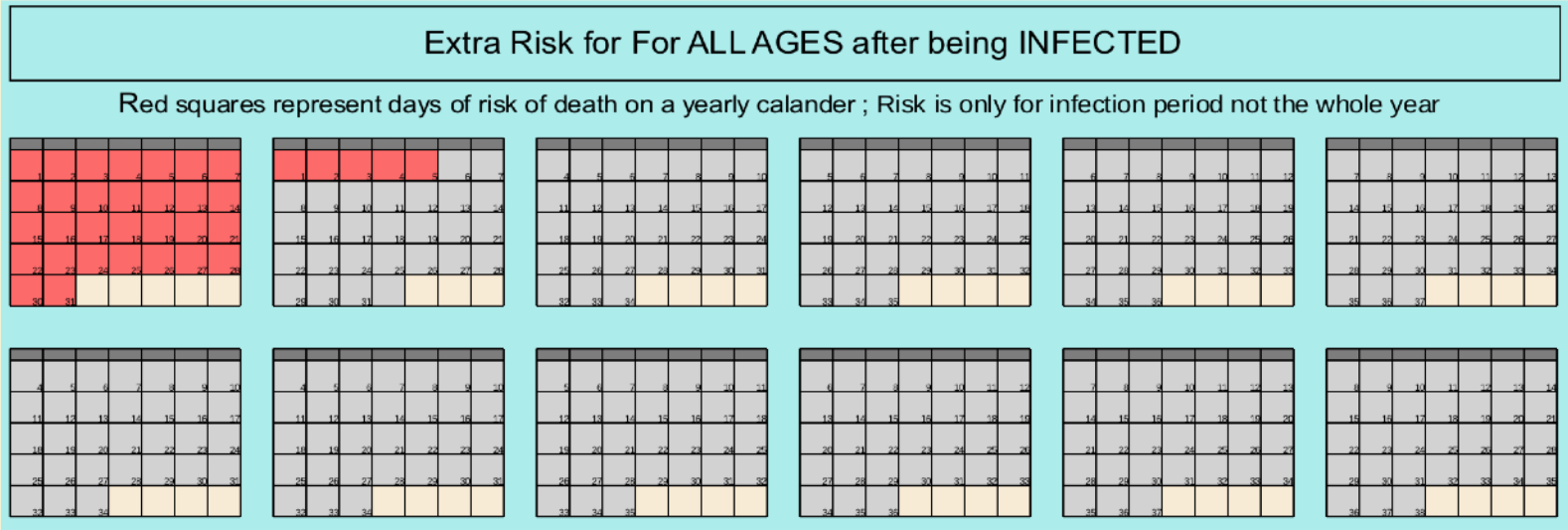
Comparing the extra risk of being 100% exposed to Covid-19 to the risk of living, there's **under a month**'s worth of extra risk for **ages over 65**

Risk For Exposed Population of Ages Over 65

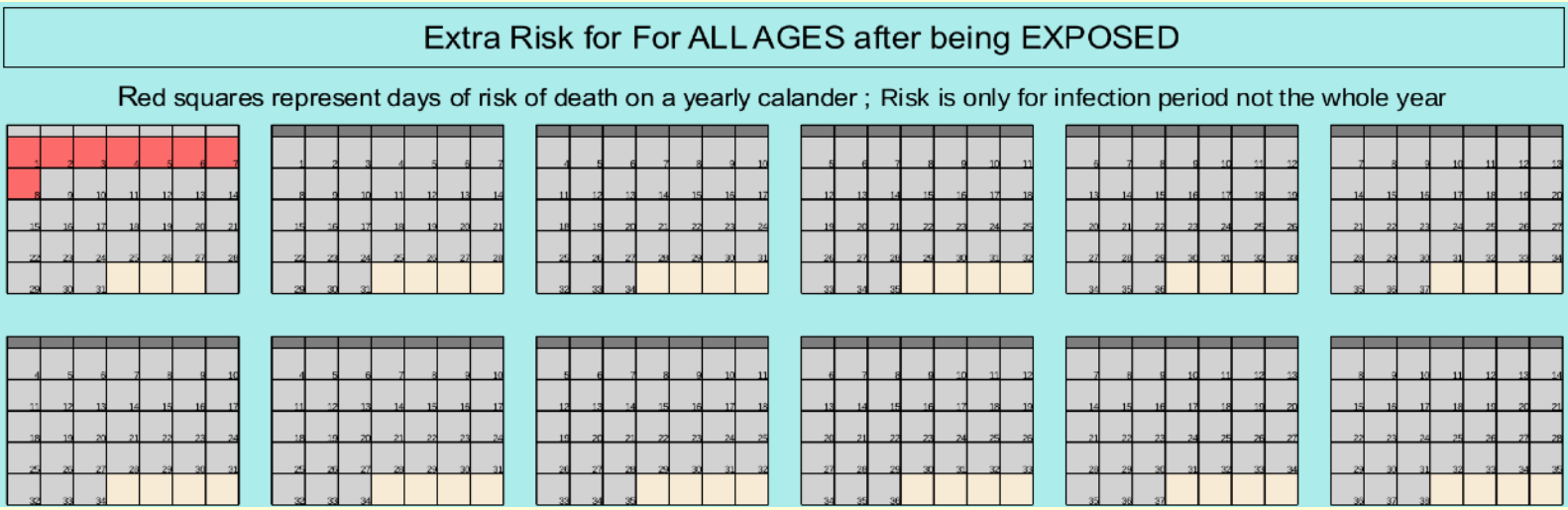
From Russell et al Diamond Princess population & death				ALL Background	split 60 to 70 age group	RelativeRisk Ratio % PFR divided by	multiply by 12 to get	Averaged
AGE	DP POP	DEATHS	age PFR %	Mortality %	into 65 to 70	Background Mortality	months of Risk	
0-9	16	0						Equivalent Months of Normal Death
10-19	23	0						
20-29	347	0						
30-39	428	0						
40-49	334	0						
50-59	398	0						
60-69	923	0	0	1.2				
60-64					0.6			
65-70					0.6	0	0	0.87
70-79	1015	6	0.59	3.38	3.38	0.17	2.10	
80 over	216	1	0.46	10.79	10.79	0.04	0.51	3 ½ weeks

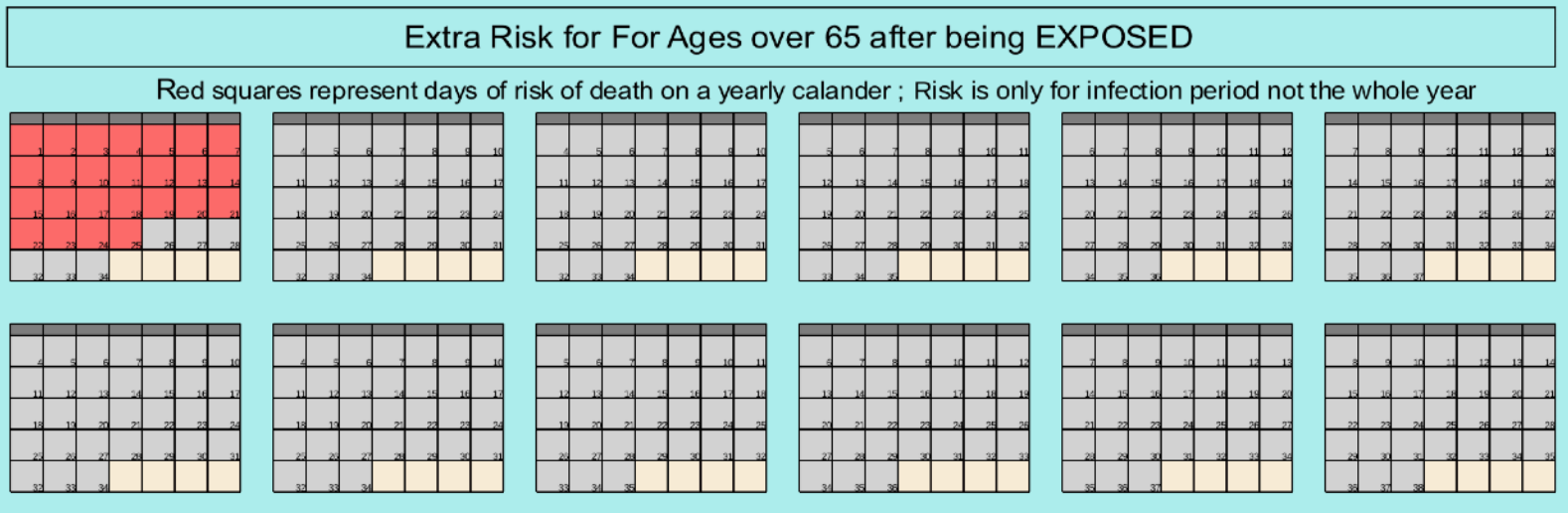
EXTRA RISK SHOWN AS DAYS OF RISK ON A CALENDAR

Comparing the extra risk of being infected with Covid-19 to the risk of living there's a bit over **1 month**'s worth of risk to a population



Comparing the extra risk of being 100% exposed to Covid-19 to the risk of living, its a bit over **1 week**'s worth of risk to a population, while for **ages over 65 its under a month**





Fatality by Age Group

A quick way to get projected deaths is to only use over age 65 populations and fatality ratios, since no deaths occured under age 65. Here using the ICL Verity IFR and both the 100% exposure we know occured and ICL's Herd Immunity Threshold (HIT) of 81%. the ICL estimates are far too high, ***almost 10 times too high.***

DIAMOND PRINCESS			Diamond	Verity ICL		Verity ICL	Verity ICL	Multiply	using HIT of 81%	
Age	POP	Divide	Princess	IFR %	Divide	IFR %	In Decimal	by Pop to find Projected Deaths	81.00% of Pop>65	projected Deaths
0-9	16	60-69	Population	0.002	60-69					
10-19	23	group	>65	0.006	group					
20-29	347	by 2		0.03	by 2		(divide by			
30-39	428	to get		0.08	to get		100)			
40-49	334	65-70		0.15	65-70					
50-59	398			0.6						
60-69	923	65-70	461.5	2.2	65-70	1.1	0.011	5	373.815	4.111965
70-79	1015	70-79	1015	5.1	70-79	5.1	0.051	52	822.15	41.92965
80 over	216	80 over	216	9.3	80 over	9.3	0.093	20	174.96	16.27128
TOTAL	3700	Total >65	1692.5	16.6	Total >65	15.5	0.155	77	1371	62

ICL Estimates were almost 10 times too high			
% population over 65	ICL projected deaths	Divide by Actual Deaths	Error by factor of
100.00%	77	7	11
81.00%	62	7	9

The same basic estimates can be done proportionally by separating out the >65 age groups, since all deaths occured there, as Dr. Levitt showed on Twitter [61], taking population of the Diamond Princess over age 65 dividing that by deaths and dividing the population of a country (here the UK) by that scaling factor. Then it can be translated into months of normal deaths as was shown on pg 5 under "Equivalent Months of Death".

ALL AGES									Equivalent		NOTES
DIAMOND PRINCESS				UK	UK	UK	UK	Divide by	Months of		INF=infections
Exposure Level	Population infected	Pop/Deaths to get scaling factor for DP		Exposure Level	Population	Expected Deaths (UK Pop/DP scaling factor)		Deaths per Month	Normal Death if DP Deaths are		% INF on Princess=19% % cases on Princess =9%
		7 deaths	14 deaths			7 deaths	14 deaths		7	14	
19.00%	703	100.43	50.21	100.00%	64000000	637268.85	1274537.70	50000	12.75	25.49	INF% to ALL Pop
19.00%	703	100.43	50.21	81.00%	51840000	516187.77	1032375.53	50000	10.32	20.65	INF% to ICL HIT (match ICL)

Looking at ICL's predications quickly, knowing that 19% of the Princess was infected and there were 7 deaths, then extrapolating that to a % of the population of the UK, one can see that does match ICL's prediction and one might think its accurate. For comparison, Ferguson's estimate of 510,000 deaths from Covid, divided by normal deaths per month (50000) is 10.2

Fatality by Age Group and Proportion

However on closer inspection we see that, unlike Dr. Levitt's analysis, that would be a straight infection fatality to population ratio that doesn't consider the populations of age bands or age-related susceptability, like non-uniform age-stratified attack and fatality rates.

Neither would it consider the amount of people who have been exposed, or the presence of any undetected asymptomatics. One would have to assume all asymptomatic infections were acknowledged, which Ferguson knew would not be the case [36] , and accepting the idea that only 19% were infected when that is unlikely.

AGES OVER 65											Notes:
DIAMOND PRINCESS				UK	UK	UK	UK	Divide by	Equivalent		INF=infections
Exposure Level	Population > age 65	Pop/Deaths to get scaling factor for DP Deaths if :		Exposure Level	Population > age 65	Expected Deaths (UK Pop/DP scaling factor)		Deaths per Month	Months of Normal Death if		% INF on Princess=19%
		7 deaths	14 deaths			7 deaths	14 deaths		DP Deaths are:		% cases on Princess =9%
100.00%	1692.5	241.79	120.89	100.00%	12695253.5	52506.22	105012.44		7	14	
81.00%	1370.9	195.85	97.92	81.00%	10283155.3	52506.22	105012.44				
61.00%	1032.4	147.49	73.74	61.00%	7744104.6	52506.22	105012.44	50000	1.05	2.10	LEVITT scaling
19.00%	321.6	45.94	22.97	19.00%	2412098.17	52506.22	105012.44	50000			
19.00%	321.6	45.94	22.97	100.00%	12695253.5	276348.52	552697.03	50000	5.53	11.05	INF % to all >65
9.00%	152.325	21.76	10.88	100.00%	12695253.5	583402.43	1166804.85	50000	11.67	23.34	Case % to all >65 (match ICL)
9.00%	169.25	24.18	12.09	81.00%	10283155.34	472555.96	945111.93	50000	9.45	18.90	Case % to HIT of all > 65

Also notice that if exposure level on the Princess matches exposure of a population, no matter how low or high the percent is, the amount of equivalent death is the same. It is only if more exposure would take place in the UK population than what occurs on a cruise ship that the proportion of deaths would be higher in the UK than the Diamond Princess.

What might have gone wrong with ICL-Ferguson prediction:

- using a CFR instead of an IFR
- did not properly account for non-uniform attack rates across age bands
- ignored asymptomatics
- miscaluted Herd Immunity Threshold

What Went Wrong: Verity and ICL's IFR was really a CFR

Part of the reason ICL-Ferguson's estimates were so wrong may be that they used a CFR as an IFR. Despite accusations leveled at those who opposed lockdowns that they were confusing infections with cases, it was in fact Neil Fersguson and ICL themselves who appear to have confused or conflated the two. An IFR should be lower than a CFR, and as Dr. Levitt knew from his work on China [42] [25], the ICL-Verity IFR was far too high. It is actually much closer to ***case*** fatality ratio, ***not*** an infection fatality ratio.

All infections on the Princess were defined as cases, every postive result was considered a case regardless of whether there were symptoms or contact with other infected people, cases were then just differentiated by being 'symptomatic' or 'asymptomatic'.

The ICL-Verity IFR is a much better match when instead of using all cases, it is applied to just symptomatic cases, which are more likely to be the classical definition of a case and closer to how the Chinese define a case.

The original Verity IFR [36], (column C) before it was altered by ICL, was an even closer match to a Case Fatality Ratio when applied to only symptomatics, (column D), probably because it is closer to the Chinese CFR from 14 February 2020 [42]

		A				B			C	D		
	The IFR from VERITY et al was actually a CFR								Original		Applied to	CHINA 14 Feb 2020	
AGE	DP Population	Verity ICL IFR %	ALL CASES	Projected DEATHS	Actual Deaths	SYMPTOMATIC CASES	Projected DEATHS	Actual Deaths	VERITY "IFR"	Applied to ALL Cases	only Symptomatic	CFR Normalized to age & pop	Applied To POP
0-9	16	0.002	1	0.000		0	0.000		0.0016	0.000	0.000	0.0000	0.000
10-19	23	0.006	5	0.000		2	0.000		0.007	0.000	0.000	0.0008	0.000
20-29	347	0.03	28	0.008		25	0.008		0.031	0.009	0.008	0.0053	0.018
30-39	428	0.08	34	0.027		27	0.022		0.084	0.029	0.023	0.0111	0.047
40-49	334	0.15	27	0.041		19	0.029		0.16	0.043	0.030	0.0247	0.083
50-59	398	0.6	59	0.354		28	0.168		0.6	0.354	0.168	0.0823	0.328
60-69	923	2.2	177	3.894		76	1.672		1.9	3.363	1.444	0.2867	2.646
70-79	1015	5.1	234	11.934		95	4.845		4.3	10.062	4.085	0.6140	6.232
80 over	216	9.3	54	5.022		29	2.697		7.8	4.212	2.262	1.0994	2.375
sum	3700	17.468	619	21.280	7	301	9.440	7		18.072	8.020	2.1244	11.729
				off by 3 times			off by 1.4 times				1.2 times off		off by 1.7 times

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