Cambridge Centre for Risk Studies

2022 Risk Summit

RISK FLASH - PANDEMIC

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2014

- 2014 CRS publishes Sao Paulo virus scenario
- Based on a fictional H8N8 Influenza
- Four scenarios explored:
  - S1 : Standard
  - S2 : Response failure
  - S3 : Vaccine failure
  - X1 : Response and Vaccine failure

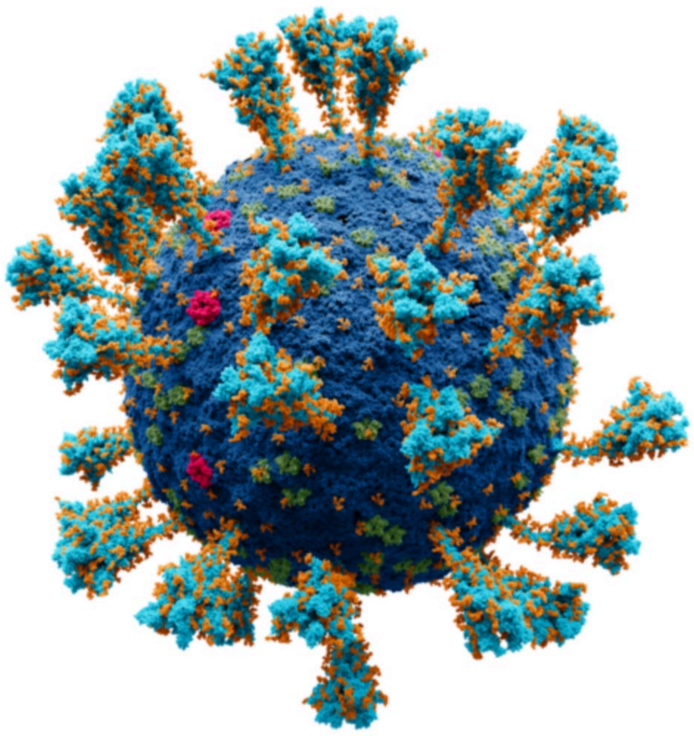
WEF survey – availability bias?

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1st	Blow up in asset prices	Blow up in asset prices	Asset price collapse	Asset price collapse	Fiscal crises	Financial failure	Financial failure	Fiscal crises	Water crises	Climate action failure	Weapons of mass destruction	Weapons of mass destruction	Weapons of mass destruction	Climate action failure
2nd	Deglobalization	Deglobalization (developed)	Deglobalization (developed)	Deglobalization (developed)	Climate change	Water crises	Water crises	Climate action failure	Infectious diseases	Weapons of mass destruction	Extreme weather	Extreme weather	Climate action failure	Weapons of mass destruction
3rd	Interstate and civil wars	China hard landing	Oil and gas price spike	Oil price spikes	Geopolitical conflict	Food crises	Fiscal imbalances	Water crises	Weapons of mass destruction	Water crises	Water crises	Natural disasters	Extreme weather	Biodiversity loss
4th	Pandemics	Oil price shock	Chronic diseases	Chronic disease	Asset price collapse	Fiscal imbalances	Weapons of mass destruction	Unemployment	Interstate conflict	Involuntary migration	Natural disasters	Climate action failure	Water crises	Extreme weather
5th	Oil price shock	Pandemics	Fiscal crises	Fiscal crises	Energy price volatility	Energy price volatility	Climate action failure	Infrastructure breakdown	Climate action failure	Energy price shock	Climate action failure	Water crises	Natural disasters	Water crises

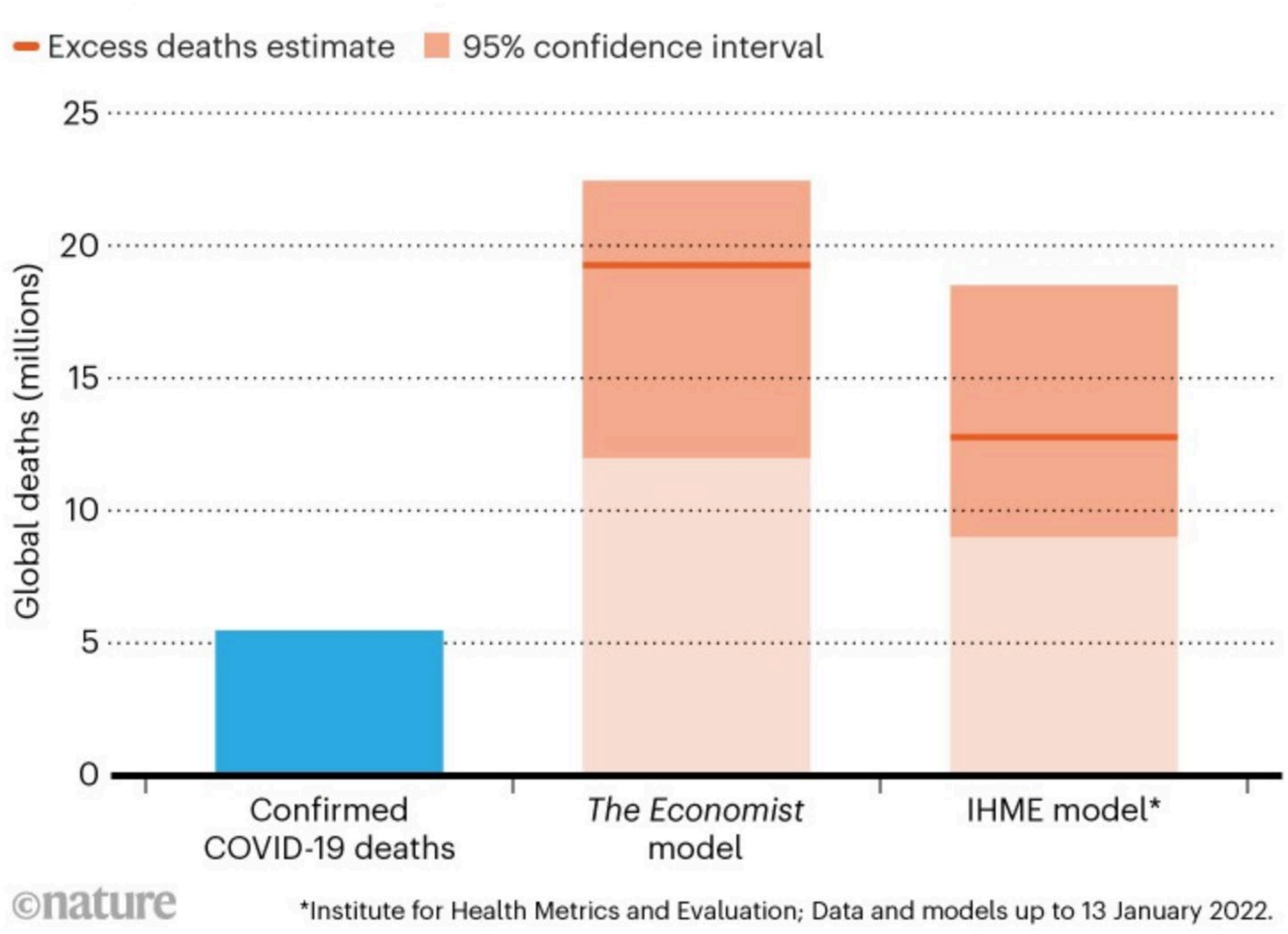
WEF top threats by impact – Global perceptions survey
https://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

(2019) 2020

- First coronavirus discovered in 1965 – the common cold
- Named after their “crown” like appearance
- SARS first emerged in China in 2002 – spread to 28 countries: 8000 infected
- SARS-COV-2 : Covid-19: November 2019, Wuhan, China
- Declared a pandemic by WHO on 11 March 2020
  - Alpha (UK); Beta (S Africa) : 18 December 2020
  - Gamma (Brazil): 11 Jan 2021
  - Delta (India): 4 Apr 2021
  - Omicron (Multiple): 24 Nov 2021
- UK approves Vaccines on 2 December 2020 – “miracle”
- Living with Covid: endemic: expect a “winter seasonal illness”



Published death rate materially understates



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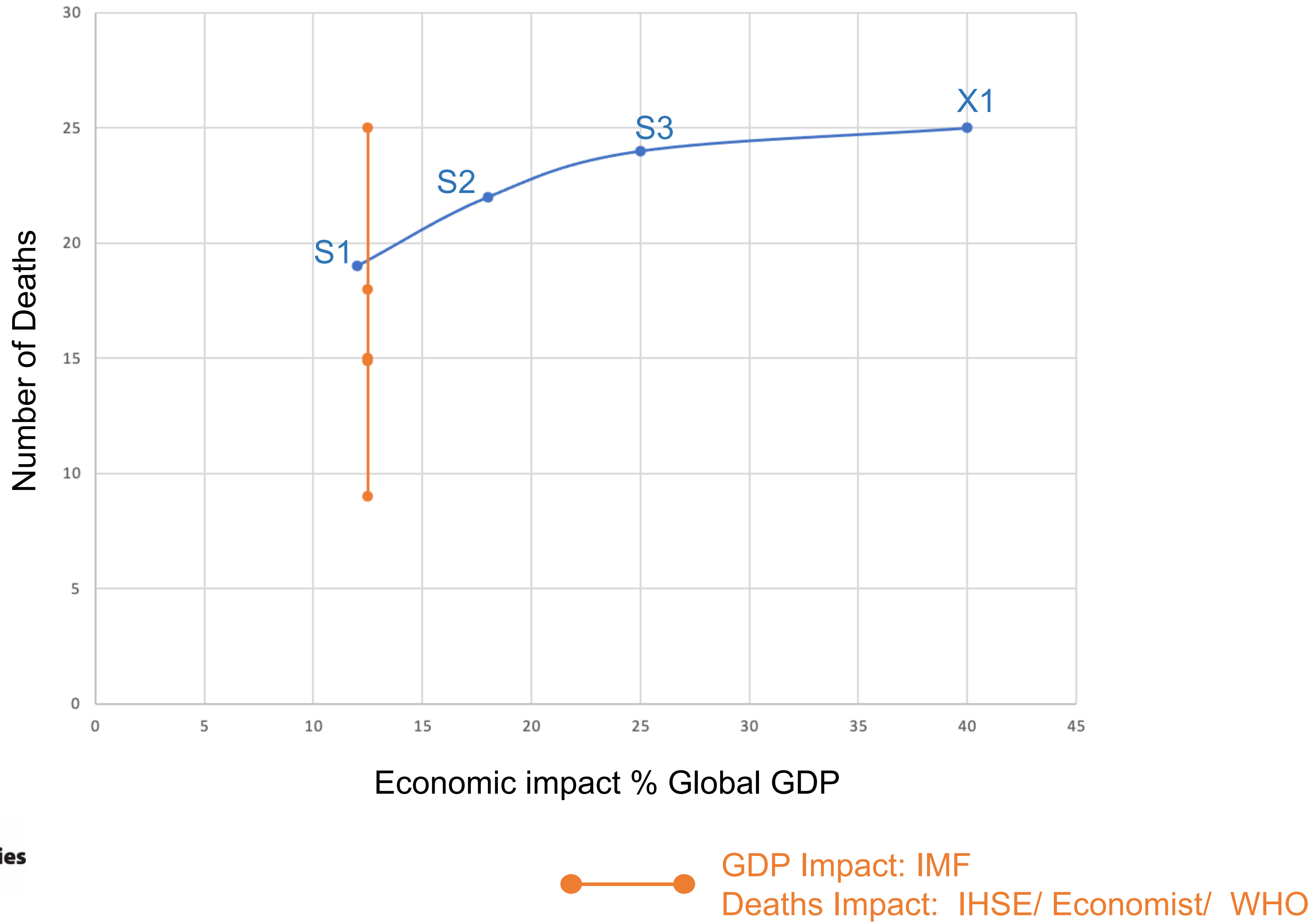
https://github.com/TheEconomist/covid-19-the-economist-global-excess-deaths-model

CRS Sao Paulo estimates vs actuals



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Covid differences to Influenza

- More contagious
- Contagious 2-3 days before symptoms vs 1
- Contagious for longer
- Symptoms last 2-14 days (vs 1-4)
- More serious illness in some
- Different drugs required to treat

Covid (whilst awful) is a moderate pandemic

Metric	COVID-19	Flu 2009 (H1N1)	Flu 1968 (H3N2)	Flu 1957–59 (H2N2)	Flu 1918–20 (H1N1)
Per-capita excess mortality rate (estimate)	0.15–0.28%	0.005%	0.03%	0.04%	1%
Global excess deaths (estimate) adjusted to 2020 population	12 million–22 million	0.4 million	2.2 million	3.1 million	75 million
Mean age at death (years; United States and Europe only)	73–79	37	62	65	27

Sources: Simonsen, L. & Viboud, C. *eLife* **10**, e71974 (2021); COVID-19 estimates: *The Economist*'s model (to January 2022); age of death data: US CDC, UKHSA.

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Covid in context

- Marani et al
- Epidemics database of 539 epidemics from 1500 to 1960
- Available from : https://zenodo.org/record/4626111#.YoOk3C8w1m8
- Fitted statistical models to create return period estimates

- Spanish Flu
  - 32 m deaths
  - 3 years
  - Global population: 1.87bn
  - Epidemic Intensity = 32 / (3 * 1.87) = 5.7

Intensity and frequency of extreme novel epidemics

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Observational knowledge of the epidemic intensity, defined as the number of deaths divided by global population and epidemic duration, and of the rate of emergence of infectious disease outbreaks is necessary to test theory and models and to inform public health risk assessment by quantifying the probability of extreme pandemics such as COVID-19. Despite its significance, assembling and analyzing a comprehensive global historical record spanning a variety of diseases remains an unexplored task. A global dataset of historical epidemics from 1600 to present is here compiled and examined using novel statistical methods to estimate the yearly probability of occurrence of extreme epidemics. Historical observations covering four orders of magnitude of epidemic intensity follow a common probability distribution with a slowly decaying power-law tail (generalized Pareto distribution, asymptotic exponent = −0.71). The yearly number of epidemics varies ninefold and shows systematic trends. Yearly occurrence probabilities of extreme epidemics, P_y, vary widely: P_y of an event with the intensity of the "Spanish influenza" (1918 to 1920) varies between 0.27 and 1.9% from 1600 to present, while its mean recurrence time today is 400 y (95% CI: 332 to 489 y). The slow decay of probability with epidemic intensity implies that extreme epidemics are relatively likely, a property previously undetected due to short observational records and stationary analysis methods. Using recent estimates of the rate of increase in disease emergence from zoonotic reservoirs associated with environmental change, we estimate that the yearly probability of occurrence of extreme epidemics can increase up to threefold in the coming decades.

epidemics | extremes | infectious diseases

Long-term observations and analysis tools to investigate nonstationary processes are available in several disciplines (1, 2). However, extensive epidemiological information at the global scale remains fragmented and virtually unexplored from this perspective, leading to a lack of analyses attempting to reconcile observations of a heterogeneous past. The objectives of this work are to identify the emergent features of the probability distribution of epidemic intensities and to quantify the probability of occurrence of extreme epidemics by assembling and analyzing a global historical dataset. This long historical record of infectious disease epidemics (1600 to present) was assembled from an extensive literature (3–9) and includes 476 documented infectious disease epidemics (217 epidemics with known occurrence, duration, and number of deaths, 145 known to have caused less than 10,000 deaths, and 114 for which only occurrence and du-

The composition of the dataset, in terms of the primary reemerging diseases and of disease types, is summarized in *SI Appendix*. We subsequently further selected epidemics to be analyzed by the following additional criteria: 2) epidemics were considered only if they are not currently active (e.g., AIDS/HIV, malaria, and COVID-19 were excluded), and 3) epidemics that were ended by the introduction of vaccines or effective treatments were excluded. This last condition, together with the difficulty of determining how some epidemics were ended at a global scale, led to the exclusion of all epidemics occurring after the end of World War II in 1945. Conditions two and three ensure that the disease dynamics are governed by the properties of the pathogen and by transmission dynamics (susceptible-infected interactions possibly mediated by vectors), unaffected by treatments or interventions. In summary, the 1600 to 1945 dataset includes 182 epidemics with known occurrence, duration, and number of deaths, 108 known to have caused less than 10,000 deaths, and 105 for which only occurrence and duration are recorded, for a total of 395 epidemics.

Results

The Probability Distribution of Epidemic Intensity. The empirical exceedance frequency distribution of epidemic intensity is well described by a generalized Pareto distribution (GPD, Fig. 1) over almost four orders of magnitude of the independent variable. The GPD notably exhibits a power-law tail, which signals the absence of a characteristic epidemic intensity and a slowly decaying probability of intense epidemics (10). The fitted GPD is characterized by a power-law tail exponent $\alpha = -0.71$ approximately for $i > 3 \times 10^{-2}$ ‰/year (Fig. 1), and is robust with respect to the uncertainty characterizing historical accounts of

Significance

Estimates of the probability of occurrence of intense epidemics based on the long-observed history of infectious diseases remain lagging or lacking altogether. Here, we assemble and analyze a global dataset of large epidemics spanning four centuries. The rate of occurrence of epidemics varies widely in time, but the probability distribution of epidemic intensity assumes a constant form with a slowly decaying algebraic tail, implying that the probability of extreme epidemics decreases slowly with epidemic intensity. Together with recent estimates of increasing rates of disease emergence from animal reservoirs associated with environmental change, this finding suggests a high probability of observing pandemics similar to COVID-19 (probability of experiencing it in one's lifetime currently about 38%), which may double in coming decades.

Author contributions: M.M., G.G.K., W.K.P., and A.J.P. designed research; M.M. performed research; M.M. analyzed data; and M.M., G.G.K., W.K.P., and A.J.P. wrote the paper.

The authors declare no competing interest.

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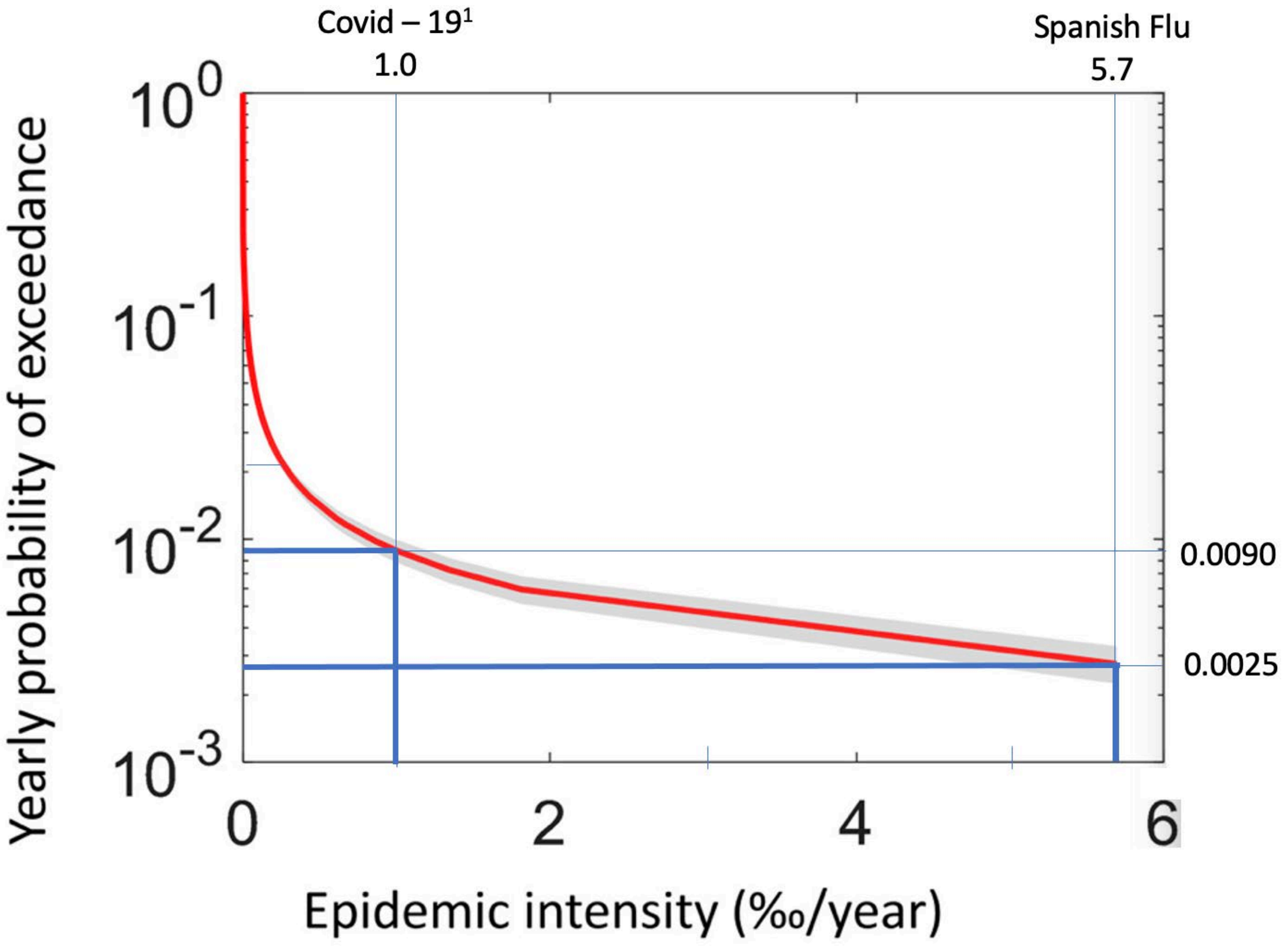
Location	Start Year	End Year	# deaths (thousands)	World Population (thousands)	Relative Epidemic size (per mil)	Intensity (deaths per mil/year)	Disease	References	N
China, Kwangsi	1500	1500	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Shansi	1504	1504	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Hunan, Hupeh, Kwangtun, Kwangsi, yunnan,	1506	1506	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
Hispaniola	1507	1541	300	463230	0.647626449	0.018503613	Smallpox	Kohn, 1999	
Pandemic, Influenza	1510	1510	-999	463230	-2.156596075	-2.15659608	Influenza	Morens et al., 2010	
China, Chekiang	1511	1511	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Yunnan	1514	1514	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Hupeh	1516	1516	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Fukien	1517	1517	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
China, Hopei, Shantung, Chekiang	1519	1519	-999	463230	-2.156596075	-2.15659608	Unknown	McNeill, 1998	
Ireland	1519	1525	-999	463230	-2.156596075	-0.30808515	Plague	Kohn, 1999	
Mexico	1519	1520	6500	463230	14.0319064	7.015953198	Smallpox	Acuna-Soto et al., 2002	
European diseases in the Americas	1520	1635	10300	474800	21.69334457	0.187011591	Smallpox, etc.	Kohn, 1999; Lovell, 1992	
China, Shensi	1522	1522	-999	476580	-2.09618532	-2.09618532	Unknown	McNeill, 1998	
China, Shantung	1525	1525	4.1	479250	0.008555034	0.008555034	Unknown	McNeill, 1998	
French army in Italy	1528	1528	21	481920	0.043575697	0.043575697	Typhus	Socolovschi and Raoult, 2009	
China, Shansi, Hupeh, Szechwan, Kweichow	1528	1529	-999	481920	-2.072958167	-1.03647908	Unknown	McNeill, 1998	
England, Germany, northern Europe	1529	1529	-999	482810	-2.069136928	-2.06913693	Sweating Sickness	Kohn, 1999	
Edimburgh	1530	1530	-999	483700	-2.06532975	-2.06532975	Plague	Kohn, 1999	
China, Shensi, Hupeh, Chekiang, Hunan, Fukien	1532	1535	-999	485480	-2.057757271	-0.51443932	Unknown	McNeill, 1998	
Ireland	1535	1536	-999	488150	-2.0465021	-1.02325105	Unknown	Kohn, 1999	
China, Kwangsi	1538	1538	-999	490820	-2.035369382	-2.03536938	Unknown	McNeill, 1998	
Ottoman war	1542	1542	30	494380	0.060682066	0.060682066	Typhus	Socolovschi and Raoult, 200	
China, Shansi, Honan, Fukien	1543	1545	-999	495270	-2.017081592	-0.67236053	Unknown	McNeill, 1998	
Americas	1545	1548	10000	497050	20.11870033	5.029675083	Cocolitzli	Acuna-Soto et al., 2000; 200	
India, Goa	1545	1545	8	497050	0.01609496	0.01609496	Smallpox	Fenner et al., 1988	
England	1551	1551	-999	502390	-1.988494994	-1.98849499	Sweating Sickness	Kohn, 1999	
Siege of Metz	1552	1552	10	503280	0.019869655	0.019869655	Typhus	Conlon, 2009	
China, Hopei	1554	1554	-999	505060	-1.977982814	-1.97798281	Unknown	McNeill, 1998	
Brazil	1555	1563	-999	505950	-1.974503409	-0.21938927	Smallpox	Kohn, 1999; Cliff, 2004	

Return period of Covid or Worse: 111 years



111 years

400 years

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[1] Assuming 15m deaths

Why you should care about 1 in 500 risks

- Short answer: Risks stack up
- 10 x 1/500 = 1 in 50: expect to see one of them in your lifetime
- 10 Extreme Threats to care about:
  - Pandemic
  - Space weather
  - Cyber storm
  - Food system shock
  - Financial crisis
  - Water crisis
  - Dangerous technology
  - Biodiversity loss
  - Major Long lasting Energy blackout
  - Climate action failure

Key messages

- CRS Scenarios gave a good feel for GDP costs and death-toll
- Don’t assume one scenario for pandemic planning
- Risks stack: don’t ignore 1-in-500 risks : there are lots of them
- Our deep dive session this afternoon will explore methods to create scenarios and other modelling approaches

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