LEARNING FROM COVID-19

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People's lives have been severely disrupted by COVID-19, with high numbers in hospitals and many deaths after the initial outbreak in China. If the efforts of many statistics educators were fulfilled to increase the number of statistically literate citizens who can make evidence-based decisions based on accurate data, we may have had lower infection and death rates. Unfortunately, the data is rather unreliable, especially with the use of self-testing and reporting. In this paper, we assert that statistics requires context to quantify risk. We present data and a summary of developments in Australia and England with the hope that case studies can be developed for students to understand risk better.

INTRODUCTION—COVID-19 PANDEMIC

Risk is the underlying motivation for the concept of probability and has existed from time immemorial, though people thought that risk had been minimised from global health in the 20th century in the western world (after the flu pandemic around 1918). There have been a number of epidemics, but the COVID-19 pandemic exposed the limitations in this view. In December 2019, the first cases of COVID-19 were reported in Wuhan, China. At the end of January 2020, the World Health Organisation (WHO) declared a pandemic. We believe that the pandemic presents a valuable opportunity for students to explore ideas of risk, and hence of probability, in a realistic situation (Kapadia, 2021).

In practice, responses to the pandemic were linked to the political situation in each country, as well as its geography and cultural context. With the declaration of a pandemic, governments made decisions about means of controlling the pandemic and the reproduction number. Approaches amounted to *suppression* of the virus (a, b, c), *mitigation* (d, e, f, g, h), or (strong) *advice* (i). Decisions based on these approaches, in terms of decreasing severity, were:

(a) Travel bans between countries, admission based on testing, and quarantining 7–14 days upon arrival;
(b) Suppression by legally enforced internal isolation to eliminate the virus;
(c) Testing systems to test-trace-isolate (t-t-i) the virus;
(d) Strict lock-down with limited movement across all businesses and venues in a state or country;
(e) Closure of all non-essential shops, establishments, and businesses;
(f) Indoor social distancing;
(g) Restrictions on meeting sizes;
(h) Compulsory use of face masks; and
(i) Guidance and (strong) advice offered but not legally enforced.

Countries such as China, Australia, New Zealand, and small island-nations decided on suppression of COVID-19 and used all of the strategies listed above (University of Oxford, 2022). Most European countries decided on the fourth option of mitigation and tried to implement (c), with limited success because numbers rose too rapidly. An outlier was Sweden, where the legal system prevented strict lockdown, though there was strong guidance, with (g) and (h) introduced a few months after the pandemic was declared. In South America, approaches varied, with Brazil taking the final option, and some senior politicians denying the existence of the virus. The United States took various options, decided by each state, with denials about the virus from some senior politicians. Far East Asian countries mainly took the same approach as China, whereas other Asian countries mainly aimed at mitigation (d). In Africa, the approach varied, but was sometimes the final option (i).

It is virtually impossible to suppress a pandemic by banning travel in countries with large land borders. In the Far East, the cultural norm enabled strict restrictions, including systematic tracking of the virus. In Europe, with its emphasis on openness and discussion, strict restrictions were problematic. In Africa, with its younger population, the virus was less deadly. A game changer was the approval of a vaccine, announced to have about 95% efficacy to prevent major illness from COVID-19 (but not to stop its transmission) by Pfizer on 9 November 2020 (Pfizer, 2020).

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RISK MANAGEMENT

How should individuals react to the pandemic? This is a complicated question to answer, as is shown by the range of responses across the world. A key aspect of reaction is the availability of information. Even more important is the validity and reliability of the information, which reinforces the need to teach students about risk management as a routine part of their education. We start from the following definition of risk: "By risk we understand a … situation with inherent uncertainty about the (future) outcomes, which are related to impact (cost, damage, or benefit)" (Borovcnik & Kapadia, 2011, p. 3). This builds on the work of Gigerenzer (2002), whose school has developed ideas in detail in Berlin.

Early in the 1990s, Kapadia and Borovcnik (1991) listed 10 assertions to be aware of when thinking about risk and teaching probability. The first three are all relevant for understanding people's decision making, especially when decision making often depends on gut feelings rather than rational risk assessment: (a) people use personal experience in assessing chance in a rather haphazard manner; (b) people process information in a rather incomplete way; and (c) people process information in a way biased by memorable events. Therefore, it is important to educate students about probability and decision making under uncertainty based on possible risks to avoid decision making based on gut feelings.

Two examples of personal decision making without proper quantification of risk are *use of face masks* and *uptake of vaccines*. A major area of international discussion has been on the *use of face masks*. In some countries, this was seen as a routine approach (University of Oxford, 2022). For example, in Singapore, the government gave every household four face masks to use if they had symptoms or were in crowded places. Later, quarantine measures were announced for those with COVID-19. The *use of vaccines* created discussions and outcries around the world. In Hong Kong, after the first (Chinese) vaccine was administered, rumours spread about possible severe illness or even death after taking the vaccine. Subsequently, only 15% of elderly people were reported to have taken the second jab. When omicron struck Hong Kong in March 2022, there was a huge spike in daily deaths. This was not the case in New Zealand and Singapore, with similar populations but where a high percentage of people took the second or even third jabs. Many more examples should be collected to illustrate the underlying ideas and risks and how to evaluate them.

This paper presents real and modelled data. Possible questions are raised that could be incorporated in case studies about the pandemic. A short illustrative summary is presented for Australia and England, which took very different approaches of suppression and mitigation. We suggest that more data should be collated to show different aspects of the situation in different countries or federal states. This would enable probability calculations and facilitate the creation of case studies on the pandemic to help students at school and tertiary levels to learn about dealing with risk, specifically public and private risk, which can and are perceived very differently by individuals, who want to be free, and governments, who want to provide security and safety.

DATA AND ITS RELIABILITY

In Australia, East Asia, and China, COVID-19 deaths have been reported to be relatively low. The most severe adverse effects of COVID-19 were in the United States, South America, and Europe, with its relatively aged population. There were reported to be 2,000–3,000 deaths per million in these latter countries (University of Oxford, 2022). There was a high economic cost, and slogans such as 'lives versus livelihood' or 'health versus wealth' were common in political discourse.

How COVID-19 deaths are recorded differs between countries. Some countries only counted hospital deaths, whilst others also included deaths in homes. There is no internationally agreed definition of death from COVID-19. In the United Kingdom (UK), death from COVID-19 was defined by language on the death certificate, with COVID-19 listed either as the sole cause or with other (linked) health issues (Office for National Statistics, 2021). Approximately 80% of deaths were of people aged over 80, and most people had another adverse health condition. In Australia, national guidelines define a COVID-19 death as "a death in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19 (e.g., trauma)" (OECD, 2021, Annex 3). Table 1 is based on data from John Hopkins University (JHU, 2022). It gives the number of cases in selected countries, the number of deaths per million from the virus (micromort), their population, as well as actual number of deaths. The term micromort (mm) is the risk of death per million of population, as devised by Spiegelhalter (Blastland & Spiegelhalter, 2013) and helps to understand low risk/probability. For the UK, the risk of death for the population as a whole was around 2,500 mm on 4 January 2022, a sort of

subjective probability. Given that 80% of deaths were amongst those aged over 80, their risk of death was much higher, around 40,000 mm; conversely, the risk of death for a young child was less than 1 mm. This is a stark reminder of how risk varies for individuals, which is why such ideas should be explored by students to help them become statistically literate in the future.

Table 1. John Hopkins University 1 April 2022 COVID-19 cases and deaths

Country	Cases	Micromorts Deaths (pm)	Population (m)	Deaths
Australia	4,628,163	245	26	6,365
UK	21,379,545	2,444	68	166,168
Sweden	2,487,852	1,837	10	18,365
China	1,400,358	9	1,440	12,583
India	43,027,035	372	1,400	521,264
United States	80,142,876	2,939	334	981,780

The actual death toll from COVID-19 is much higher than reported due to limited testing and problems with attributions for cause of death. We believe that a better measure of the impact of COVID-19 is *excess deaths*. In practice, it is complicated to calculate excess deaths in each country. The *Economist* (2021) attempted this calculation in 2021, and a subset of their results (modelled data) is given in Table 2. Their model illustrates the large uncertainty in estimates, which is worthy of wider discussion. The range of excess deaths is much narrower in developed countries than in developing countries. Table 2 reports statistics for continents, not countries, which hides information due to aggregation of the data from different countries that may differ markedly. The WHO (2022) estimated that there have been around 15 million deaths, more than double the JHU count of around 6 million and in some countries a tenfold under-counting of deaths.

Table 2. Excess deaths per million population (Economist, 2021)

Region	Official deaths (mm)	Excess deaths (mm)	Range
Asia	228	2000	740 to 2500
Latin America	2218	3200	3,000 to 3,400
Europe (incl. EU)	1591	2500	2,400 to 2,600
Africa	146	1100	620 to 1600
North America	1832	2250	2,100 to 2,400
European Union	1697	1850	1,800 to 1,900
Oceania	42	-100	−240 to 160

Our view is that the data from developed countries is less susceptible to bias because of their mature political systems and well-established systems of data collection. *Fearless, independent media* also play a role in ensuring more transparency and accuracy in the data. However, there are some negative aspects in that, with the aim of increasing revenue, the media tend to focus on negative and alarming aspects.

We propose the need for a well-coordinated, cross-curricular approach for teaching risk and probability linked to the pandemic. We present a small sample of typical *key questions* for discussion within the classroom. For example, careful data would need to be collated with regards to questions relating to lives versus livelihood. The case studies in this paper present currently available data from Australia and England and their specific circumstances, which need to be considered when the following questions are explored statistically.

1. How reliable is the data given that data collection varies between/within countries?
2. Does instant information such as daily case numbers help or hinder the decision making of citizens?
3. Which strategy is best to deal with a pandemic—suppression, mitigation, or strong guidance?

4. How should one balance health and economic costs: lives versus livelihood?
5. Should (can) we put a value on human life when making a decision to lockdown or not to lockdown?
6. What are the short and long terms effects of school closures on children and society?
7. What are the short and long terms effects of closing the borders on a country's hospitality industry?
8. How should one consider adverse events such as *long COVID-19* and days lost for those who catch it?
9. Should I or my family follow the lockdown rules?
10. Should I or my family get vaccinated/boosted?

For a case study on risks relating to the pandemic, each country should have its context considered and discussed, as well as the reliability of obtained data. This was the approach taken in the innovative teaching materials produced by the Schools Council (1980), which remains relevant today. There is a case study (Testing, Testing) linked to the benefits and risks of cancer screening of a population. Health systems tend to support mass screening, but recent research shows some limitations in terms of cost and even efficacy. A similar approach can be taken to explore some of the questions above, especially with respect to individual responses to perceived risk and actions to take. For COVID-19, the risk was higher for older people than children, hence the need to discuss who should take a vaccine.

AUSTRALIA

Australia, being an island nation, was able to close its borders on 19 March 2020 except to its citizens. Many citizens were unable to return to Australia due to limited arrivals caps (5,000 to 7,000 per day) set by the government based on hotel quarantine capacity. The number of Australians who were stuck overseas stayed at approximately 30,000 to 40,000 due to some citizens still going overseas for personal reasons such as sick family members overseas (Ritchie, 2021). According to the Australian Bureau of Statistics (2021), "in June 2021 arrivals decreased 93.4% compared to pre-COVID-19 levels in June 2019." In later years, it may be possible to estimate the impact of the cap and the number of deaths caused by the international travel restrictions. Leaving Australia was also hard because the only way to do so is by flying, and there were hardly any flights to and from Australia (Stobart & Duckett, 2021). The delivery times and costs of goods from overseas increased due to limited flights. The international travel ban lasted more than 700 days, which led to media reports about *fortress Australia*. The second largest city in Australia, Melbourne, had the longest lockdowns in the world with 262 days (Aljazeera, 2021).

Kompas et al. (2021) argued that strict lockdowns in Australia have been highly effective in controlling the virus as well as economically beneficial for Australia. However, their approach has some limitations. They provide welfare loss estimates of COVID-19 patients using the *value of a statistical life* of A$4.9 million, adjusted by 0.70 for those older than 70. For the unmitigated spread scenario, the losses are very large, amounting to A$572.8 billion (about a quarter of Australia's GDP). Their 'estimated economic losses' are roughly A$51.98 billion. Kompas et al. conclude that "Our findings provide robust evidence that a 'go hard, go early' mandated suppression, at least in a high-income country like Australia, is the preferred approach from both a public health and an economy perspective" (p. 16). The Australian author of this paper supports these conclusions. The British author is less convinced. The chosen *value of a statistical life year* is very high while the economic costs have been under-estimated. The approach for England below comes to a rather similar conclusion about lockdown 'cost,' though the actual figures are crude and subject to much variability. Such data would thus provide an excellent basis for discussion in the classroom. If Australia had followed an approach similar to Sweden, the expected deaths due to COVID-19 would have been around 38,000 (Table 1 Swedish micromort applied to Australian population), which is 6 times more than reported. However, this estimate is based on the questionable assumption that Sweden and Australia have similar demographics and geography. We can say that the restrictions helped a significant number of Australians to avoid COVID-19 deaths, but one also needs to estimate deaths from other reasons such as lack of health support or personal anguish leading to suicide, and deaths abroad.

ENGLAND

Initially, there was a strict lockdown across the UK for 114 days (less than many other countries) from 24 March 2020, a few days later than other countries. Restrictions were relaxed in summer 2020 but imposed again several times before all restrictions were lifted in spring 2022.

In England, an issue that arose early in the pandemic was elderly care homes, where many deaths occurred because of their population. Another issue was ensuring that the health system could cope with increased demand. In practice, the virus led to long delays for hospital operations. Travel was not banned initially. The hospitality sector was particularly severely hit.

Surveys were set up by Office for National Statistics (ONS) to provide valuable information about COVID-19 spread and transmission. In some ways, this was the most successful part of the response in England, because the data was relatively trustworthy and reliable, a key aspect of dealing with a health emergency. Over 2021, the delta and omicron variants had a significant impact, yet England decided to 'live with the virus' beginning in March 2022, when ONS surveys showed that around 8% (about 4 million) of people had the virus, including many for the second time, despite being vaccinated twice (ONS, 2022).

In 2020, there were about 80,000 (12%) excess deaths in England, compared to deaths over the previous five years (ONS, 2021). This is termed a serious adverse event (SAE). In April 2021, excess deaths fell to 6% below the average for 2015–19 but rose above the average in July 2021, though not markedly so. It is hard to estimate the number of extra deaths from the virus without legal lockdown. Our very crude estimate is around an extra 20,000 deaths (still an SAE), based on deaths in other countries with limited or no lockdowns such as Brazil and some states in the United States. Without lockdown, there would have been more days lost from sickness and a significant number of people also getting long COVID-19. Currently, it is hard to estimate the numbers for these so-called adverse events (AE). Estimates from ONS noted that about a million people initially self-reported having long COVID-19 in early 2022, but this figure is open to doubt.

The economic cost in UK is estimated by ONS to be about GBP 170 billion (€200 billion). It is likely that there would be an economic cost of around half that amount even without lockdown. This is a crude estimate but there were certainly extra costs (€80 billion) from a 'furlough' scheme, whereby the government covered the costs for many businesses that could not function, especially the hospitality and events industries. This gives an estimated cost of around GBP 5 million per SAE—20,000 excess deaths prevented by lockdown. Trying to take AE into account is difficult but it is likely that the cost would still be over GBP 1 million. More lives were lost with less strict lockdown but at a high cost.

CONCLUDING COMMENTS

Kapadia and Borovcnik (1991) and Kapadia (2021) have advocated the need to include risk as a key component of education. We believe that the COVID-19 pandemic provides an excellent opportunity to explore risk in practice. This can be done from the perspective of probability within the mathematics curriculum for schools and in general university statistics courses.

In our experience, using news and current affairs as examples for teaching statistics addresses two important issues. Firstly, authentic data provides a justification for explaining the importance of statistics in everyone's lives, especially for statistics service courses where students see statistics as a hurdle to be jumped over instead of an opportunity to learn useful tools to understand the world around them. Secondly, disengagement of children and students with their learning has been increasing around the world with empty classrooms. Use of COVID-19 statistics could encourage students to be more engaged with their learning, particularly if they can relate what is presented to them as useful for making their own evidence-based decisions. We may have intense, lively discussions in our classrooms instead of silence or the lone teacher's voice.

It is important that students learn to understand *statistics* is not *mathematics* and COVID-19 statistics presented to them are not dry numbers. This understanding will enable them to use government data sources after careful consideration of the definition of variables, how the definitions have changed, and implications of the numbers to the risk factors associated with their lives. The key ideas they would learn are (a) the use of (subjective) probability in decision making, (b) the ways to check reliability and trustworthiness of data in the media, and (c) a better awareness of the relevance of data in everyday life.

Case studies would educate students about risk by using authentic data. With better educated students in statistics, we might have a snowball effect where students educate their immediate families

and friends to look at statistics sensibly in an era of fake news. Students would learn how to make better informed decisions in a pandemic, such as decisions about wearing masks, taking the vaccine, or obeying social distancing rules. They would learn how to avoid the three fallacies noted above and thereby deal with risk more effectively.

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