The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

YOUR QUESTION

What mathematical modelling evidence is available to inform us of what will happen when we begin to move out of lockdown from COVID-19? What are the factors that may predict a second surge of COVID-19 activity?

IN A NUTSHELL

There are various mathematical models relating to the duration of and exit from COVID-19 pandemic restrictions proposed in the international literature, although there is as yet no conclusive evidence as to their reliability or effectiveness.

Several countries have now published roadmaps as part of their exit strategies from the restrictions imposed on their population[5,6,7,9,10,11] and the EU has published an over-arching roadmap to guide EU countries as they publish their own strategies[8]. The EU roadmap calls for an exit strategy that is coordinated with member states and that will prepare the ground for a comprehensive recovery plan and unprecedented investment.

The WHO[2] continues to advise all countries considering the easing of lockdown measures according to six guiding criteria:

- First, that surveillance is strong, cases are declining and transmission is controlled.
- Second, that health system capacities are in place to detect, isolate, test and treat every case and trace every contact.
- Third, that outbreak risks are minimized in special settings such as health facilities and nursing homes.
- Fourth, that preventive measures are in place in workplaces, schools and other places where it's essential for people to go.
- Fifth, that importation risks can be managed.

— Sixth, that communities are fully educated, engaged and empowered to adjust to the 'new norm.'

The risk of returning to lockdown remains very real if countries do not manage the transition extremely carefully, and in a phased approach.

HIQA[1] notes that certain triggers are essential before the easing of restrictions should be considered, namely declining or stabilising of new cases and deaths, low rates of COVID-19-related hospital admissions and sufficient supply of personal protective equipment and ventilators in hospital settings.

Petersen et al[33] reviewed evidence on specific approaches adopted in different countries and isolated three key factors that should be considered as exit strategies are put in place: 1. reintroduction from countries with ongoing community transmission; 2. the need for extensive testing capacity and widespread community testing; and 3. adequate supply of personal protective equipment to protect health care workers. Lifting social distancing, how to reopen manufacturing, construction and logistics, the reopening of higher educational institutions and schools and the use of electronic surveillance are also discussed.

In emerging literature, Bin et al[12] propose that fast, intermittent lockdown intervals as an alternative COVID-19 exit strategy to the widely adopted policy of total lockdown may have the potential to be a method of virus suppression, while at the same time allowing continued — albeit reduced — economic activity. DeVlas et al[15] propose an exit strategy based on a phased lifting of restrictions in which successive parts of the country such as provinces stop stringent control, and COVID-19 related ICU admissions are distributed over the country as a whole. Importantly, vulnerable individuals need to be shielded until herd immunity has developed in their geographic area. Karin et al[23] propose a cyclic schedule of 4-day work and 10-day lockdown, or similar variants, can prevent resurgence of the epidemic while providing part-time employment. Conversely, Yap et al[43] contend that submaximal lockdowns perform better than pulsatile lockdowns.

The use of face masks by the general population has potential value in curtailing community transmission and the burden of the pandemic[19, 30, 52]. The community-wide benefits may be greatest when face masks are used

in conjunction with other non-pharmaceutical practices such as social-distancing, and when adoption is nearly universal compliance is high.

Ryan et al[38] emphasize that aligning decisions around the easing or removal of restrictions with societal needs will help to ensure that all segments of society are taken into consideration while managing the crisis; and that the process of incremental easing of restrictions to facilitate the resumption of community foundations such as commerce, education and employment is carried out in a manner that protects those most vulnerable to COVID-19. West et al[42] note that human behaviour is central to transmission of SARS-Cov-2 and changing behaviour is crucial to preventing transmission in the absence of pharmaceutical interventions. Isolation and social distancing measures including edicts to stay at home have been brought into place across the globe to reduce transmission of the virus, but at a huge cost to individuals and society. In addition to these measures, effective interventions to increase adherence to behaviours that individuals in communities can enact to protect themselves and others are urgently needed: use of tissues to catch expelled droplets from coughs or sneezes; use of face-masks as appropriate; hand-washing on all occasions when required; disinfecting objects and surfaces; physical distancing; and not touching one's eyes, nose or mouth.

IRISH AND INTERNATIONAL GUIDANCE

What does HIQA say?

Health Information and Quality Authority (2020) Review of restrictive public policy measures to limit COVID-19[1]

As growth in the spread of COVID-19 has begun to slow in some countries, there has been a shift toward easing and lifting restrictions. Some of the restrictions that are being eased internationally include the re-opening of schools and non-essential services and widening the limits on social gatherings. Triggers for the decision to ease restrictions include: declining or stabilising of new cases and deaths; low rates of COVID-19 related hospital admissions; and sufficient supply of personal protective equipment and ventilators in hospital settings.

What does the World Health Organization say?

World Health Organization (2020) WHO Director General's opening remarks at the media briefing on COVID-19 - 6 May 2020[2]

As more countries consider how to ease lockdown restrictions, the Director General reiterated the six criteria that WHO recommends countries to consider:

- First, that surveillance is strong, cases are declining and transmission is controlled.
- Second, that health system capacities are in place to detect, isolate, test and treat every case and trace every contact.
- Third, that outbreak risks are minimized in special settings such as health facilities and nursing homes.
- Fourth, that preventive measures are in place in workplaces, schools and other places where it's essential for people to go.
- Fifth, that importation risks can be managed.
- Sixth, that communities are fully educated, engaged and empowered to adjust to the 'new norm.'

The risk of returning to lockdown remains very real if countries do not manage the transition extremely carefully, and in a phased approach.

World Health Organisation (2020) Considerations in adjusting public health and social measures in the context of COVID-19: interim guidance, 16 April 2020[3]

The decision to introduce, adapt, or lift public health and social measures should be based on a risk assessment with a standard methodology to balance the risk of relaxing measures, capacity to detect a resurgence in cases, capacity to manage extra patients in health facilities or other locations, and ability to re-introduce public health and social measures if needed. A national risk assessment should be supported and implemented through subnational or even community level risk assessment as the transmission of COVID-19 is not typically homogenous within a country.

What does the European Centre for Disease Prevention and Control say?

European Centre for Disease Prevention and Control (2020) Coronavirus disease 2019 (COVID-19) in the EU/EEA and the UK. Ninth Update[4]

The risk of resurgence of sustained community transmission in the EU/EEA and the UK is currently moderate if measures are phased out gradually and

accompanied by appropriate monitoring systems and capacities with the option to reintroduce measures if needed; and remains very high if measures are phased out without appropriate systems and capacities in place, with a potential rapid increase in population morbidity and mortality.

What do the Centers for Disease Control and Prevention (United States) say?

Centers for Disease Control and Prevention (2020) Opening Up America Again[5]

Proposed State or regional gating criteria which should be satisfied before proceeding to reopening are designated as:

Symptoms	Cases	Hospitals
Downward trajectory of ILIs within a 14-day period	Downward trajectory of reported cases within a 14-day period	Treat all patients without crisis care
AND	OR	AND
Downward trajectory of COVID-19 syndromic cases within a 14-day period	Downward trajectory of positive tests as percentage of total tests within a 14-day period [flat or increasing volume of tests]	Robust testing program in place for at-risk health workers including emerging antibody testing

Centers for Disease Control and Prevention (2020) Helping to get and keep America open[6]

In order to get and keep America open states, tribes, localities and territories must be able to quickly identify new cases, break chains of transmission and protect first responders and health workers from infection.

Centers for Disease Control and Prevention (2020) CDC Activities and Initiatives Supporting the COVID-19 Response[7]

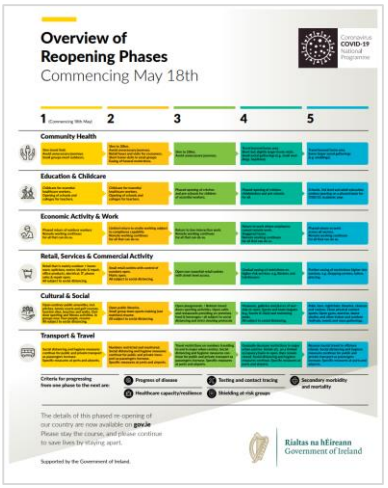
The plan for reopening America outlines a three-phased approach for reducing community mitigation measures while protecting vulnerable populations. The guidelines propose the use of six gating indicators to assess when to move through from one mitigation phase to another.

European Commission (2020) Joint European Roadmap towards lifting COVID-19 containment measures[8]

The joint European Roadmap towards lifting COVID-19 containment measures, presented by the President of the European Commission and the President of the European Council, responds to the European Council Members' call for an exit strategy that is coordinated with Member States and that will prepare the ground for a comprehensive recovery plan and unprecedented investment.

Government of Ireland (2020) Roadmap for Reopening Society and Business[9]

The roadmap sets out Ireland's plan for lifting COVID-19 restrictions.



Other pathways to reopening:

- Northern Ireland
- UK

INTERNATIONAL LITERATURE

What does the international literature say?

AMBIKAPATHY et al (2020) Mathematical modelling to assess the impact of 'lock down' on COVID19 transmission in India[10]

The developed model is efficient in predicting the number of COVID-19 cases compared to the actual reported cases in 14 countries. For India, the model

predicted marked reductions in cases for the intervention periods of 14 and 21 days of lockdown and significant reduction for 42 days of lockdown. Such intervention exceeding 42 days does not result in measurable improvement. Finally, for the scenario of panic shopping or situations where there is a sudden increase in the factors leading to higher exposure to infection, the model predicted an exponential transmission, resulting in failure of the considered intervention strategy.
Implementation of a strict lockdown for a period of at least 21 days is expected to reduce the transmission of COVID-19. However, a further extension of up to 42 days is required to significantly reduce the transmission of COVID-19 in India. Any relaxation in the lockdown may lead to exponential transmission, resulting in a heavy burden on the health care system in the country.

BARBAROSSA et al (2020) [Preprint Not Yet Peer-Reviewed] A first study on the impact of current and future control measures on the spread of COVID-19 in Germany[11]

We present the preliminary results of a mathematical study directed at informing on the possible application or lifting of control measures in Germany. The developed mathematical models allow us to study the spread of COVID-19 among the population and to assess the impact of non-pharmaceutical interventions. The overall goal is to suggest strategies for the mitigation of the current outbreak, slowing down the spread of the virus and thus reducing the peak in daily diagnosed cases, the demand for hospitalization or ICU admissions, and eventually fatalities.

BIN et al (2020) [Preprint Not Yet Peer-Reviewed] On Fast Multi-Shot COVID-19 Interventions for Post Lock-Down Mitigation[12]

Fast intermittent lock-down intervals at regular intervals are suggested as an alternative COVID-19 exit strategy to the widely adopted policy of total lockdown. Many proposed exit strategies have risks and uncertainties which could lead to a second wave of infection. We demonstrate that our proposed policies have the potential to be a method of virus suppression, while at the same time allowing continued—albeit reduced—economic activity. These policies, while not eliminating the virus, can nevertheless be sustained over long periods of time until a vaccine or treatment becomes available. The robustness of these policies stems from the fact that they are open loop methods; namely, lockdown periods are not triggered by measurements [inevitably uncertain and delayed] over short time scales such as hospital

admissions, but are instead driven by predictable, high-frequency, periodic triggers in and out of lockdown. A slow and inherently robust outer supervisory feedback loop based on measurements over longer time scales is used to tune the parameters of the mitigation strategy. These methods can act alone or can be used in combination with other mitigation strategies to provide additional levels of effectiveness in their operation.

BRETHOUWER et al (2020) [Preprint Not Yet Peer-Reviewed] 'Stay Nearby or Get Checked': A COVID-19 Lockdown Exit Strategy[13]

This paper repurposes the classic insight from network theory that long-distance connections drive disease propagation into a strategy for controlling a second wave of COVID-19. We simulate a scenario in which a lockdown is first imposed on a population and then partly lifted while long-range transmission is kept at a minimum. Simulated spreading patterns resemble contemporary distributions of COVID-19 across nations, regions and provinces, providing some model validation. Results suggest that the proposed strategy may significantly flatten a second wave. We also find that post-lockdown flare-ups remain local longer, aiding geographical containment. Public policy may target long ties by heavily focusing medical testing and mobility tracking efforts on traffic and transport. This policy can be communicated to the general public as a simple and reasonable principle: Stay nearby or get checked.

CHOWELL et al (2019) A novel sub-epidemic modeling framework for short-term forecasting epidemic waves[14]

Simple phenomenological growth models can be useful for estimating transmission parameters and forecasting epidemic trajectories. However, most existing phenomenological growth models only support single-peak outbreak dynamics whereas real epidemics often display more complex transmission trajectories.

Our findings highlight how overlapping sub-epidemics can capture complex epidemic dynamics including oscillatory behavior in the trajectory of the epidemic wave. This observation has significant implications for interpreting apparent noise in incidence data where the oscillations could be dismissed as a result of overdispersion, rather than an intrinsic part of the epidemic dynamics. Unless the oscillations are appropriately modeled, they may give a false positive or negative impression of the impact from public health interventions. These preliminary results using sub-epidemic models can help

guide future efforts to better understand the heterogenous spatial and social factors shaping sub-epidemic patterns for other infectious diseases.

DE VLAS et al (2020) [Preprint Not Yet Peer-Reviewed] A phased lift of control: a practical strategy to achieve herd immunity against COVID-19 at the country level[15]

Most countries are affected by the COVID-19 pandemic and experience rapidly increasing numbers of cases and deaths. Many have implemented nationwide stringent control to avoid overburdening the health care system. This paralyzes economic and social activities until the availability of a vaccine. We propose an alternative exit strategy to develop herd immunity in a predictable and controllable way: a phased lift of control. This means that successive parts of the country such as provinces stop stringent control, and COVID-19 related ICU admissions are distributed over the country as a whole. Importantly, vulnerable individuals need to be shielded until herd immunity has developed in their geographic area. We explore the characteristics and duration of this strategy using a novel individual-based model for geographically stratified transmission of COVID-19. The model predicts that individuals will have to experience stringent control for about 14 months on average, but this duration may be significantly shortened by future developments such as more ICU beds or better drugs. Clearly, the strategy will have a profound impact on individuals and society, and should therefore be considered carefully by various other disciplines—health systems, ethics, economics—before actual implementation.

DJIDJOU-DEMASSE et al (2020) [Preprint Not Yet Peer-Reviewed] Optimal COVID-19 epidemic control until vaccine deployment[16]

We use optimal control theory to explore the best strategy to implement while waiting for the vaccine. We seek a solution minimizing deaths and costs due to the implementation of the control strategy itself. We find that such a solution leads to an increasing level of control with a maximum reached near the fourth month of the epidemic and a steady decrease until vaccine deployment. This strategy strongly outperforms others with constant or cycling allocations of the same amount of resources to control the outbreak. This work opens new perspectives to mitigate the effects of the ongoing COVID-19 pandemic and may be used as a proof-of-concept in using mathematical modelling techniques to enlighten decision making and public health management.

DIMEGLIO et al (2020) The SARS-CoV-2 seroprevalence is the key factor for de-confinement in France[17]

Our statistical model for predicting the spread of SARS-CoV-2 in France is based on a diffusion and transmission coefficient that varies with an individual's age, the probability of contagion and two administration parameters [confinement and quarantine]. We use models to measure how the dynamics of the SARS-CoV-2 infection is affected by these different factors and how to adapt the de-confinement strategy.

DONSIMONI et al (2020) [Preprint Not Yet Peer-Reviewed] Should contact bans be lifted in Germany? A quantitative prediction of its effects[18]

Many countries are considering the lifting of restrictions of social contacts (RSC). We quantify the effects of RSC for Germany. We initially employed a purely statistical approach to predicting the prevalence of COVID-19 if RSC were upheld after April 20 and found that the peak of infected individuals would have be reached already by mid-April and that the number of infected individuals would fall below 1,000 at the beginning of July. When restrictions are lifted completely on April 20, the number of infected should rise sharply again from around April 27. A balance between economic and individual costs of RSC and public health objectives consists in lifting RSC for activities that have high economic benefit but low health costs. In the absence of large-scale representative testing of CoV-2 infections, these activities can most easily be identified if the federal states of Germany adopted exit strategies that differ across states.

EIKENBERRY et al (2020) To mask or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic[19]

Our results suggest that use of face masks by the general public is potentially of high value in curtailing community transmission and the burden of the pandemic. The community-wide benefits may be greatest when face masks are used in conjunction with other non-pharmaceutical practices such as social-distancing, and when adoption is nearly universal and compliance is high.

FLAXMAN et al (2020) Report 13: Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries[20]

Cognizant of the lag of 2-3 weeks between transmission changes and when their impact can be observed in mortality trends, for most of the countries

considered here it remains too early to be certain that recent interventions have been effective. If interventions in countries at earlier stages of their epidemic are more or less effective than they were in the countries with advanced epidemics, on which our estimates are largely based, or if interventions have improved or worsened over time, then our estimates of the reproduction number and deaths averted would change accordingly. It is therefore critical that the current interventions remain in place and trends in cases and deaths are closely monitored in the coming days and weeks to provide reassurance that transmission of SARS-Cov-2 is slowing.

GERMAN et al (2020) [Preprint Not Yet Peer-Reviewed] Modeling Exit Strategies from COVID-19 Lockdown with a Focus on Antibody Tests[21]

This paper presents two epidemiological models that have been developed in order to study disease dynamics of the COVID-19 pandemic and exit strategies from lockdown. A strategy is needed such that both the health system is not overloaded letting people die in an uncontrolled way and also that the majority of people can get back their social contacts as soon as possible. We investigate the potential effects of a combination of measures such as continuation of hygienic constraints after exiting lockdown, isolation of infectious persons, repeated and adaptive short-term contact reductions and also large-scale use of antibody tests in order to know who can be assumed to be immune and participate in public life without constraint. We apply two commonly used modeling approaches—extended SEIR models formulated both as System Dynamics and Agent-Based Simulation—in order to get insight into the disease dynamics of a complete country such as Germany and also into the more detailed behavior of smaller regions. We confirm that without intervention the consequences of the pandemic can be catastrophic and we extend such findings with effective strategies to overcome the challenge. Based on modeling assumptions it can be expected that repeated short-term contact reductions will be necessary in the next years to avoid overload of the health system and that on the other side herd immunity can be achieved and antibody tests are an effective way to mitigate the contact reductions for many.

GILBERT et al (2020) Preparing for a responsible lockdown exit strategy[22]

In just a few weeks' time, leaders across the globe will have to start making decisions about lifting lockdown policies with considerable social, economic and political consequences. We propose a framework for what is arguably

the most difficult health challenge that governments have faced since the beginning of this century: a responsible lockdown exit strategy.

KARIN et al (2020) [Preprint Not Yet Peer-Reviewed] Adaptive cyclic exit strategies from lockdown to suppress COVID-19 and allow economic activity[23]

Many countries have applied lockdown that helped suppress COVID-19 but with devastating economic consequences. Here we propose exit strategies from lockdown that provide sustainable—albeit reduced—economic activity. We use mathematical models to show that a cyclic schedule of 4-day work and 10-day lockdown, or similar variants, can prevent resurgence of the epidemic while providing part-time employment. The cycle pushes the reproduction number below one by reduced exposure time and by exploiting the virus latent period: those infected during work days reach peak infectiousness during lockdown days. The number of work days can be adapted in response to observations. Throughout, full epidemiological measures need to continue including hygiene, physical distancing, compartmentalization, testing and contact tracing. This conceptual framework, when combined with other interventions to control the epidemic, can offer the beginnings of predictability to many economic sectors.

KISSLER et al (2020) Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period[24]

We projected that recurrent wintertime outbreaks of SARS-CoV-2 will probably occur after the initial, most severe pandemic wave. Absent other interventions, a key metric for the success of social distancing is whether critical care capacities are exceeded. To avoid this, prolonged or intermittent social distancing may be necessary into 2022. Additional interventions, including expanded critical care capacity and an effective therapeutic, would improve the success of intermittent distancing and hasten the acquisition of herd immunity. Longitudinal serological studies are urgently needed to determine the extent and duration of immunity to SARS-CoV-2. Even in the event of apparent elimination, SARS-CoV-2 surveillance should be maintained since a resurgence in contagion could be possible as late as 2024.

LAI et al (2020) Effect of non-pharmaceutical interventions to contain COVID-19 in China[25]

The early detection and isolation of cases was estimated to have prevented more infections than travel restrictions and contact reductions, but combined NPIs achieved the strongest and most rapid effect. The lifting of travel restrictions since February 17, 2020 does not appear to lead to an increase in cases across China if the social distancing interventions can be maintained, even at a limited level of 25% reduction on average through late April. Our findings contribute to an improved understanding of NPIs on COVID-19 and to inform response efforts across the World.

LEUNG et al (2020) First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment[26]

The first wave of COVID-19 outside of Hubei has abated because of aggressive non-pharmaceutical interventions. However, given the substantial risk of viral reintroduction, particularly from overseas importation, close monitoring of R_t and cCFR is needed to inform strategies against a potential second wave to achieve an optimal balance between health and economic protection.

LINKA et al (2020) Outbreak dynamics of COVID-19 in Europe and the effect of travel restrictions[27]

The precise effects of travel restrictions on the outbreak dynamics of COVID-19 remain unknown. Here we combine a global network mobility model with a local epidemiology model to simulate and predict the outbreak dynamics and outbreak control of COVID-19 across Europe. We correlate our mobility model to passenger air travel statistics and calibrate our epidemiology model using the number of reported COVID-19 cases for each country. Our simulations show that mobility networks of air travel can predict the emerging global diffusion pattern of a pandemic at the early stages of the outbreak. Our results suggest that an unconstrained mobility would have significantly accelerated the spreading of COVID-19, especially in Central Europe, Spain and France. Ultimately, our network epidemiology model can inform political decision making and help identify exit strategies from current travel restrictions and total lockdown.

MAIER et al (2020) Effective containment explains subexponential growth in recent confirmed COVID-19 cases in China[28]

The recent outbreak of COVID-19 in China was characterized by a distinctive subexponential increase of confirmed cases during the early phase of the epidemic, contrasting an initial exponential growth expected for an unconstrained outbreak. We show that this effect can be explained as a direct consequence of containment policies that effectively deplete the susceptible population. To this end, we introduce a parsimonious model that captures both quarantine of symptomatic infected individuals and population-wide isolation practices in response to containment policies or behavioral changes and show that the model captures the observed growth behavior accurately. The insights provided here may aid the careful implementation of containment strategies for ongoing secondary outbreaks of COVID-19 or similar future outbreaks of other emergent infectious diseases.

MORAN et al (2020) [Preprint Not Yet Peer-Reviewed] Estimating required 'lockdown' cycles before immunity to SARS-CoV-2: Model-based analyses of susceptible population sizes, 'S0', in seven European countries including the UK and Ireland[29]

Following stringent social distancing measures, some European countries are beginning to report a slowed or negative rate of growth of daily case numbers testing positive for the novel coronavirus. The notion that the first wave of infection is close to its peak begs the question of whether future peaks or second waves are probable. We sought to determine the current size of the effective—ie susceptible—population for seven European countries to estimate immunity levels following this first wave. We compare these numbers to the total population sizes of these countries in order to investigate the potential for future surges. Our results indicate that after the current wave, a large proportion of the total population will remain without immunity. This suggests that in the absence of strong seasonal effects, new medications or more comprehensive contact tracing, a further set of epidemic waves in different geographic centres are probable. These findings may have implications for exit strategies from any lockdown stage.

NGONGHALA et al (2020) Mathematical assessment of the impact of non-pharmaceutical interventions on curtailing the 2019 novel Coronavirus[30]

This study emphasizes the important role that social-distancing plays in curtailing the burden of COVID-19. Increases in the adherence level of social-

distancing protocols result in dramatic reduction of the burden of the pandemic and the timely implementation of social-distancing measures in numerous states of the US may have averted a catastrophic outcome with respect to the burden of COVID-19. Using face-masks in public including low efficacy cloth masks is very useful in minimizing community transmission and burden of COVID-19, provided their coverage level is high. The masks coverage needed to eliminate COVID-19 decreases if mask-based intervention is combined with a strict social-distancing strategy.

NUSSBAUMER-STREIT et al (2020) Quarantine alone or in combination with other public health measures to control COVID-19: a rapid review[31]

Current evidence for COVID-19 is limited to modelling studies that make parameter assumptions based on our current, fragmented knowledge. Findings consistently indicate that quarantine is important in reducing incidence and mortality during the COVID-19 pandemic. Early implementation of quarantine and combining quarantine with other public health measures is important to ensure effectiveness. In order to maintain the best possible balance of measures, decision makers must constantly monitor the outbreak situation and the impact of the measures implemented. Testing in representative samples in different settings could help assess the true prevalence of infection and would reduce the uncertainty of modelling assumptions.

PEIRLINCK et al (2020) Outbreak dynamics of COVID-19 in China and the United States[32]

Our results demonstrate how mathematical modeling can help estimate outbreak dynamics and provide decision guidelines for successful outbreak control. We anticipate that our model will become a valuable tool to estimate the potential of vaccination and quantify the effect of relaxing political measures including total lockdown, shelter in place and travel restrictions for low-risk subgroups of the population or for the population as a whole.

PETERSEN et al (2020) COVID-19: we urgently need to start developing an exit strategy[33]

Experts from different countries experiencing COVID-19 review evidence and country specific approaches and the results of their interventions. Three key factors are important: 1. reintroduction from countries with ongoing community transmission; 2. the need for extensive testing capacity and widespread community testing, and 3. adequate supply of personal

protective equipment to protect health care workers. Lifting social distancing, how to reopen manufacturing, construction and logistics, the reopening of higher educational institutions and schools and the use of electronic surveillance are all discussed.

PETO et al (2020) Universal weekly testing as the UK COVID-19 lockdown exit strategy[34]

We recommend evaluation of weekly SARS-CoV-2 antigen testing of the whole population in an entire city as a demonstration site with strict household quarantine after a positive test. Quarantine would end when all residents of the household test negative at the same time; everyone else in the city can resume normal life if they so choose. This testing programme should be assessed for feasibility in one or more cities with 200,000 to 300,000 people.

PREM et al (2020) The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study[35]

Restrictions on activities in Wuhan if maintained until April would probably help to delay the epidemic peak. Our projections suggest that premature and sudden lifting of interventions could lead to an earlier secondary peak, which could be flattened by relaxing the interventions gradually. However, there are limitations to our analysis including large uncertainties around estimates of R_0 and the duration of infectiousness.

RODA et al (2020) Why is it difficult to accurately predict the COVID-19 epidemic?[36]

In our study, we demonstrate that nonidentifiability in model calibrations using confirmed-case data is the main reason for wide variations in previous model projections. Using the Akaike Information Criterion for model selection, we show that an SIR model performs much better than an SEIR model in representing the information contained in the confirmed-case data. This indicates that predictions using more complex models may not be more reliable. We present our model predictions for the COVID-19 epidemic in Wuhan after the lockdown and quarantine of the city on January 23. We also report our results on the impact of strict quarantine measures and potential for a second outbreak.

ROY (2020) [Preprint Not Yet Peer-Reviewed] COVID-19 pandemic: Impact of lockdown, contact and non-contact transmissions on infection dynamics[37]

Any premature withdrawal of lockdown following signs of a brief retracement can backfire and can lead to a quicker, sharper and higher secondary peak due to reactivation of the two transmission routes: direct person-to-person contact transmission and indirect airborne and fomites-driven transmission. Based on these results, this study recommends that any exit policy from lockdown, should take into account the level of transmission reduction in both routes, the absolute scale of which will vary among countries depending on their health service capacity, but should be computed using accurate time-series data on infection cases and transmission rates.

RYAN et al (2020) COVID-19 Community Stabilization and Sustainability Framework: An Integration of the Maslow Hierarchy of Needs and Social Determinants of Health[38]

All levels of government are authorized to apply COVID-19 protection measures; however, they must consider how and when to ease lockdown restrictions to limit long-term societal harm and societal instability. Leaders that use a well-considered framework with an incremental approach will be able to gradually restart society while simultaneously maintaining the public health benefits achieved through lockdown measures. Economically vulnerable populations cannot endure long-term lockdown, and most countries lack the ability to maintain a full nationwide relief operation. Decision-makers need to understand this risk and how the Maslow hierarchy of needs and the social determinants of health can guide whole of society policies. Aligning decisions with societal needs will help to ensure that all segments of society are taken into consideration while managing the crisis; and that the process of incremental easing of lockdowns to facilitate the resumption of community foundations such as commerce, education and employment is carried out in a manner that protects those most vulnerable to COVID-19. Those desiring a successful recovery from the pandemic need to adopt an evidence-based framework now to ensure community stabilization and sustainability.

SARWAL et a (2020) [Preprint Not Yet Peer-Reviewed] Mitigating COVID-19 With Lockdowns: A Possible Exit Strategy[39]

Lockdown is now accepted as an effective public health measure of prevention and mitigation of COVID-19 pandemic. Over 1 billion people have been asked to stay home in over 50 countries and territories. There is little clarity on the optimal duration of a lockdown and how to strategize easing of restrictions without igniting a subsequent round of outbreak.
Lockdown involves hard choices and challenging to maintain essential services. We explore an exit strategy from lockdowns based on the natural history of the disease. We add value to the concept of intermittent social distancing by adding a localization strategy after 14 days of lockdown within externally quarantined areas in which normal economic and educational activity can be resumed. We call it 'COVID-Free, Externally Quarantined Territories' or CF-EQT.

SCALA et al (2020) [Preprint Not Yet Peer-Reviewed] Time, Space and Social Interactions: Exit Mechanisms for the COVID-19 Epidemics[40]

We developed a minimalist compartmental model to study the impact of mobility restrictions in Italy during the COVID-19 outbreak. We show that an early lockdown shifts the epidemic in time; however, beyond a critical value of lockdown strength, the epidemic tends to restart as restrictions are eased or removed. As a consequence, specific mitigation strategies must be introduced. We characterize the relative importance of different broad strategies by accounting for two fundamental sources of heterogeneity: geography and demography. First, we consider Italian regions as separate administrative entities in which social interactions between age classes occur. Due to the sparsity of the inter-regional mobility matrix, once started the epidemics tend to develop independently across areas, justifying the adoption of solutions specific to individual regions or to clusters of regions. Second, we show that social contacts between age classes play a fundamental role and that measures which take into account the age structure of the population can provide a significant contribution to mitigating rebound effects. Our model is general and, while it does not analyze specific mitigation strategies, highlights the relevance of several key parameters on non-pharmaceutical mitigation mechanisms for the epidemic.

VINER et al (2020) School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review[41]

In response to the COVID-19 pandemic, 107 countries had implemented national school closures by March 18, 2020. We undertook a systematic review to identify what is known about the effectiveness of school closures and other school social distancing practices during coronavirus outbreaks. We included 16 of 616 identified articles. School closures were deployed rapidly across mainland China and Hong Kong for COVID-19. However, there are no data on the relative contribution of school closures to transmission control. Data from the SARS outbreak in mainland China, Hong Kong and Singapore suggest that school closures did not contribute to the control of the epidemic. Modelling studies of SARS produced conflicting results. Recent modelling studies of COVID-19 predict that school closures alone would prevent only 2%-4% of deaths, much less than other social distancing interventions. Policy makers need to be aware of the equivocal evidence when considering school closures for COVID-19 and that combinations of social distancing measures should be considered. Other less disruptive social distancing interventions in schools require further consideration if restrictive social distancing policies are implemented for long periods.

WEST et al (2020) Applying principles of behaviour change to reduce SARS-CoV-2 transmission[42]

Human behaviour is central to transmission of SARS-Cov-2 and changing behaviour is crucial to preventing transmission in the absence of pharmaceutical interventions. Isolation and social distancing measures including edicts to stay at home have been brought into place across the globe to reduce transmission of the virus, but at a huge cost to individuals and society. In addition to these measures, we urgently need effective interventions to increase adherence to behaviours that individuals in communities can enact to protect themselves and others: use of tissues to catch expelled droplets from coughs or sneezes; use of face-masks as appropriate; hand-washing on all occasions when required; disinfecting objects and surfaces; physical distancing; and not touching one's eyes, nose or mouth. There is an urgent need for direct evidence to inform development of such interventions, but it is possible to make a start by applying behavioural science methods and models.

YAP et al (2020) [Preprint Not Yet Peer-Reviewed] Time-variant strategies for optimizing the performance of non-pharmaceutical interventions (NPIs) in protecting lives and livelihoods during the COVID-19 pandemic[43]

A stochastic Individual Contact Model (ICM) using SIR compartments allowing for time-variant parameters was used to simulate 100 non-pharmaceutical intervention strategies and exit trajectories for a hypothetical population, and to collect epidemiological and non-epidemiological outcomes to measure the performance of these strategies over the course of a period of intervention for a total duration of one-year to allow the full implications of the strategy and endgame to manifest. We found that variations in the time dimension and intensity of various strategies can have vastly different performance outcomes: 1. the timing of NPIs can 'shrink the area under the curve' [cumulative infections] not just flatten the curve; 2. prolonged lockdowns have diminishing margins of returns; 3. smooth, submaximal lockdowns perform better than pulsatile lockdowns; and 4. the efficiency of various strategies incorporating both epidemiological and non-epidemiological outcomes vary substantially. Most sobering, none of the simulated strategies allow for an acceptable path to exit within six months due to very large gaps in health system capacity.

ZHIGLJAVSKY et al (2020) [Preprint Not Yet Peer-Reviewed] Comparison of different exit scenarios from the lock-down for COVID-19 epidemic in the UK and assessing uncertainty of the predictions[44]

The models we use are flexible, comprehensive, fast to run and allow us to incorporate the following: time-dependent strategies for handling the epidemic; spatial heterogeneity of the population and heterogeneity of development of the epidemic in different areas; special characteristics of particular groups of people, especially people with specific medical pre-histories and the elderly. Standard epidemiological models such as SIR and many of its modifications are not flexible or precise enough. Decision-makers gain benefit from using better and more flexible models as they can better plan exit strategies based on local population data, different stages of the epidemic in different areas and specific groups of people—all resulting in a mitigated impact on the economy and improved forecasts of regional demand [on health services] allowing for intelligent allocation of resources.

OTHER

Ainslie (2020) Report 11: Evidence of initial success for China exiting COVID-19 social distancing policy after achieving containment[45]

At the peak of the outbreak in China, there were between 2,000 and 4,000 new confirmed cases per day. For the first time since the outbreak began there have been no new confirmed cases caused by local transmission in China reported for 5 consecutive days up to 23 March 2020. This is an indication that the social distancing measures enacted in China have led to control of COVID-19.

These interventions have also impacted economic productivity and the ability of the Chinese economy to resume without restarting the epidemic is not yet clear. Here, we estimate transmissibility from reported cases and compare those estimates with daily data on within-city movement, as a proxy for economic activity. Initially, within-city movement and transmission were very strongly correlated in the 5 provinces most affected by the epidemic and Beijing. However, that correlation is no longer apparent even though within-city movement has started to increase. A similar analysis for Hong Kong shows that intermediate levels of local activity can be maintained while avoiding a large outbreak. These results do not preclude future epidemics in China, nor do they allow us to estimate the maximum proportion of previous within-city activity that will be recovered in the medium term; however, they do suggest that after very intense social distancing which resulted in containment, China has successfully exited their stringent social distancing policy to some degree. In a global context, China is at a more advanced stage of the pandemic. Policies implemented to reduce the spread of COVID-19 in China and the exiting strategies that followed can inform decision making processes for countries once containment is achieved.

Nature (2020) [Editorial] Coronavirus: share lessons on lifting lockdowns[46]

When can lockdowns be lifted, and how should this happen? These urgent questions are being asked in each of the 180 or so countries and territories that enacted full or partial restrictions on movement in response to the new coronavirus. As countries start tentatively to reopen schools, businesses and public places, it is also becoming clear that there is little consensus on how

this should be done, because efforts to coordinate actions globally are running into the ground.
Countries are having to make difficult decisions as lockdowns are eased and they are doing so while their researchers are still gathering and processing data. These data should be published and shared. Circumstances in individual countries will necessarily be different, but the world will benefit from the mutual learning that will come from such a global effort.

DYER (2020) COVID-19: Projections of mortality in the US rise as states open up[47]

Academics behind the model most cited by the White House in predicting the loss of life from COVID-19 have nearly doubled their estimate of US mortality over the next three months.
The modellers from the Institute for Health Metrics and Evaluation at the University of Washington said that there are likely to be 134,475 deaths from COVID-19 [95% range 95,092 to 242,890] in the US by 4 August, up from the 90,000 that they initially forecast, which they adjusted to 60,000 last month. The grimmer outlook takes account of the fact that many lockdowns are now lifting and that the public became more mobile in recent weeks, even before any official easing of restrictions.

FADLALLAH (2020) Exiting the COVID-19 lockdown: a roadmap for action[48]

With the growing attention worldwide to easing lockdown and the lack of clarity on the way forward, this guidance document aims to fill the knowledge gap by synthesizing the best available evidence and country experiences to provide a road map for countries on how to exit the lockdown while preserving the health of their population.

JEFFERSON et al (2020) Covid 19: Epidemic 'Waves'[49]

Waves, as in the sea, are usually preceded by a trough, but this visual analogy is hardly ever mentioned; nor the appropriateness of forecasting waves in a coronavirus pandemic. We reviewed the evidence underpinning second-wave theory.
Making absolute statements of certainty about 'second waves' is unwise, given the current substantial uncertainties and novelty of the evidence. As we cannot see the future and our understanding of this new agent is in its infancy we think preparedness planning should be inspired by robust surveillance, the flexibility of response and rigid separation of suspected or

confirmed cases. These measures should stand for all serious outbreaks of respiratory illness.
Better evidence and better understanding are needed. COVID-19 will focus our minds.

MULHEIRN et al (2020) A sustainable exit strategy[50]

The lockdown imposed in the UK to slow the spread of COVID-19 has saved many lives. Across Europe, only full lockdown has worked to reduce the reproduction number of COVID-19, slowing the rate of spread and buying time. But the economic, social and other health consequences of the suppression measures are severe. The Office for Budget Responsibility [in the UK] anticipates a 35 per cent fall in GDP in Q2 if current restrictions remain in force through June, and unemployment is expected to rise by 2 million to 10%. The longer lockdown goes on, the greater the chance of a significant permanent reduction in living standards.
The UK now needs a sustainable strategy for COVID-19 that limits the damage to both public health and the economy. But easing the lockdown is risky. Without effective countermeasures, lifting social distancing and suppression measures could accelerate the spread of the virus, quickly putting us on a path to a very high number of deaths. To minimise the trade-off, a twin-track strategy of containment through measures including mask-wearing, testing and contact-tracing and shielding the most vulnerable from the virus is needed. This paper examines this twin-track strategy and its possible components while also looking at the exit strategies in place in other countries.

PETERSEN et al (2020) COVID-19 travel restrictions and the International Health Regulations: call for an open debate on easing of travel restrictions[51]

While travel restrictions that significantly interfere with international traffic may be justified at the beginning of an outbreak since they allow countries time to implement effective preparedness measures based on careful risk assessment, they should be based on a reasoned scientific evaluation of the available evidence on their possible effectiveness. They should also be time-limited and reconsidered and revisited on a regular basis as better information on both the effectiveness and the socioeconomic impact of the measures emerges.

THOMSON (2020) COVID-19: Leaving Lockdown[52]

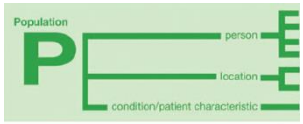
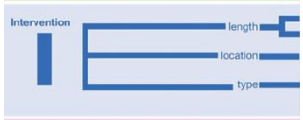
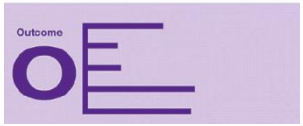
The world will move toward relaxation of lockdown, but it is important that COVID-19 does not re-emerge in epidemic proportions again. There appears to be a strong body of evidence and also guidance from respected international authorities to support the use of society-wide homemade face masks and the use of better protection for health workers exposed to the risks of COVID-19.

United Nations (2020) A UN framework for the immediate socio-economic response to COVID-19 (2020)[53]

The framework comprises 5 workstreams: 1. ensuring that essential health services are still available and protected; 2. helping people cope with adversity through social protection and basic services; 3. protecting jobs, supporting small and medium-sized enterprises and informal sector workers through economic response and recovery programmes; 4. guiding the necessary surge in fiscal and financial stimulus to make macroeconomic policies work for the most vulnerable and strengthening multilateral and regional responses; and 5. promoting social cohesion and investing in community-led resilience and response systems.

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at 14 May 2020. This evidence summary collates the best available evidence at the time of writing and **does not replace clinical judgement or guidance**. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.

The following PICO(T) was used as a basis for the evidence summary:

	LOCKDOWN/RESTRICTIONS IMPOSED TO CONTROL THE COVID-19 PANDEMIC
	MODELS/EXIT STRATEGIES
	
	PREVENTION OF FURTHER OUTBREAKS

The following search strategy was used in Medline

COVID-19 OR coronavirus OR corona virus OR Wuhan N2 virus OR "2019 n-cov" OR "2019 ncov" OR "severe acute resiratory syndrome coronavirus 2" OR "severe acute respiratory syndrome coronavirus 2" OR SARS-CoV-2 OR (2019 and (new or novel) and coronavirus) OR
(MH "Coronavirus+")
AND
math* N2 (model OR modelling OR modelled) OR prediction* OR simulation* OR model OR modelling OR modelled OR mathematical projection* OR (MH "Models, Statistical") OR (MH "Models, Theoretical+")
AND
Lockdown OR lock down OR peak OR social N2 (distanc* OR isolation) OR mitigation measure* OR self isolat* OR deconfinement OR de-confinement OR second* peak OR second* wave OR exit mechanism OR exit measures OR exit strateg* OR (lift* OR ease OR easing OR reduc* OR exit*) N2 (restriction* OR lockdown OR lock down)

† Helen Clark, Librarian, Sligo University Hospital [Author]; Brendan Leen, Regional Librarian, HSE South, St. Luke's General Hospital, Kilkenny [Editor]

References

[1] Health Information and Quality Authority (2020) Review of restrictive public policy measures to limit COVID-19 https://www.hiqa.ie/reports-and-publications/health-technology-assessment/review-restrictive-public-policy-measures [Accessed 12/05/2020]
[2] Adhanom, Tedros (06/05/2020) WHO Director-General's opening remarks at the media briefing on COVID-19 - 6 May 2020 https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---6-may-2020 [Accessed 08/05/2020]
[3]World Health Organization. (2020). Considerations in adjusting public health and social measures in the Organization. https://apps.who.int/iris/handle/10665/331773. [Accessed 12/05/2020]
[4] European Centre for Disease Prevention and Control (2020) Coronavirus disease 2019 (COVID-19) in the EU/EEA and the UK– ninth update https://www.ecdc.europa.eu/en/publications-data/rapid-risk-assessment-coronavirus-disease-2019-covid-19-pandemic-ninth-update [Accessed 11/05/2020]
[5] The Whitehouse/Centers for Disease Control and Prevention (United States) Opening up America again: guidelines https://www.whitehouse.gov/openingamerica/ [Accessed 12/05/2020]
[6] Centers for Disease Control and Prevention (United States) Helping to get and keep America openhttps://www.cdc.gov/coronavirus/2019-ncov/php/open-america/index.html [Accessed 11/05/2020]
[7] Centres for Disease Control and Prevention. CDC Activities and Initiatives Supporting the COVID-19 Response and the President's Plan for Opening America Up Again. https://www.cdc.gov/coronavirus/2019-ncov/downloads/php/CDC-Activities-Initiatives-for-COVID-19-Response.pdf [Accessed 11/05/2020]
[8] European Commission (2020) Joint European Roadmap towards lifting COVID-19 containment measures https://ec.europa.eu/info/sites/info/files/communication_-_a_european_roadmap_to_lifting_coronavirus_containment_measures_0.pdf [Accessed 13/05/2020]
[9] Government of Ireland (2020) Roadmap for Reopening Society & Business https://www.gov.ie/en/news/58bc8b-taoiseach-announces-roadmap-for-reopening-society-and-business-and-u/ [Accessed 13/05/2020]
[10] Ambikapathy B, Krishnamurthy K. Mathematical Modelling to Assess the Impact of Lockdown on COVID-19 Transmission in India: Model Development and Validation. *JMIR Public Health Surveill.* 2020;6(2):e19368. Published 2020 May 7.
[11] Barbarossa M V, Fuhrmann J, Heidecke J, Varma H V, Castelletti N, Meinke J H, Krieg S, Lippert T (2020) A first study on the impact of current and future control measures on the spread of COVID-19 in Germany https://www.medrxiv.org/content/10.1101/2020.04.08.20056630v1 [Accessed 12/05/2020]
[12] Bin, M et al (2020) On Fast Multi-Shot COVID-19 Interventions for Post Lock-Down Mitigation https://arxiv.org/abs/2003.09930 [Accessed 12/05/2020]
[13] Brethouwer, J-T et al (2020) "Stay Nearby or Get Checked": A COVID-19 Lockdown Exit Strategy https://arxiv.org/abs/2004.06891v1 [Accessed 13/05/2020]
[14] Chowell G, Tariq A, Hyman JM.. BMC Med. 2019;17(1):164. Published 2019 Aug 22. doi:10.1186/s12916-019-1406-6 [Accessed 22 April 2020]
[15] De Vlas, S J et al A phased lift of control: a practical strategy to achieve herd immunity against COVID-19 at the country level https://www.medrxiv.org/content/10.1101/2020.03.29.20046011v2 [Accessed 12/05/2020]
[16] Djidjou-Demasse R, Michalakis Y, Choisy M, Sofonea MT, Alizon S. Optimal COVID-19 epidemic control until vaccine deployment. medRxiv; 2020. DOI: 10.1101/2020.04.02.20049189. https://europepmc.org/article/PPR/PPR139452 [Accessed 12/05/2020]
[17] Dimeglio C, Loubes JM, Deporte B, et al. The SARS-CoV-2 seroprevalence is the key factor for deconfinement in France [published online ahead of print, 2020 Apr 29]. *J Infect.* 2020;S0163-4453(20)30242-5. doi:10.1016/j.jinf.2020.04.031
[18] DONSIMONI, JEAN ROCH, et al. (2020) Should contact bans be lifted in Germany? A quantitative prediction of its effects https://www.medrxiv.org/content/10.1101/2020.04.10.20060301v1
[19] Eikenberry SE, Mancuso M, Iboi E, et al. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infect Dis Model.* 2020;5:293- 308. Published 2020 Apr 21. doi:10.1016/j.idm.2020.04.001
[20] Flaxman, S et al (2020) Report 13: Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-13-europe-npi-impact/ [Accessed 13/05/2020]

[21] GERMAN, REINHARD, et al (2020) Modeling Exit Strategies from COVID-19 Lockdown with a Focus on Antibody Tests https://www.medrxiv.org/content/10.1101/2020.04.14.20063750v1 [Accessed 12/05/2020]
[22] Gilbert, M., Dewatripont, M., Muraille, E. et al. (2020) Preparing for a responsible lockdown exit strategy https://www.nature.com/articles/s41591-020-0871-y#article-info [Accessed 13/05/2020]
[23] KARIN, O et al (2020) Adaptive cyclic exit strategies from lockdown to suppress COVID-19 and allow economic activity https://www.medrxiv.org/content/10.1101/2020.04.04.20053579v4 [Accessed 12/05/2020]
[24] Kissler SM, Tedijanto C, Goldstein E, Grad YH, Lipsitch M. Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period [published online ahead of print, 2020 Apr 14]. *Science*. 2020;eabb5793. doi:10.1126/science.abb5793
[25] Lai S, Ruktanonchai NW, Zhou L, et al. Effect of non-pharmaceutical interventions to contain COVID-19 in China [published online ahead of print, 2020 May 4]. *Nature*. 2020;10.1038/s41586-020-2293-x. doi:10.1038/s41586-020-2293-x
[26] Leung K, Wu JT, Liu D, Leung GM. First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment. *Lancet*. 2020;395(10233):1382- 1393. doi:10.1016/S0140-6736(20)30746-7
[27] Linka K, Peirlinck M, Sahli Costabal F, Kuhl E. Outbreak dynamics of COVID-19 in Europe and the effect of travel restrictions [published online ahead of print, 2020 May 5]. *Comput Methods Biomech Biomed Engin*. 2020;1- 8. doi:10.1080/10255842.2020.1759560
[28] MAIER, B et al (2020) Effective containment explains subexponential growth in recent confirmed COVID-19 cases in China https://science.sciencemag.org/content/early/2020/04/07/science.abb4557 [Accessed 13/05/2020]
[29] MORAN, R et al (2020) Estimating required 'lockdown' cycles before immunity to SARS-CoV-2: Model-based analyses of susceptible population sizes, 'S0', in seven European countries including the UK and Ireland https://www.medrxiv.org/content/10.1101/2020.04.10.20060426v1.article-info [Accessed 13/05/2020]
[30] Ngonghala CN, Iboi E, Eikenberry S, et al. Mathematical assessment of the impact of non-pharmaceutical interventions on curtailing the 2019 novel Coronavirus [published online ahead of print, 2020 May 1]. *Math Biosci*. 2020;325:108364. doi:10.1016/j.mbs.2020.108364
[31] Nussbaumer-Streit B, Mayr V, Dobrescu AI, et al. Quarantine alone or in combination with other public health measures to control COVID-19: a rapid review. *Cochrane Database Syst Rev*. 2020;4(4):CD013574. Published 2020 Apr 8. doi:10.1002/14651858.CD013574
[32] Peirlinck M, Linka K, Sahli Costabal F, Kuhl E. Outbreak dynamics of COVID-19 in China and the United States [published online ahead of print, 2020 Apr 27]. *Biomech Model Mechanobiol*. 2020;1- 15. doi:10.1007/s10237-020-01332-5
[33] Petersen E, Wasserman S, Lee SS, et al. COVID-19-We urgently need to start developing an exit strategy [published online ahead of print, 2020 Apr 28]. *Int J Infect Dis*. 2020;S1201-9712(20)30251-4. doi:10.1016/j.ijid.2020.04.035
[34] Peto J, Alwan NA, Godfrey KM, et al. Universal weekly testing as the UK COVID-19 lockdown exit strategy. *Lancet*. 2020;395(10234):1420- 1421. doi:10.1016/S0140-6736(20)30936-3
[35] Prem K, Liu Y, Russell TW, et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study [published correction appears in Lancet Public Health. 2020 May;5(5):e260]. *Lancet Public Health*. 2020;5(5):e261- e270. doi:10.1016/S2468-2667(20)30073-6
[36] Roda WC, Varughese MB, Han D, Li MY. Why is it difficult to accurately predict the COVID-19 epidemic? *Infect Dis Model*. 2020;5:271- 281. doi:10.1016/j.idm.2020.03.001
[37] ROY, SHOVONLAL (2020) COVID-19 pandemic: Impact of lockdown, contact and non-contact transmissions on infection dynamics https://www.medrxiv.org/content/10.1101/2020.04.04.20050328v1 [Accessed 12/05/2020]
[38] Ryan BJ, Coppola D, Canyon DV, Brickhouse M, Swienton R. COVID-19 Community Stabilization and Sustainability Framework: An Integration of the Maslow Hierarchy of Needs and Social Determinants of Health [published online ahead of print, 2020 Apr 21]. *Disaster Med Public Health Prep*. 2020;1- 7. doi:10.1017/dmp.2020.109
[39] Sarwal, Rakesh and Sarwal, Tanvi, Mitigating COVID-19 With Lockdowns: A Possible Exit Strategy (March 29, 2020). Available at SSRN: https://ssrn.com/abstract=3563538 or http://dx.doi.org/10.2139/ssrn.3563538 [Accessed 13/05/2020]
[40] SCALA, A. et al (2020) Time, Space and Social Interactions: Exit Mechanisms for the COVID-19 Epidemics https://arxiv.org/abs/2004.04608 [Accessed 13/05/2020]
[41] Viner RM, Russell SJ, Croker H, et al. School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. *Lancet Child Adolesc Health*. 2020;4(5):397- 404. doi:10.1016/S2352-4642(20)30095-X
[42] West R, Michie S, Rubin GJ, Amlôt R. Applying principles of behaviour change to reduce SARS-CoV-2 transmission [published online ahead of print, 2020 May 6]. *Nat Hum Behav*. 2020;10.1038/s41562-020-0887-9. doi:10.1038/s41562-020-0887-9
[43] YAP, WEI AUN et al (2020) Time-variant strategies for optimizing the performance of non-pharmaceutical interventions (NPIs) in protecting lives and livelihoods during the COVID-19 pandemic. https://www.medrxiv.org/content/10.1101/2020.04.13.20063248v1[Accessed 12/05/2020]
[44] Zhigljavsky, A et al (2020) Comparison of different exit scenarios from the lock-down for COVID-19 epidemic in the UK and assessing uncertainty of the predictions https://www.medrxiv.org/content/10.1101/2020.04.09.20059451v1 [Accessed 13/05/2020]
[45] Ainslie, K.E.C (2020) Report 11: Evidence of initial success for China exiting COVID-19 social distancing policy after achieving containment http://www.imperial.ac.uk/medicine/departments/school-public-health/infectious-disease-epidemiology/mrc-global-infectious-disease-analysis/covid-19/report-11-china-exiting-social-distancing [Accessed 13/05/2020]

[46] Coronavirus: share lessons on lifting lockdowns. *Nature*. 2020;581(7806):8. doi:10.1038/d41586-020-01311-x
[47] Dyer O. COVID-19: Projections of mortality in the US rise as states open up. *BMJ*. 2020;369:m1846. Published 2020 May 6. doi:10.1136/bmj.m1846
[48] FADLALLAH, R ET AL (2020) Exiting the COVID-19 lockdown: a roadmap for action. Knowledge to Policy (K2P) Center, Faculty of Health Sciences, American University of Beirut https://www.aub.edu.lb/k2p/Documents/K2P%20COVID_19%20Series_Exiting%20the%20COVID-19%20Lockdown_A%20Road%20Map%20for%20Action_April%2021_2020__.pdf [Accessed 12/05/2020]
[49] JEFFERSON, TOM et al (2020) Covid 19 - Epidemic 'Waves' https://www.cebm.net/covid-19/covid-19-epidemic-waves/ [Accessed 12/05/2020]
[50] MULHEIRN, I et al (2020) A sustainable exit strategy https://institute.global/policy/sustainable-exit-strategy-managing-uncertainty-minimising-harm [Accessed 13/05/2020]
[51] Petersen E, McCloskey B, Hui DS, et al. COVID-19 travel restrictions and the International Health Regulations - Call for an open debate on easing of travel restrictions [published online ahead of print, 2020 Apr 17]. *Int J protection for health workers exposed to the risks of COVID-19.Infect Dis*. 2020;94:88- 90. doi:10.1016/j.ijid.2020.04.029
[52] Thomson GA. COVID-19: Leaving Lockdown - Of Schrodinger, Cats, Testing and Masks [published online ahead of print, 2020 Apr 21]. *Int J Clin Pract*. 2020;e13519. doi:10.1111/ijcp.13519
[53] United Nations (2020) A UN framework for the immediate socio-economic response to COVID-19 https://unsdg.un.org/resources/un-framework-immediate-socio-economic-response-covid-19 [Accessed 12/05/2020]