Non-pharmaceutical interventions (NPIs) such as mask wearing and contact tracing were the only available measures to control the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) before vaccines became available. The emergence of highly transmissible variants of SARS-CoV-2 such as the delta variant are a serious concern. As a result, even countries with high vaccination rates have required continued use of NPIs. Many studies have reported on the effectiveness of NPIs in reducing Covid-19 transmission. However, NPIs impose restrictions on people’s lives and may adversely affect the economy; they are also difficult to sustain for a long time. In 2021, now that many countries are vaccinating their populations, the continued use of many NPIs has been questioned. Here, we describe the effect of NPIs before and after the introduction of vaccines against coronavirus disease 2019 (Covid-19) and discuss whether NPIs should be abandoned after vaccine programmes start, especially when the delta variant is now the dominant circulating strain.

Before the emergence of the delta variant, herd immunity was feasible with the current vaccines. A vaccine with 90% efficacy against SARS-CoV-2 could achieve herd immunity by vaccinating 66% of the population, which could be done without vaccination of children. However, the herd immunity threshold for the delta variant with an estimated reproductive number of 5 or higher may exceed 90% of the population vaccinated. The current vaccines were designed to work against the ancestral strains of SARS-CoV-2, but a third booster dose of a vaccine that is well matched to the delta and other variants would lower the herd immunity threshold again. Until then, the use of NPIs and vaccines together is essential for the most effective control of SARS-CoV-2.

### Key Messages
- NPIs are effective for control of SARS-CoV-2 transmission, especially when used in combination.
- NPIs are still required for disease control during the early stages of Covid-19 vaccination programmes.
- Booster doses matched to variants of concern will make herd immunity more achievable.
- Effective NPIs that do not greatly affect people’s lives, such as universal mask wearing, should continue, while NPIs that impose greater societal restrictions should be implemented on a regional basis as required.

### NPI use before Covid-19 vaccines
Since the first reports of SARS-CoV-2 in China, most countries have experienced large epidemics of Covid-19. In the absence of effective vaccines or treatments for Covid-19 in 2020, NPIs were the only approach to controlling the pandemic.

Contact tracing and quarantine, case isolation, and physical distancing are effective in epidemic control. Countries that have controlled Covid-19 well have used meticulous contact tracing and quarantine, while countries that have been overwhelmed by SARS-CoV-2 often abandoned this control measure. Physical distancing has also been used widely and has been effective, presumably by reducing close contact aerosol transmission.

In addition to traditional technology, modern technology can be used to help contain the outbreak. China introduced a health code, which is produced using data from the health commission and transportation authorities, as well as communications, airline, and railway companies, to allow people to know whether they have been in close contact with anybody with Covid-19 or have been in an area where the virus has been identified. In addition, the health code is used to identify people at high risk and prevent them from entering public areas.

The use of face masks by the public is a controversial measure, especially in countries where mask wearing is not familiar. However, the use of masks has been accepted worldwide as an effective control measure. The World Health Organization, US Centers for Disease Control and Prevention and many other agencies initially advised against the use of masks by the general public. However, the early introduction of mass mask use was an important factor in China’s success in containing the spread of Covid-19. A household study found that mask wearing by family members was protective only when using masks before the onset of symptoms in the index case. The results highlight the need for the universal use of masks because the virus can be transmitted before disease symptoms emerge and hence transmitted by asymptomatic cases. Other studies also confirm the effectiveness of masks in Covid-19 control. During community epidemics, infectious people may not be identifiable and may not know they are infected, so the use of masks by the public prevents infected people from emitting infectious aerosols (source control) and also protects people from inhaling infectious aerosols. Universal mask use, including the use of non-medical (cloth) masks, has been shown to be effective in reducing the number of new infections of SARS-CoV-2. A meta-analysis showed that face masks resulted in an 85% reduction in the risk of infection, with greater reduction for N95 (FFP2 in Europe) respirators compared with disposable surgical masks or similar.

The objection to wearing masks is not only about doubts about their necessity and effectiveness, but also related to concerns about supply and pollution. To increase supplies of masks, the Chinese government and businesses rapidly organised and funded production of face masks. The Japanese government distributed reusable cloth face masks to households amid growing concern over shortages of medical face masks. Innovations to improve face mask production, functioning, and sustainability have emerged, such as improvements in the design of cloth masks.
CHINA’S RESPONSE TO COVID-19

As of December 2021, approximately 2.5% of the world’s population had been fully vaccinated against SARS-CoV-2, with notable disparities in vaccine distribution by country. The rapid rollout of vaccines and the adoption of non-pharmaceutical interventions (NPIs) have been critical in reducing transmission and saving lives. China has been at the forefront of these efforts, with its successful experience offering valuable lessons for the global community.

Cultural differences also influence attitudes to the use of masks. Since the outbreak of severe acute respiratory syndrome in 2003, Asians have become accustomed to wearing masks on a daily basis, while in other cultures people may fear that wearing masks will result in discrimination. However, as a result of covid-19, mask wearing has gradually been accepted worldwide, and most national and international guidelines now recommend the use of mask by the public during epidemic periods.

The control of the covid-19 pandemic cannot be achieved solely by using masks or any other NPI alone. The combined use of NPIs has a bigger effect. A study of 190 countries showed that the use of any type of NPI, including movement restrictions, social distancing, mandatory mask wearing, and quarantine, was significantly associated with a decrease in the transmission of SARS-CoV-2, and using multiple measures can lead to an 11-60% increase in effectiveness compared with using a single measure. Chinese data show that without NPIs, the number of covid-19 cases in China would have been 67 times higher in the first two months of the outbreak. Moreover, NPIs targeted at SARS-CoV-2 transmission not only reduced the spread of covid-19 but also significantly reduced the influenza burden and may have an effect on the transmission of other respiratory illnesses such as tuberculosis. This is an important advantage because when covid-19 is co-circulating with other respiratory infections such as influenza, it poses a greater health risk.

Need for NPIs after vaccination

Despite the benefit of NPIs in epidemic control, these interventions limit people’s lives and are not easily sustained, especially in western countries. Mandatory mask wearing may be seen to interfere with personal freedom, so in many countries mask use is only recommended for people who are unwell and in vulnerable populations, even though people can transmit SARS-CoV-2 before covid-19 symptoms appear. With vaccines expected to bring a return to normal life, many people think the need for NPIs will be past or reduced. Ideally, the use of NPIs can be relaxed gradually as vaccine effectiveness improves. However, in the United States, after vaccination rates reached over 50% and mandates on the use of masks were removed, many outbreaks of the delta variant occurred which affected people who had been vaccinated. This resulted in reinstatement of mandates on mask use.

Since vaccines became available, focus has been placed on the need for global vaccination, although access to the vaccines varies by country. In the past eight months, 30% of the world’s population has received at least one dose of a covid-19 vaccine, but only 16% are fully vaccinated with two doses. In addition, the differences in vaccination rates between high income and low income countries are substantial. It may be many years before high rates of vaccination are achieved globally. A modelling study has shown that, during this period of vaccination, if NPIs are abandoned and even if vaccine effectiveness is high, the pandemic may resurge.

We have also seen a resurgence of the pandemic in several countries with high vaccination rates as a result of the delta variant. Therefore, maintaining NPIs is necessary to reduce SARS-CoV-2 transmission, especially in large populations with little natural immunity.

Even if high coverage is achieved with high efficacy vaccines matched to the variants of concern, whether herd immunity can be reached is still not known. At this point, emergence of mutant strains is the greatest threat to control of the pandemic. Studies have shown that the effectiveness of the vaccines against the delta variant is lower, which means that to reach herd immunity, higher vaccination rates or third booster doses are needed. If vaccine effectiveness against SARS-CoV-2 drops to less than 70%, herd immunity cannot be achieved and the risk of outbreaks will continue. Therefore, the road to achieving herd immunity is long and uncertain. The use of booster doses matched to variants of concern will make herd immunity more achievable. During this time, the use of NPIs and vaccines together is important to protect the community, even in countries with high vaccination coverage.

In China, the delta variant has caused the latest outbreak with more than 1000 cases in more than a dozen provinces. As soon as the outbreak occurred, the affected communities were locked down and mass testing was performed among people in those communities and their close contacts. Movement restrictions were implemented in regions at high and middle risk. Compulsory mask wearing was emphasised and restrictions on large gatherings were imposed. Social level NPI measures have never been relaxed in China. For example, masks have been mandatory in indoor public areas throughout the pandemic, which may be why the delta outbreak had not spread more widely when the first case in this outbreak was detected. Up to mid-August 2021, China largely controlled SARS-CoV-2 because of the early and continuing implementation of NPIs.

Another important measure to reduce transmission of the delta variant is strict broader control. All people entering in China must go into compulsory quarantine regardless of symptoms to prevent asymptomatic transmission. In addition, the length of quarantine and times of testing have been increased in response to the changing global epidemic. The strict control at ports greatly reduces the chance of community transmission led by imported cases and makes case investigation and contact tracing feasible in community cases. However, there is no guaranteed strategy to manage covid-19. The strict NPIs taken by China have had a high cost and required substantial public health resources, and the cost effectiveness has not been accurately estimated. In the United Kingdom, estimates suggest that implementation of NPIs, including lockdowns, has been less costly than not applying such measures and allowing covid-19 to spread. The same study showed that over 10 years, the use of vaccines with lower efficacy would result in ongoing epidemics of covid-19.

The features of NPIs and their recommended use during and after the introduction of vaccines are summarised in table 1.

Conclusion

Despite the unprecedented and successful efforts in vaccine development, our fight against SARS-CoV-2 is ongoing. The vaccine pipeline is not static, and better vaccines and well matched booster doses will become available, but ongoing covid-19 hotspots in the world will drive the emergence of new variants of concern. Therefore, interventions such as universal use of masks and social distancing will help control the spread of SARS-CoV-2 as these measures have relatively low social and economic costs and contribute to the prevention and control of other infectious diseases as well. On the other hand, the use of measures that have a substantial effect on society should be considered
shutdowns should be used only when necessary. However, once the number of cases has begun to surge and health systems are overburdened, efforts to suppress an outbreak will require more stringent and costly measures.

High vaccination coverage globally will take years to achieve, and vaccine resistant variants may continue to emerge, so NPIs will have an ongoing role in the control of the covid-19 pandemic.

Table 1 | Features of non-pharmaceutical interventions and their recommended use during and after the introduction of vaccines against coronavirus disease 2019

<table>
<thead>
<tr>
<th>Type of intervention</th>
<th>Benefits</th>
<th>Drawbacks</th>
<th>Recommendations on use</th>
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| Contact tracing and quarantine | • Efficient and accepted  
  • Digital tracing and monitoring of quarantine can help with surge capacity | Manual contact tracing and centralised quarantine is not sustainable when case numbers surge | • Use contact tracing and quarantine whenever a case is diagnosed  
  • Home based self-quarantine is more feasible when the disease incidence is high  
  • Some applications can be used to help monitor people under home quarantine |
| Mass testing of possible contacts (high risk populations such as a localised community) | Enables detection of asymptomatic cases | Exhausts limited resources | • Use nucleic acid tests for all close contacts at the start, during and end of quarantine to prevent transmission from people with asymptomatic infection  
  • Use when outbreak occurs at a crowded place, such as markets, apartment blocks, railway stations or other local settings, and close contacts are hard to define |
| Movement restrictions | | | |
| Travel restriction | Avoids disease spread and importation | Country level restrictions substantially disrupt society and economy | • Develop criteria for implementing this measure  
  • Implement on a regional basis  
  • Develop different restrictions for vaccinated and unvaccinated people and mechanisms to differentiate, eg, vaccine passports |
| Lockdown | • Avoids disease spread and importation, especially when cases are surging  
  • Protects the economy compared with uncontrolled transmission | Disrupts society and the economy greatly | • Develop criteria for implementing this measure  
  • Implement on a regional basis, eg, targeted community lockdown |
| Social distancing | | | |
| Physical distancing | • Easy to carry out  
  • Effectiveness confirmed  
  • Helps prevent other diseases such as influenza | Hard to monitor adherence in a populated area | Use throughout the pandemic |
| School and workplace closure | Prevents disease spread in indoor settings | • Disrupts families and requires home care  
  • May cause unemployment and economic losses  
  • Interrupts education  
  • Home based work or learning requires internet access | • Develop strict criteria for implementing this measure  
  • Conduct daily health surveillance and prohibit attendance while sick to help avoid school and workplace closure |
| Avoidance of mass gatherings | Prevents disease spread | Disturbs social interaction and quality of life | Develop strict criteria for implementing this measure |
| Disinfection measures | | | |
| Hand hygiene | • Easy to carry out  
  • Helps prevent other infectious diseases | • Handwashing damages the natural skin barrier function and disinfectants can cause dermatological problems  
  • May lead to over-reliance and less attention to airborne precautions  
  • Does not prevent airborne transmission | Use throughout the pandemic |
| Environmental disinfection | Helps prevent infection caused by contact with contaminated surfaces | • May lead to over-reliance and less attention to airborne precautions  
  • Does not prevent airborne transmission | Educate people to use disinfection properly and avoid overuse  
  • Use professionals for disinfection of hospitals and isolation hotels |
| Other | | | |
| Face masks | • Effectiveness confirmed  
  • Accepted and recommended globally | • Cultural barriers  
  • Disrupts communication  
  • May cause breathing difficulty  
  • May contribute to environmental pollution  
  • May be supply shortages (disposable masks) | Recommend universal mask wearing throughout the pandemic |
| Border measures | Avoid importation of cases, including variants of concern | • Include temperature testing, nuclear acid testing, quarantine and health report  
  • Strict measures are time consuming and costly—eg, quarantining for 14 days at a hotel  
  • Relaxed border measures may lead to missed cases and local transmission of new variants | Continue with strict border measures, such as compulsory quarantining for 14 days and nucleic acid testing for all entrants, for the time being |
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