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Non-pharmaceutical interventions: evaluating challenges and priorities for future health shocks

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Standfirst: Non-pharmaceutical interventions implemented during health shocks such as the covid-19 pandemic require rapid, robust and rigorous evaluation that can generate timely evidence to guide government policy and maintain public confidence.

The Covid-19 pandemic has been among the most challenging global health crises in the post-World War 2 era.[1] Alongside the high COVID-19 infection, hospitalisation, and mortality rates, there were significant impacts on mental and physical health, long term complications, delayed diagnoses for other conditions, direct and indirect social and economic costs (e.g. child education) [2–4] and disruptions to overall healthcare delivery.[5–8]

In the initial absence of effective pharmaceutical tools such as vaccines or drug treatments, countries implemented a range of non-pharmaceutical interventions (NPIs); also referred to as public health and social measures (PHSMs). NPIs are non-vaccine, non-drug measures that are implemented to reduce the transmission of an infectious disease (Box 1).[9–11]

While NPIs helped to reduce transmission rates and prevent healthcare systems from being overwhelmed early in the pandemic, they also had secondary consequences, such as increasing mental health disorders due to isolation; as well as widespread economic, cultural, and educational disruptions.[12,13] Hence, research infrastructure for the rapid evaluation of NPIs – including any unintended negative effects – is essential to guide policy decisions by governments and other key stakeholders and to maintain public confidence in control measures, especially for any future health shocks – non-infectious as well as infectious.

Box 1. Examples of Non-Pharmaceutical Interventions (NPIs)

NPI measures	Anticipated role
Handwashing	Improved personal and collective hygiene to prevent any potential hand-to-face transmission.
Surface cleaning	Improved personal and collective hygiene to prevent any potential transmission from contaminated surfaces.
Improved indoor ventilations	Improved indoor ventilation systems to replace any potential contaminated air with outside fresh air.
Mask and face coverings	Improved containment of the virus to minimise person-to-person and person-to-surface transmission.
Test, trace, and isolate	Improved identification of people with SARS-CoV-2 infection, and their recent contact to identify people who could isolate temporarily to minimise further transmission of the virus.
Physical distancing (social distancing or 'lockdowns')	Reduced person-to-person contact.
Closures of schools and workplace	Reduced person-to-person contact.
Restrictions on public gatherings	Reduced person-to-person contact.
Border control and travel restrictions	Improved containment of people with infection or high-risk exposure.
Shielding	Reducing risks to the most vulnerable in the society such as the elderly and the immunocompromised.
Health communications	Improved understanding by the public of updated science, policy, and regulations; as well as developing skills e.g., to assess and manage risk.

Methods for Evaluating NPIs

Evaluating NPIs during a fast-moving crisis like the covid-19 pandemic presented a formidable challenge for policymakers, researchers, clinicians, and public health specialists. The need to act

urgently often outpaced the generation of robust evidence, requiring decisions to be made in the face of uncertainty and with incomplete data. This led to tension between the need for timely action and the aim for evidence-based policy making.

The simultaneous implementation of multiple NPIs across different populations, created a complex set of interactions that obscured the impact of individual measures.[10] This complexity was compounded by the variability in implementation. For example, differences in how interventions were applied, such as the strictness of lockdowns or the enforcement of mask mandates, can affect outcomes and make evaluation challenging. Furthermore, public adherence to NPIs is influenced by cultural, social, and psychological factors, including trust in the government and science, which can vary widely between societies and change over time. The impact of NPIs was also influenced by the stage of the pandemic at which they were implemented. For example, interventions earlier in the pandemic might have had different effects compared to those introduced later when population immunity through infection and vaccination was greater.[14]

Without evidence from randomised controlled trials for many interventions,[15,16] policy-makers and researchers often relied on observational studies, which are vulnerable to bias and confounding. For instance, the impact of school closures on community infection transmission rates was difficult to isolate when other concurrent measures, like workplace closures and travel restrictions, were in place. Modelling studies were also important in predicting outcomes and guiding policy, but they depend on the quality of the data and the assumptions built into the models, which can lead to large uncertainties in their predictions. Finally in-depth qualitative interviews and lived experiences engaging patients and public with particular emphasis on vulnerable and marginalised population can be useful in framing research questions for subsequent analysis; and dissemination and implementation of the findings.

The UK's evaluation infrastructure

The UK’s rapid action in generating and disseminating research findings during the pandemic demonstrates the value of having a robust public health infrastructure that can generate data for planning and evaluation quickly (for example, the revival of CORSAIR study), and inform public health policy.[17,18] Data from NHS electronic health records (EHRs) played a key role in the UK’s response and enhanced the quality of observational studies by providing timely, high-quality data across the entire population. These records allow for more nuanced analysis of the impact of NPIs, adjusting for individual patient characteristics and healthcare interactions, which can help mitigate some of the biases and confounding present in observational data or in ecological studies. Furthermore, data was released at varying degrees of aggregation, allowing anonymised data to be accessed more freely than individual level data.

The dismantling of these systems post-pandemic is concerning, however.[19] For the future, a national pandemic preparedness body could be established to map potential future threats, identify theme-specific continuously updated multidisciplinary expert pools, explore relevant data sources including any barriers to linkage with other data (e.g., NHS EHR), design a safe research environment for efficient data-sharing agreements that maintain patient confidentiality while facilitating essential research, establish a comprehensive framework for unified rapid ethical approval across the data owners/custodians, and secure a commitment for rapid funding.

Routine healthcare data use over the course of a pandemic

Routine healthcare data was widely used during the pandemic in addition to informing clinical practice. This ranged from tracking health system performance to disease monitoring to testing, determining susceptibility through to who was at risk of severe outcomes, who should shield, and who should be vaccinated and when.[20] Whist not designed for research, NHS data offer an essential platform to understand service provision and the effects of public health interventions.

The UK was in a very strong position to use healthcare data at the start of the pandemic given the availability of linked data and governance processes for secure data access. But there were still architectural and infrastructure changes required which were made at pace to exponentiate the use of the data. Rapid creation of a national English data resource,[21] including over 96% of the English population for covid-19 and cardiovascular research in addition to models such as the OpenSAFELY platform;[22] a secure and transparent open-source mechanism for analysis of routine healthcare data, paved the way for rapid analytics to be undertaken to inform policy and decision making. There were also many international collaborative efforts, such as the International Consortium for Clinical Characterisation of covid-19 by EHR and the International Covid-19 Data Alliance, which led to trustworthy international research partnerships.

However, global data access was not always straightforward, and the quality of data was not equitable during the pandemic, with much more limited data from low-income countries, leading to discrepancies in mapping disease trajectories and deaths internationally.[23,24] Additionally, data were not always recorded that would have been helpful for pandemic preparedness.

Whilst equity in access to healthcare services and health outcomes does not always exist in a pandemic, routine data can help to determine where mitigation measures need to be implemented, allowing regional and demographic differences to be explored. Details around ethnicity, deprivation or occupation were not always captured; and missing data where not considered or unmeasured confounding in some early studies led to biased estimates of effect when not interpreted in the context required. Differences in who used healthcare, who was tested and when changed over the course of the pandemic and, without knowing the subtleties of this, could lead to erroneous interpretation of who was at greatest risk of poor outcomes.

Ultimately, data contributed to evidence synthesis and guideline development, including psychological and socioeconomic impacts and unintended consequences, balancing competing pressures and informing public communication. Privacy issues sometimes raised by the public were less of an issue; partially due to better messaging and communication, and an understanding of the importance of data for rapid decision making at the time. Health Data Research UK (HDR UK) played a pivotal role in the pandemic in healthcare data infrastructure, bringing the research community together and highlighting the importance of collaborating at scale.[25] For example, through HDR UK initiatives, people were rapidly identified to take part in clinical trials (e.g. RECOVERY).

The pandemic also expedited the creation of trusted research environments to allow federated analytics. Collaboration across the research data community facilitated the prioritisation of research questions to be answered by the by national health data research covid response team. Whist at least in the UK, there was centralisation of data, standardised coding and algorithms did not always exist; leading to different results and difficulty in tracking across time in a rapidly moving clinical landscape. This was particularly an issue at the start of the pandemic. As time went on, common data models became more readily available with more data standardised (e.g. using the Observational Medical Outcomes Partnership (OMOP) Common Data Model), making cross country comparisons easier, without losing the granularity of the data that is essential in decision making.

As part of future pandemic preparedness, we need more robust and standardised data collection. Paper-based medical data collection and multiple EHR systems in England make federated analytics challenging. Standardisation of coding of recording of diseases would allow comparisons to be made more easily and the effects of implementations assessed more clearly. There also remains a lack of availability and access to social care data. Further data linkage including social care data as well as laboratory data with EHR data could help future responses. Proper and regular communication with the patients and public to acknowledge and address their concerns will uphold and enhance public trust, and help minimise the effect of misinformation and disinformation campaigns.

Evaluating Socio-Economic and Psychological Impacts of NPIs

The socio-economic and psychological impacts of NPIs during the covid-19 pandemic were substantial and multifaceted, affecting many aspects of life globally. These included the large reduction in economic activity seen in the UK and many other countries early in the pandemic. Industries such as travel, hospitality and retail faced severe losses, and some businesses were forced to shut down permanently, leading to a rise in unemployment. The pandemic also exacerbated existing income inequalities. Individuals in poorer-paid jobs generally faced greater financial instability and job losses whilst many higher-income workers could work remotely.[26]

School closures impacted student learning across the world, with potential long-term implications. The shift to online learning highlighted the digital divide, as those without access to adequate technology or internet access at home faced significant disadvantages. Access to healthcare was also affected, particularly elective care.

Psychological impacts from isolation, fear of infection, economic stress, and uncertainty led to a rise in mental health issues, including anxiety, depression, and stress-related disorders.[13] Lockdowns and quarantine measures led to an increased risk of domestic violence as victims found themselves trapped with abusers with less access to support services. The long-term socio-economic and psychological impacts of NPIs will continue to be studied for many years to come, as societies grapple with and adapt to the changes brought about during the pandemic.

In light of lessons learned on the population disproportionately affected by the pandemic, future pandemic preparedness should focus on the collection and availability of up-to-date data on occupation, employment, income, social care needs, mental health (including psychotherapy and counselling), strengthening healthcare to provide services remotely when needed, effective communication on individual inconvenience, collective altruism and resilience, devise a pragmatic plan to offer proportionate financial and other social support to vulnerable groups.[27]

Cost-effectiveness of NPIs

While NPIs can be effective during health shocks, they come with substantial economic costs due to reduced economic activity in addition to the direct costs of their implementation. Many studies on the cost-effectiveness of NPIs are based on models that make various assumptions about infection rates, the effectiveness of interventions, compliance levels, and the economic value of health outcomes. Real-world data can differ from these models, which means that the estimated cost-effectiveness of NPIs can vary.[28]

While some studies have shown NPIs to be cost-effective in many scenarios, especially when considering the value of lives saved and healthcare costs averted, the overall picture is complex. The effectiveness and economic impact of these interventions depend on the context in which they are applied, how they are implemented, and the behaviour of the population. Policy decisions in a future

pandemic should consider cost-effectiveness early to allow policymakers to implement those that are most cost-effective and minimise the negative outcomes from NPIs.

Enhancing International Collaboration and Future Preparedness

The covid-19 pandemic has underscored the interconnectedness of global health and the need for international cooperation in managing public health crises. It has also stressed the importance of robust healthcare systems and the requirement for ongoing investment in public health infrastructure and preparedness for future pandemics including the capacity for rapid research and evaluation of NPIs. This includes the timely and transparent sharing of information on the nature of the disease and its transmission, and global collaboration on the evaluation of NPIs. This underpins the importance of international bodies like the World Health Organization (WHO) and the need for strong collaboration between countries such as adhering to the proposed WHO pandemic agreement.[29]

Summary of Lessons Learned and Recommendations

As the pandemic evolved and more tools became available to manage covid-19, including vaccination and antiviral drugs, along with greater immunity from infection, the reliance on NPIs decreased. However, the experience of the Covid-19 pandemic has highlighted the importance of NPIs as a critical component of the public health arsenal in managing infectious disease outbreaks and health shocks from other causes, particularly in the early stages when fewer effective options for prevention and treatment are available.

The use of some NPIs such as face masks and school closures remains controversial. The endpoints for evaluating NPIs are typically defined in terms of their impact on Covid-19 transmission, morbidity, and mortality. However, we must also consider the potential for unintended consequences, such as the impact of school closures on children's mental health, risk of obesity, educational attainment, and future economic prospects.[2,3] These unintended consequences can be difficult to measure, but they are an important part of the overall impact of NPIs.

The experience during the Covid-19 pandemic provides many lessons for preparing for future health shocks. Such emergencies can potentially be more general than acute infection emergencies and be the result of natural or geopolitical causes. First, it is important to have a robust system for evaluating NPIs. This system should be able to rapidly assess the effectiveness of new interventions and to identify any unintended consequences. Second, it is important to have a clear understanding of the potential benefits and harms of different NPIs. These will help governments make informed decisions about which interventions to implement. Third, it is important to have international collaboration in the evaluation of NPIs. Such collaborations will help ensure that the best available evidence is used to inform policy decisions. Engaging key stakeholders including the patients and the public, especially those at high risk of medical complications and death, in the decision-making process is critical. Learning from the covid-19 experience, it is essential to invest in systems that allow for the agile, accurate, and ethical evaluation of interventions to inform policy decisions and protect public health.

Key messages:

- Many non-pharmaceutical interventions (NPIs) were found to be effective in reducing the transmission of SARS-CoV-2 that helped 'flatten the curve' with subsequent reductions on hospitalisations and deaths. However, - healthcare policymakers should consider the unintended consequences of NPIs such as the effects on the economy, educational attainments of children, and mental health and wellbeing.

- Systems for evaluating NPIs should be flexible enough to provide essential data to guide policy for health shocks from different causes, including non-infectious as well as infectious shocks (for example, environmental shocks such as extremes of temperature and floods; and man-made disasters such as wars.

- For the future, a national pandemic preparedness body could be established to map potential future threats, identify theme-specific continuously updated multidisciplinary expert pools, explore relevant data sources, design a safe research environment for efficient data-sharing agreements, establish a comprehensive framework for unified rapid ethical approval across the data owners/custodians, and secure a commitment for rapid funding.

- In light of lessons learned on the population disproportionately affected by the pandemic, future pandemic preparedness should focus on the collection and availability of up-to-date data on occupation, employment, income, social care needs, mental health (including psychotherapy and counselling), strengthening healthcare to provide services remotely when needed, effective communication on individual inconvenience, collective altruism and resilience, devise a pragmatic plan to offer proportionate financial and other social support to vulnerable groups.

- Appropriate stakeholder engagement– including with the most vulnerable groups in society – is essential in ensuring that public confidence is maintained, and any proposed interventions are publicly acceptable.

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