including 3 interventional, 9 observational and 85 modelling studies. The included studies were highly heterogeneous and were conducted under pandemic conditions when it was imperative to make predictions at speed about the potential impact of policy decisions. Most of the modelling studies did not report numerical effect estimates with CI but instead often reported graphs with different scenarios with and without the use of one or various NPIs. Thus, our findings report the direction, but not magnitude, of the likely effects of NPIs on COVID-19 outcomes.

For six NPI categories (the use of face coverings to reduce the risk of COVID-19 transmission, physical distancing, personal/household hygiene, contact tracing, targeted/local lockdown and shielding) the level of certainty in the evidence was considered inconclusive due to inconsistency in the direction of effect found by the authors. However, we were able to identify a moderate level of certainty for test and release strategies for case contacts (largely due to two high-quality RCTs). Evidence for the effectiveness of the remaining 13 NPI categories was assessed as low or very low certainty because of study design limitations, heterogeneity in study characteristics and NPI implementation and lack of precision estimation.

What is already known on this topic

Our findings are consistent with those of global systematic reviews of observational and interventional studies.[123,124] Talic *et al.* found evidence for the effectiveness of face coverings, physical distancing and testing followed by isolation,[123] with moderate to high/critical risk of bias and high levels of study heterogeneity, precluding meta-analysis. A recent review of global systematic reviews found only 8 of 94 reviews to have moderate to high confidence ratings.[125] It found low certainty of evidence for the effectiveness of multicomponent measures and active surveillance and very low certainty for travel, personal protective and environmental measures. Comparison with international studies is difficult, as multiple NPIs tended to be implemented together, making it challenging to isolate the effect of a single measure. Secondly measures such as closing of borders for long periods, as implemented in Australia,[126] or provision of free masks and hand sanitizers for the entire population, as implemented in Singapore,[127] may not be feasible in the UK.

What this study adds

To the best of our knowledge, our study is the only one to synthesize all the available evidence, including from modelling studies, on NPIs as implemented in the UK. We conducted a comprehensive literature search up until January 2024, used a systematic approach to study selection, quality appraisal

and data analysis and synthesized evidence from modelling as well as interventional and observational studies. A key advantage of this approach is that it allowed for the inclusion of 11 additional NPI categories for which no interventional or observational studies have been published in UK populations (e.g. ventilation, asymptomatic testing).

Consistent with other reviews,[124,125] we found the validity and reliability of the available evidence to support the effectiveness of individual NPIs to control the spread of COVID-19 to be weak and not to provide robust evidence to inform future pandemic preparedness. The main lesson from this review is the need to improve evidence generation to support future pandemic decision-making, including building rapid evaluation into the response to pandemic and other public health emergencies. This includes the development of 'sleeper' study platforms and protocols,[128] which can be activated during an epidemic or pandemic,[129] such as the COVID-19 rapid survey of adherence to interventions and responses (CORSAIR study).[130] Another approach is the delivery of rapid adaptive trials for the simultaneous testing of various NPIs, such as the rapid adaptive trials for pharmaceutical interventions PRINCIPLE[131] and PANORAMIC.[132] To facilitate rapid research and evaluation during public health emergencies, pandemic preparedness plans should embed processes for incorporating rapid data governance and ethical approvals,[133] including the design of ethical trials (for instance, of multiple NPIs) and appropriate development of sleeper protocols that would undergo ethical approval in advance. It is also imperative to invest in data systems and develop routine health data sources like Open Safely,[134] which would allow for a clearer indication of the effectiveness of interventions in near real-time.

Limitations of this study

As this was a rapid review, some processes were truncated, which could have introduced bias (e.g. data extraction was not conducted in duplicate and we adapted a critical appraisal tool for modelling studies). Focusing exclusively on the UK reduced some of the heterogeneity due to differences between countries but resulted in the exclusion of potentially high-quality and relevant evidence from other populations. By excluding laboratory studies on the physical properties of the SARS-CoV-2 virus and physical studies on the behaviour of airborne particles, we may have missed important studies that could have provided evidence on mechanistic aspects and efficacy of NPIs. Most of the included studies had a high risk of bias. Only three were RCTs but even these are at risk of residual confounding from environmental and behavioural factors. Finally, our review has considered the impact of NPIs on reducing COVID-19 outcomes, but this needs to be balanced against the potential adverse economic, political or

social effects associated with the adoption of NPIs during the COVID-19 pandemic.[135]

Conclusion

Our review found that evidence for the effectiveness of individual NPIs as implemented in the UK to control the spread of COVID-19 is weak. The best available evidence was for test and release strategies for case contacts (moderate certainty), which was suggestive of a protective effect. Although evidence for school-related NPIs and universal lockdown was also suggestive of a protective effect, this evidence was considered low certainty. Evidence certainty for the remaining NPIs was very low or inconclusive. There were limitations in study designs and methodological quality, heterogeneity in study characteristics and challenges in isolating the effects of single interventions, in the context of multiple interventions being implemented simultaneously. These results do not necessarily reflect a lack of effectiveness of packages of NPIs implemented in the UK. However, they highlight the need to build evaluation into the design of public health interventions to improve evidence generation in order to support future pandemic decision-making.

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Author contributions

D.D. designed the mapping review which this review was based on. Protocols for this review were developed by E.McS., M.D., E.T. and R.McQ. with support from J.M.O.M., D.D., S.C.[1] and S.B. J.H. devised the search strategy with screening of title and abstract and full text conducted by B.E., D.D., J.H. and M.Q. Z.S. and T.K. contributed to full-text screening and undertook study categorization with B.E. and

D.D. Data extraction and quality appraisal were conducted by T.A., E.McS., R.McQ., E.A.M., M.N., N.A., J.R.K., M.B.S.M., V.V., B.L., E.K., S.R., P.K., U.D.S., E.O.I., J.R., A.Z., K.O., M.H., D.M. and S.C.[2]. Support for modelling studies was provided by T.A., J.R.K., J.M.O.M. and E.T. T.A. drafted the manuscript with support from R.McQ. E.McS., M.D., E.T., G.C., J.M.O.M., S.D.L., A.S., D.D., S.C.[1] and S.B. reviewed and edited the manuscript. All authors approved the manuscript for submission. S.C.[1] refers to S. Carville and S.C.[2] refers to S. Chishty.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Conflict of interest

SDL is the Director of the Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC), the English primary care sentinel surveillance system, sponsored by UKHSA. AS has served on a number of UK and Scottish Government COVID-19 advisory groups.

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Data availability

Data extraction and quality appraisal for all included studies can be obtained by contacting the corresponding author.

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